Project Completion Report

Innovations in the Area of New Materials and Processing – A Pilot Study

Sponsored by

National Science & Technology Management Information System (NSTMIS) Division
Department of Science and Technology
Government of India

Implemented by

Prof. Hem Shanker Ray
Principal Investigator
Indian Association for Productivity, Quality & Reliability
AD-276, Sector-I, Salt Lake City
Kolkata 700 064

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Team Members

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"Start by doing what is necessary.

Then do what is possible and

Suddenly you are doing the impossible."

- *St. Francis of Assissi (1182 – 1226)*

CONTENTS

PREFACE

This report relates to a Pilot Project on Innovations in New materials and Their Processing that was taken up by the Indian Association for Productivity, Quality and Reliability and was sponsored by the Department of Science and Technology, Government of India. The Pilot Project was meant to provide some useful inputs for planning and conducting a more comprehensive study covering the entire country.

The present study was quite restrictive in its scope and coverage. Initially, it was to remain confined to Calcutta and its neighbourhood. This was subsequently extended to cover CSIR-NML and R&D Division of Tata Steel in Jamshedpur, IIT Kharagpur and CSIR-CMERI, NIT and DSP in Durgapur. The outstation organizations were visited because they are all nearby. IIT Kharagpur is a reputed institution for research, CMERI and NML are CSIR Laboratories. Both, particularly, NML does a lot of research on metals and materials. NIT Durgapur has a department of Metallurgy. Durgapur Steel Plant and Tata Steel have their own R&D centres which work, among other things, on materials. No funds were taken from the project for these visits. Innovations in the area of new materials and related applications which have taken place in the concerned institutions since the year 2000 were to be covered.

While results of a good number of research and development projects undertaken by university departments, research organizations and even some industries were claimed to be 'innovations' by the concerned institutions , many of these did not result in concrete entities that entered the market and impacted the society. In fact, the Project Team had given due attention to the Science, Technology and Innovation Policy 2013 in delineating innovations. According to the STI Policy innovation implies S&T based solutions that are successfully deployed in the economy or the society. We found during our field-work that some innovations have taken place in Tata Steel as also in Durgapur Steel Plant which had been patented in some cases and were absorbed with some modifications by the respective industries. It can be safely argued that these innovations conform to the STI Policy requirement and, accordingly, the Project Team took due account of them.

We started off with the notion that there would be a sizeable number of innovations in the field of new materials in the institutions visited by our team. We could eventually come to reckon only a handful of the claimed-to-be innovations as innovations in line with the STI Policy 2013. We have separately noted a category of 'innovations' which stopped at the stage of material/ technology development but did not proceed for technology transfer and, hence, commercialization. In some of these cases, manufacturing readiness level was not assessed by the concerned laboratories. In fact, this is a hard task for a laboratory. We also recorded results of researches in the field of new materials which have been published in relevant journals, though little attempt was made to patent the resulting products or processes, not to speak of their commercialization.

Even in respect of the few 'innovations' that were upto the STI Policy 2013 mark, not much information about the projects that led to the innovations by way of motivation for the project, cost and time involved, problems faced, collaborations sought and secured, potential benefits of the innovation, commercialization efforts and outcomes, etc. could be collected. Thus , we could not come up with a detailed data-base on innovations within our limited scope and no data-mining or text-mining exercise was called for.

Whatever limited information we could gather from the internet, through field visits and discussions as also through follow-up request for materials available on the 'innovation' projects have been duly assessed by the Team and presented in the pages that follow. We even tried to understand the S&T content of each of the few 'innovations' that have been recognized as such, not in terms of an absolute scale but using an implicit comparison with high-impact innovations with high S&T content reported in the relevant literature.

We have made only a few recommendations to promote innovations on the basis of our findings in this Pilot study. And we badly feel the necessity to extend our investigation to cover the entire country with the hope that we will be able to recognize many 'innovations' in the connotation of STI Policy 2013 and will be able to develop a useful data-base on innovations in the broad area of new materials and related applications.

Calcutta | H.S.Ray
March 16, 2016 | Principal Investigator

EXECUTIVE SUMMARY

Indian S&T is passing through a critical phase. From Science Policy to Technology Policy and then integrating both, the new Science, Technology and Innovation Policy (STIP 2013) has been announced by the Government of India. There is now an urgent need to invigorate the S&T led solutions for successful deployment in the economy or society of the country. In the entire game of innovation, the role of new materials and their processing need not be over-emphasized.

The present project involving a pilot study undertaken to examine the status of innovations in the area of New Materials and their Processing being pursued by the R&D laboratories, academic institutions and industries in and around Kolkata and to identify pitfalls is meant to chalk out a better road map for the purpose.

Towards this, a survey has been conducted among a few individual experts, faculty members of Universities and IIT - Kharagpur, R&D personnel of two reputed industries and senior scientists of three CSIR laboratories in and around Kolkata region. Information was also collected from the Patent office at Kolkata. A workshop was organized on the subject. In the Workshop, key note speakers were invited to talk about their views on innovation. There were about one hundred and seventy delegates and some of them presented the outcomes of their R&D activities. A special session was also arranged for interaction with young participants.

A carefully prepared questionnaire was canvassed amongst the individuals and institutions visited to elicit relevant data as well as opinions.

Items of information, thus obtained from different sources, have been compiled for analysis. Unfortunately, it has been observed that majority of the persons are not aware of the Science, Technology and Innovation Policy (STIP) 2013 of the Government of India. During interaction, the main theme of the policy has been explained to them and their views were sought. Many persons, mainly from academic institutions, have different opinions on the definition of innovation. Some have opined that innovations of high impact in society and economy may not be necessarily based on high quality S&T.

Academic institutions prefer publications of their research outputs. R&D laboratories work for development of new technologies but they feel that majority of them remain within the laboratories for lack of interest from the industries and bureaucratic method of technology transfer procedure.

There are many factors which explain why R&D centres do not have a satisfactory record on innovations. Those include : a poor subjective horizon, competition with imported technologies, inadequate returns on efforts, poor laboratory records, thrust on science, lack of focus and a sense of mission, lack of trust and, consequently, opposition, lack of commitment and strict decision making, inadequate networking with other laboratories and the industry, poor definition of deliverables, absence of a carrier chain to take inventions forward, cost of R&D, poor facilities for scae up, bureaucracy, problems with patents, lack of mandates on innovation etc. These have been discussed in some detail in Section 3.3.

The R&D outputs of different organisations have been examined in line with the theme of STI Policy 2013. However, as observed even in the globally developed countries, conversion of R&D output from conceptualization to a successful and beneficial technology passes through different stages of development that require long time, sometimes in the order of ten years or more. Therefore, the R&D outcomes of different organization have been categorized in three groups – a) technologies transferred to industries, b) technologies supposedly ready for transfer and c) technologies under progress and having potential for industrial application.

The technologies under the first category include the following:

Category (a)

CSIR-NML

1. Synthetic nanocrystalline Hydroxyapatite.
2. Synthetic nanocrystalline Hydroxyapatite and β-Tricalcium phosphate composite.
3. Technology for production of rare grade nano iron oxide from waste pickle liquour.
4. Technology for recovery of lead from zinc plant residue.
5. Technology for production of tungsten metal powder from hard tungsten carbide scraps.
6. Technology for nickel recovery from spent catalysts.

7. Wide metallic glass ribbon processing unit.
8. Magstar : A device for nondestructive evaluation of steel structure/component.
9. Microwave-IR : a noninvasive device for iron ore compositional analysis.
10. Development of biphasic calcium phosphate.
11. Paving blocks from flyash, blast furnace slag, steel slag, etc.
12. Recovery of gold from waste mobile phones and scraps of various equipment.

CSIR-CGCRI

1. Ceramic membrane based pre-treatment system for BRWO/SRWO plants
2. Ceramic Bio-medical implants
3. Hard and abrasion resistant coating
4. Special glass nodules for nuclear waste immobilization
5. Development of transparent, hard and protective coatings on CR-39 ophthalmic lenses and related plastics.

Durgapur Steel plant (DSP)

1. Micro alloyed BG Coaching wheels

Some of the above technologies will be beneficial for the society and strategic sector.

Academic institutions cover wide range of research areas mainly for advancement of knowledge. They have large number of publications in reputed journals. Some of their research outputs are ready for commercialization. However, they are not associated with innovation in line with STIPolicy 2013.

During the workshop, the following two technologies have been identified which can be converted to beneficial innovations with suitable industrial participation:

1) Master alloy for modification and grain refining of hypoeutectic Al-Si based foundry alloys and its process for manufacture
2) Monel alloy resistant to stress corrosion crack in hydrofluoric acid

It may be mentioned that information on R&D achievements of different laboratories was seldom readily available.

Information for categories (b) and (c) has been given in page 32 of this report. They are omitted here for the sake of brevity.

The collected information has been compiled and the parameters related to innovation have been graded qualitatively for comparison. The study shows that technologies developed in CSIR laboratories are mainly related to processing of materials. Development of new materials took place in limited cases. The academic institutions are mainly involved in knowledge generation and publication. Although they claim that many technologies are available for commercialization, the culture of patenting is limited. Most of the developed technologies are aimed at benefits to the society but very few get commercialized. Cost involved in materials or technology development in the respective laboratories, extents of market penetration of the new materials/technologies and economic or social benefits could not be examined in the absence of pertinent data.

It has also been observed that industry linkage which is essential for successful deployment of innovations in the R&D laboratories has been generally less than expected. The survey among different organisations indicates that Bio and Nano materials are common areas of research. However, from their research outcomes, benefits are yet to be received by the society. It was strange to notice that majority of the organisations and persons are not aware of STI Policy 2013. The culture and the necessity of innovations need to spread among the organisations involved in research and development activities.

MAJOR RECOMMENDATIONS

Several important recommendations by way of suggested actions on the part of different players to promote Innovation as a key driver of National Development have been made in the STI Policy 2013 document. We strongly feel that these recommendations be implemented in right earnest as early as possible. It is, of course, true that the process of implementation will require scientists and technologists working in universities or research organizations or industries to ponder over the recommendations seriously, besides requiring concerned bureaucracy to be more sensitive and imaginative to provide the desired support to the Innovation Exercise.

To make recommendations on the basis of facts and figures revealed during this limited study may not sound wise and we should wait for the larger nation-wide study to come up with some meaningful recommendations. However, some unexpected -- or not much expected— findings during our visits to different institutions motivate us to suggest some measures to improve the Innovation scenario in our country. Some of the somewhat disturbing findings during field visits as well as during the Workshop are the following.

Most scientists working in academic and research organizations as also in industrial R&D set-ups are not aware of the contents and connotations of the STI Policy 2013. And they differ among themselves quite remarkably about what constitutes an 'innovation' or how is an innovation distinct from a simple product improvement or even an invention or a new process developed but not transferred to any manufacturer. Methodologies for new product development, systematic problem-solving and related fields are not much known. Similarly lacking is the knowledge about Intellectual Property Rights and Patent Regime.

Secondly, we noticed a general lack of focus on innovations in the university system. While, it must be admitted that in some of the university departments good quality research efforts are on, results of these efforts end up in publication of research papers in most cases. One problem is not difficult to visualize. There is hardly a strong interaction with Industry and a facility to ascertain the Industry-readiness of any material or process or product that may result from the research efforts.

Another finding should not be glossed over. Research projects taken up in publicly funded research organizations that fortunately end in some innovation have not proceeded in a systematic and documented fashion within a conducive environment. Many extraneous problems stand in the way of serious researchers keen to come up with something new and useful.

It was also noticed that university departments/ centres, research organizations and industrial R&D set-ups work in silos, without any effective integration in their project planning and execution activities. Often the up to date records are not available. Neither there is a ready handbook on technologies available.

The hurdles for technology transfer and measures to promote innovations have been discussed in some detail in Section 3 of this text.

The foregoing statements may justify the following suggestions from the project Team.

1. *Measures need to be taken to remove hurdles as discussed in the text (see Section 3.3) so that laboratories can be enabled to help create innovations from their inventions.*

2. *DST may organize structured programmes in several selected cities to expose scientists working in academic and research organizations to the Intentions and Directions for Innovation as spelt out in the STI Policy 2013 in a comprehensive manner. Attempts should also be made to address any doubts and reservations by the participants about any comment or statement made in the Policy Document.*
(Incidentally, members of the project Team have earlier taken up this task to familiarize scientists in different S&T organizations with the contents of the Science and Technology Policy Statement 2013.)

3. *Universities should arrange discussions and Workshop on IPR issues for some selected faculty members. In fact, it may be a good idea to introduce at least an optional course on IPR and Technological Innovations for post-graduate students and research scholars.*
A mechanism should be evolved to take due cognizance of innovations and patents in the process of assessment of faculty members. Any new process or product developed, but not

transferred to a manufacturer for some reasons or the other, should also qualify for some credit.

4. *Incentives should be offered to research workers in all R&D set-ups for undertaking innovation-oriented projects, may be in consultation with potential users and manufacturers right from the very beginning. Top Management should provide all necessary encouragement and support and should treat cases of failures despite sincere efforts with sympathy.*

5. *Research workers in universities and research laboratories should interact between them quite strongly and work in tandem with industry whenever a project meant to end in a process or technology development.*

6. *Each laboratory should define its mandate as regards innovations they aim at. Universities must also focus their attention, in addition to pure academic research, on R&D whose results can directly benefit the industry or the society.*

7. ***In conclusion, the present study indicated a prime need for more extensive study in this area on an all India basis. This was our original proposal out of which the present pilot study has evolved.***

ACKNOWLEDGEMENTS

Our organization (Indian Association for Productivity, Quality and Reliability) had initially proposed an all India survey on Innovation in New Materials and Process. We are thankful to PAC, NSTMIS Division of DST for wisely suggesting only a Pilot Project for the Kolkata region first and approving it for funding. The Project Team then suggested inclusion of IIT Kharagpur, DSP Durgapur and CSIR-NML and Tata Steel in Jamshedpur, all located nearby for a more comprehensive survey (No TA/DA for outstation trips were taken from Projects fund. These were borne by the hosts).

The PI is thankful to IIT Kharagpur and CSIR-NML for invitation to visit these institutions at their cost. The team is also thankful to the PAC for suggesting that a Workshop on this topic be held and for sanctioning a separate amount for the same.

We are grateful to Dr. A N Rai, Director, DST who has been in constant touch with us and made useful suggestions from time to time. He has also kindly arranged for timely transfer of funds.

We thank the members of the Local Project Monitoring Committee that first met in Dec 2014 for suggesting that the innovation to be tracked by the Project be limited to the period from 2000 onwards rather than 1990. Some suggestions from the members were also very useful. Some more suggestions were made in the second and last LPAC meeting held on December 30, 2015 which also helped.

We have visited some two dozen individuals in various institutions. Everywhere we received cordial welcome and full cooperation in receiving inputs against our Questionnaire and also otherwise. Some organisations and individuals were visited several times. We are grateful to all of them for sharing their views with us frankly and providing whatever information we sought. The Principle Investigator is particularly thankful to several scientists of CSIR-NML, Jamshedpur for spending many hours in discussion and providing some useful literature.

The Project Team is thankful to CSIR-CGCRI, Kolkata for collaboration with IAPQR in organising the Workshop which was a great success (A copy of the Souvenir is sent by separate post). Mr. K. Dasgupta who was the Director till July 2015 and his secretariat provided full cooperation. Dr. Rajen Basu, Head, Fuel and Batteries Division, and his large team did a commendable job in organising the event so very successfully.

Project Assistant Bikash Bhowmik and the office staff specially Dipankar Chatterjee and Pronay Mallick deserve sincere thanks for extending all help in various ways. We are particularly thankful to Bikash Bhowmik for doing most of the work on data search and compilation.

List of Abbreviations

ASTM	-	American Society for Testing and Materials
ASSOCHAM	-	Associated Chambers of Commerce of India
BWRO	-	Brackish Water Reverse Osmosis
CGCRI	-	Central Glass and Ceramic Research Institute
CII	-	Confederation of Indian Industry
CMERI	-	Central Mechanical Engineering Research Institute
CSIR	-	Council of Scientific and industrial Research
DAE	-	Department of Atomic Energy
DRDO	-	Defence Research and Development Organisation
DSP	-	Durgapur Steel Plant
DST	-	Department of Science and Technology
FICCI	-	Federation of Indian Chambers of Commerce and Industry
GDP	-	Gross Domestic Product
GOI	-	Government of India
IAPQR	-	Indian Association for Productivity, Quality and Reliability
IICB	-	Indian Institute of Chemical Biology
IIEST	-	Indian Institute of Engineering Science and Technology
IIM	-	Indian Institute of Management
IIT	-	Indian Institute of Technology
ISAMP	-	Indian Society for Advancement of Materials and Processing
ISO	-	International Organization for Standardization
ISRO	-	Indian Space Research Organisation
MRL	-	Manufacturing Readiness Level
NCL	-	National Chemical Laboratory
NMCC	-	National Manufacturing Competitiveness Council
NML	-	National Metallurgical Laboratory
PEM	-	Polymer Electrolyte Membrane
R&D	-	Research and Development
RDCIS	-	Research and Development Centre for Iron and Steel
RDSO	-	Research Design and Standards Organisation
SAIL	-	Steel Authority of India Limited
SEM	-	Scanning Electron Microscope

S&T	-	Science and Technology
SRWO	-	Sea Water Reverse Osmosis
STI	-	Science, Technology and Innovation
TEFR	-	Techno Economic Feasibility Report
TEM	-	Transmission Electron Microscope
TRL	-	Technology Readiness Level
XRD	-	X-Ray Powder Diffraction

1.0 INTRODUCTION

There have been some outstanding technological achievements by ISRO, DAE, DRDO etc. However, these cannot guarantee the country an image of an innovating society[1]. Innovations are fuelled by inventions based on science and technology and must cover all sectors. Unfortunately, the state of our science education and research remains a matter of concern. Our budget for science education and R&D remains amongst the lowest in the World. In fact, in our budget presented last year the hike is only about 3.4 percent in real time, for Science and Technology compared to the previous year[2].

International Innovation Index is a global index measuring the level of innovation in a country. This is produced by the Boston Consultancy Group (BCG) in collaboration with the manufacturing industry. This innovation index, which looks at both the business outcomes of innovation and Governments' policy to encourage and support innovation through public policy, is developed from a survey of a large number of senior executives in different countries and in-depth interviews of some select top level executives.

To understand the drivers and enablers of innovation, metrics that capture a wide array of innovation results have been used. Weights have been assigned to each of the component elements of the metrics on the basis of opinion poll of experts. The impact on innovation performance of inputs has been measured from parameters such as government and fiscal policy, education policy, and innovation environment. These inputs drive performance by either supporting or hindering the efforts of companies and industries. To evaluate innovation output performance, parameters such as patents, technology transfer, and other R&D results and the broader public impact of innovation on business migration and economic growth has been considered.

The data for 110 countries are available in the Wikipedia. Table-1 shows ranks in terms of innovation indices for 22 countries chosen arbitrarily. India is placed at forty sixth position[3].

There are other agencies which also publish data on Global Innovation Index. According to Cornell University, INSEAD and the World Intellectual Property Organisation (WIPO), the ranking of India is going down gradually. The figures for recent years are as follow: (the figures within brackets show total numbers of countries considered) 2011- 62(141), 2013 - 66(142), 2014 - 70(143). These data were based on 81 indicators.

Realizing the importance of innovation for faster and sustained development of the country, innovation has been given much importance in the policy frame work of Government of India by a new policy as 'Science, Technology and Innovation Policy – 2013 (STIP-2013)'. The Indian Association for Productivity, Quality and Reliability (IAPQR) proposed to the Department of Science and Technology (DST) to undertake a project for examination of the status of innovations in the area of materials and processing being pursued by different academic and research institutions and industrial organizations of the country.

Table-1 : Ranking of some countries according to Innovation Index (2009 figures)

Country	**Rank**
Singapore	1
South Korea	2
Switzerland	3
United States	8
Japan	9
Sweden	10
Canada	14
United Kingdom	15
Israel	16
Germany	17
Malaysia	21
China	27
Thailand	44
India	**46**
Russia	49
Egypt	65
Sri Lanka	69
Indonesia	71
Brazil	72
Argentina	92
Nepal	98
Zimbabwe	110

[Data for Pakistan are not available]

PAC, NSTMIS Scheme of the Department of Science and Technology (DST), Government of India, however, advised us to restrict the survey essentially in the Kolkata region and entrusted IAPQR with a project **'Innovations in the area of new materials and processing vis-à-vis STI-2013 – A pilot study'**. The main aim of the project was to examine various innovations being pursued by research laboratories, academic institutions and industries and their S&T contents for successful deployment in the society. This is the main spirit behind STI Policy-2013. The initial plan was to study innovations since 1991 but the Local Project Advisory Committee (LPAC) advised that the period be restricted to only innovations since 2000.

Before we discuss the project activities and outcomes in greater depth we need to first understand 'what innovation is'.

1.1 Definition of Innovation

A new model of Innovation suited to India's need is imperative and this need not follow the western world. The new model aims at

i. bridging the gaps between knowledge and the economic sectors,
ii. developing symbiotic relationship with economic and other policies,
iii. facilitating S&T-based high-risk innovations through new mechanisms, and
iv. focusing on both people for science and science for people and combining the benefits of excellence and relevance.

While it is needless to emphasize that basic research-led discoveries stimulate innovation in the long term, the new model would ensure further enhancement of basic research by fostering excellence through global benchmarks.

It would be incorrect to say that Indian innovators were oblivious of the above so far. On the contrary, they are quite aware that most innovations coming up with new products, processes and services meant to improve our Quality of Life that are based on some developments in Science and/or Technology – recent or remote, path-breaking or not-so-amazing, indigenous or imported. According to Science, Technology and Innovation Policy 2013 of the Government of India,

'Scientific research converts money into knowledge and innovation converts knowledge into wealth. Innovation is more than mere conversion of knowledge into a workable technology. It implies a S&T led solution that is successfully deployed in the economy or society.'

Many organizations, specially, the universities do not quite agree with STI Policy-2013 definition of Innovation which make deployment in the industry and/or society a precondition. There may be some point there. Recently there has been the report of a solar powered aircraft which uses no fuel. The single seater, with average car size body but very large wings runs with four 17.4 HP engines, the power supplied by 7248 solar cells on the wings and the body, is now flying around the world (The Economic Times 11.03.2015). Yet, as of now, this is not an innovation according to the preceding definition. The Hovercraft, which was a great invention, never proved to be that good an innovation because it did not serve many.

It is worthwhile to take note of other definitions and also some features that have been said about innovations in general.

According to Amit Chatterjee[4],
"The term innovation is derived from the Latin root 'nova' which means 'new'. It means, therefore, to bring something new to the world which changes the way people live, work and interact with one another. An innovation must have a kind of newness which is beneficial in some way, such that it can be celebrated in the media, protected through patents and registration, distributed quickly and efficiently to the largest number of people for this benefit and to bring about general welfare and the public good".

The Wikipedia views Innovation as the application of better solutions that meet new requirements, unarticulated needs or existing market needs. This is accomplished through more effective products, processes, services, technologies or ideas that are readily available to markets, governments and society. The term innovation can be defined as something original and, as a consequence, new, that 'breaks into' the market or society.

According to Peter Drucker, Innovation is the specific function of entrepreneurship, whether in an existing business, a public service institution or a new venture started by a lone individual in the family kitchen. It is the means by which the entrepreneur either creates new wealth producing resources or endows existing resources with enhanced potential for creating wealth. Some believe that disruptive innovation is the key to future success in business.

Innovation brings change and *vice versa*. It brings a chain reaction like the tossing of a pebble into a pond when ripples spread disturbing the calm elsewhere. Every established institution is doomed to decline if it fails to innovate.

Innovations are not restricted to breakthroughs in high science and technology e.g. rocket science, space research or communication satellite or genetics. It can be something which offers a better value proposition or a better alternative – something that results when an individual chooses to look at a problem differently.

Some experts believe that an incremental improvement can also be innovation because the ultimate objective is not to establish technological superiority but, often, maximize returns on any constrained resources by improving products and ultimately creating a market for them.
Most often, Innovation is motivated by some new knowledge in Science or Technology, may be by way of an Invention. It is true, however, that some innovations trace their origin to indigenous and ancient knowledge.

Innovations are around all of us all the time in terms of products and processes as also services that we use. Some of these may appear as simplistic, as if not worth being called 'innovations'. Most electronic and tele-communication gadgets used today were great innovations. Simple innovations, taken for granted today, like a pencil with the eraser at the bottom, a hammer, which is also a nail-puller, a child's stroller also a shopping cart, a tooth-brush also a tongue-cleaner, a mobile phone, which is also a camera, and the like are too many to enumerate. Innovators are not always great scholars or established professionals. They think over some mundane problems and use of some known solutions to problems in a related field. Such innovations may not be widely known. Some of the great innovators and entrepreneurs have been school or university drop-outs.

Essentially the concept of innovation refers to putting inventions into practice. A narrow strictly technological approach focuses specifically on product and innovations. This is usually knowledge intensive entrepreneurship. There is a close link between entrepreneurship and innovations.

Innovation is an imperative for sustainability – be it for a manufacturing/service organization or for the national economy as a whole. In fact, some say that there are only two functions of Business viz. Innovation and Marketing. Inventive ideas by themselves are not innovation and this perception implies that

Innovation = Invention + Enterprise

1.2 The Indian Scenario

Subrata Ghosh[5], Formerly Senior Scientist, Central Glass and Ceramic Research Institute, Kolkata and a member of the Project Team of the present project, recently carried out a study with Chandana Patra, Senior Technical Officer, Central Glass and Ceramic Research Institute Kolkata. They have inferred from a survey that an analysis of 570 Indian 'innovations' shows that Indian innovations owe their origins mainly to the advanced western world. They also say that the basic structure of India's S&T process does not exhibit any promise to become an advanced country in foreseeable future.

Dr. S. Srikanth, Director of CSIR-NML, Jamshedpur, who has achieved an enviable record in his laboratory as regards industry participation, has mentioned a few drawbacks on the style of activities of some projects undertaken in network mode in CSIR laboratories.[6] He opined that the networking between the laboratories was not very effective in several cases with little or no connectivity among the different modules. Moreover, the users and industries had little or no involvement or stake in the projects. The thrust towards commercialization of the outcome was also inadequate. In summary, according to Dr. Srikanth, many of these were projects perceived/conceptualized by CSIR, carried out by CSIR, funded by CSIR, reviewed (largely) by CSIR and delivered to CSIR. He suggested that it was essential to get out of this 'By CSIR, For CSIR and To CSIR' approach to reach the target of successful innovation beneficial to the society and economy.

The observations of Dr. Srikanth are better understood from the paper titled, "Production of Nickel from Chromate overburden – A promising technology of a laboratory of CSIR that has not been commercialized" by Ray[7]. The paper critically analyses the reasons for failure and these are in line with Dr. Srikanth's comments. In fact, these observations are valid formost of other R&D organisations also.

The process by which existing technology is transferred to fulfill the user's needs of useful processes, products and programmes is a widely discussed subject. Common difficulties faced include the following :

- People and organizations are naturally resistant to change.
- Often the human element of personal contact amongst the right people stand in the way of innovation diffusion and adoption.
- Technology transfer suffers from bureaucratic steps.
- A promising technology is often not commercialized because of inadequate publicity amongst professional networks.
- Acceptance of a new technology takes time, a lot of work etc.

No wonder not many R & D results eventually find successful commercialization in advanced countries too. One study[8] from the U.K. reports the following :

Raw ideas 3000 → Submitted ideas 300 → Projects initiated 125

↓

Commercial launches 1.7 ← Major developments 4 ← Large developments 9

→ Commercial success 1

It is well known that not all innovations make the same impact on the society. The impact of the steam engine that revolutionized transportation was enormous. It was driven by technology and not science but it gave birth to the discipline of thermodynamics. It has been said that the fundamental laws may undergo revision in other disciplines but the laws of thermodynamics will remain valid for all times to come. The initial development of flying machine of the Wright brothers, who were bicycle mechanics, also was based on simple engineering and air tunnels. However, a lot of science and development of engineering and of new materials revolutionized the aviation sector. The same is true for ship and submarine. As mentioned earlier, Hovercraft, developed on knowledge from different areas has been a great invention but its impact has been limited.

Some innovations which have had the greatest impact on the society in terms of numbers of users include the rubber *chappals*, sanitary towels and napkin, children's diapers, the safety pin, the paper clip, stapler, the 3M pads, cello tape, Xerox machine, the cell phone, digital camera and, of course, the computer.

Once footwear were made only from leather. Because leather was not freely available, the poorer sections had to go barefoot. The situation changed with development of polymers – rubbers, plastics etc. and other materials like canvas. Sanitary napkins and diapers employ super absorbers that can absorb, in one centimeter volume, hundreds of cubic centimeters of liquid. There is high science here. As regards the rest there exist everywhere elements of new materials, new design, new science and new ideas.

Ideally the impact of any innovation should be assessed in terms of economic parameters. However, additional parameters that should also be considered would include psychological satisfaction, comfort, effect on the sense of well being, social benefits etc. These are, however, not easy to assess.

Prof. S. Banerjee[9], former Director of CSIR-NML and former Director of RDCIS, Ranchi did some pioneering work towards quantitative assessment of the benefits of R&D outputs. He has provided a thoughtful analysis of methods of assessment in the recent Prof. Daya Swarup

Memorial lecture delivered during the annual event of the Institute of Metals, Kolkata, held in Pune in 2014. Prof. Banerjee developed a method of evaluating SAIL's R&D at RDCIS rather successfully. Outcomes of some 1500 incremental improvement of technology have been evaluated over 20 years as per the record of benefits accrued through their application in various steel plants of SAIL. Generally 60-100 innovations are worked out each year and data on the utility of these are obtained from steel plants for evaluating the outcomes.

The two parameters evaluated are the following:

1. Customer satisfaction as determined by 'Customer Satisfaction Index' (CSI), and
2. Economic Benefit as determined by Certified Annual Benefit (CAB) and Benefit to Cost Ratio (BCP).

This procedure has proved to be sound and remains in practice in SAIL. An attempt has been made to adopt a similar procedure for evaluating the impact of CSIR technologies transferred to the industry. However, this has not been successful primarily because it is difficult to get feedback from the user industries.

There is a strong need to look at the innovations in the area of New Materials and their Processing to identify pitfalls in earlier attempts to innovate and to chalk out a better road map for the purpose.

1.3 R&D Activities on Materials

Modern civilization is as much based on use of various materials as on science and technology. Today by the word 'material' we mean solid substances of which manufactured products are made. They belong to two categories – (a) natural materials like stone, clay, wood, wool, cotton, etc. and (b) extracted materials such as metals, alloys, glass, plastics, etc. The use of any material depends on the properties required for an intended use. Often new materials are manufactured with special properties for which an appropriate application is found. An example is the 'memory alloy'.

Properties of all natural materials like stone, clay, wood, plant fibers, animal fibers can be altered. Extracted materials like metals, alloys, ceramics, composite materials, plastics, rubber etc. can, of course, be varied over immense ranges by variety of treatments.

A general comparison of the traditional properties of ceramics, alloy and polymers is given in Table -2.

Table 2:Comparison of Traditional Properties of Ceramics, Alloys and Polymers

Property	**Ceramics**	**Alloys**	**Polymer**
Hardness	Very High	High	Poor
Rigidity	Very High	High	Poor
High temp. tolerance	Very High	High	Poor
Thermal conductivity	Poor	High	Poor
Malleability	Poor	High	High
Resistance to natural degradation	High	Poor	Poor
Electric & conductivity	Poor	Very high	Very poor
Density	Low	High	Low

However, thanks to materials science and technology, various unusual properties can be imparted. Special properties can also be developed by using composites that combine different materials in structure. Newer materials are being developed all the time. Biomaterials are those that interact with biological systems. They can be derived either from nature or synthesized in the laboratory using a variety of chemical approaches. Nanomaterials describe, in principle, materials of which a single unit is sized (at least in one dimension) between 1 to 1000 nanometers (10^{-9} meter) but is usually 1-100 nm. Nanomaterials research takes a materials science based approach to nanotechnology, leveraging advances in materials, metrology and synthesis which have been developed in support of micro-fabrication research. Materials with structure at the nano scale often have unique optical, electronic and mechanical properties. There are organic (carbon based) nanomaterials such as fullerenes and inorganic nanomaterials or other elements such as silicon. There are Thermoplastics which can be melted and reshaped. There are rubber like materials that show elasticity. Semi-conductors are materials that conduct electricity better than insulators but not as well as conductors at room temperatures. There are electronic, optical and magnetic materials which are semiconductors, metals or ceramics to form highly complex systems such as integrated electronic circuits, optoelectronic devices, and magnetic and optical mass storage media. These materials form the basis of our modern computing world. Radical materials advances can derive the creation of new products or even new industries. Materials science backed by materials characterization techniques play a big role in this. Thanks to modern materials science some traditional materials are undergoing revolutionary change in properties. Thus there is bullet proof glass and ceramics, metallic glasses (glasses which have metallic structure), heat resistant polymers ceramics that conduct electricity, etc. etc. Then there are composite materials which combine structured materials of two or more macroscopic phases to impart special properties in modern space age.

As mentioned earlier, by the word 'materials', one means something solid. Until medieval times materials were for construction, weaponry, jewellery, household things etc. and were ordinary materials from nature - stone, wood, terracotta, metals and alloys, glass and ceramics, natural fibers like jute, cotton, silk, etc. Then new materials came in like rubber, polymer, etc. Now there are innumerable materials for innumerable applications. There is no standard method of nomenclature. Some are named by association with areas e.g. Biomaterials, Electronic materials, Energy materials, Materials for Opto Electronics. Some are function related e.g. Structural materials, Advanced materials, etc. We would exclude Drugs from the present survey although technically many are solids.

In recent years, there has been emergence of a new discipline called 'Material Design' which helps us to produce a desired material when the intended properties are well defined.

The well known 3M company works on diverse areas of materials such as the following :
Em (Electronic Materials), Ad (Adhesion Materials), Fi (Films), Ab (Abrasives), Nt (Nanotechnology), Do (Dental and Orthodontic Materials), Am (Advanced Materials), Me (Metal Matrix Composites), Po (porous Materials and Membranes), Sm (Specialty Materials), Pp (precision Processing), Mo (Molding), Vp (Vapour Processing), Rp (Radiation Processing),

Pe (Predictive Engineering and Modeling), Su (Surface modification), Mr (Microreplication), Pm (Polymer melt processing), Pd (Particle and Dispersion Processing), Es (Electronics and Software), Ic (Integrated System Design), In (Inspection and Measurement), Md (Medical Data Management), As (Application Software), An (Analytical Service and Technology), We (Accelerated Weathering), Pr (Process Design and Control), Dd (Drug delivery), Mc (Microbial detection and control), Wo (Wound Management), Bi (Biotechnology), Fs (Filtration Separation and Purification), Mf (Mechanical Fasteners), Tt (Track and Trace), Fe (Flexible Electronics), Lm (Light Management), Ec (Energy Composites), Ac (Accoustic Control), Im (Imaging), Fc (Flexible Converting and Packaging), Op (Optical Communications). More details are available in the website of 3M Company.

In the present survey of R&D projects undertaken in various laboratories not many of these areas were found relevant. Those that were are mentioned later in this report.

As has been mentioned earlier, Universities in the Kolkata region focus on publications primarily and there are few innovations, not to speak of patents. CSIR Labs i.e. CSIR-CGCRI, CSIR-IICB and beyond Kolkata, CSIR-CMERI and CSIR-NML are, however, active in patenting. IIT, Kharagpur is also beginning to be active in IPR activities.

1.4 OBJECTIVES

All definitions of 'Innovation' essentially say that an Innovation benefits the Economy and the Society. The Government of India has laid great emphasis on Innovation, especially on Innovation based on Science and Technology in its Science, Technology and Innovation Policy - 2013.

Some innovations have been taking place in our Academic Institutions and S&T establishments, both in publicly funded research laboratories as also to a smaller extent in R&D set-ups in private enterprises. However, the country is yet to receive full benefits of all such efforts. In many cases, innovations stopped at the laboratory stage for absence of interest of potential entrepreneurs for various reasons and hence did not benefit the Society or the Economy.

There is a strong need to look at the present portfolio of innovations of the country in the area of New Materials and their Processing and to identify pitfalls in earlier attempts to innovate and to chalk out a better road map for the purpose.

Accordingly, the **objectives** of the Project have been defined as follows:

- Development of a data base for innovations carried out in the broad area of New Materials and their Processing in various laboratories as per STI Policy 2013
- Examination of these innovations as documented in the corresponding laboratories in respect of the S&T content, costs and benefits, scale and segment of adoption
- Analysis of the efforts of the scientists concerned, the problems faced, the motivations, possible co-operations and collaborations,
- Recommendation of an over-all environment and the associated exercises to strengthen the S&T bases for innovation as also to come up with more effective solutions to problems that could ensure inclusive development.

As a pilot study, the survey is restricted to only innovations since 2000 for organisations in and near Kolkata.

2. 0 METHODOLOGY

In order to achieve the objectives of the pilot study, the methodology that has been followed in the present project involves the following:

a. Study of literature on innovations and development of materials and processes

b. Visits to various centres in and around Kolkata region for interviewing faculty members, officials and/or scientists to collect responses to a Questionnaire that has been developed by the project team

c. Organising a Workshop on Indian Innovations in Materials Research: New Materials and Processes

d. Analysis of information collected in the context of the objectives of the project

e. Recommendations for measures that should promote the culture of innovation in general.

The survey has been restricted to the period 2000 to date as per the suggestion made during the first LPAC meeting.

3.0 DATA COLLECTION AND ANALYSIS

The necessary data for the examination of the status of innovation in India in line with the project objectives and to suggest possible remedial measures for giving new thrust to Indian innovation have been collected from different sources, viz., a) Interaction with experts and organisations associated with R&D activities on materials, b) Annual reports and web sites of different organisations, and c) Workshop on Indian innovation in Materials Research.

In addition, as suggested by the DST, attempts were made to obtain information from National Manufacturing Competitiveness Council (NMCC) and Indian Society for Advancement of Materials and Processing (ISAMP) in the related areas. Since, they do not have much activities in the Kolkata region, but their web sites have been searched for relevant information.

The NMCC has initiated different programmes to support mainly the small and medium scale industries in their endeavor to become competitive. It is realized that innovation is clearly crucial to the future of Indian manufacturing industry. It is felt necessary for the Government of India and its concerned Ministries jointly with relevant stakeholders/Industry Organisations like CII, FICCI and ASSOCHAM to launch a national campaign for Indian firms to invest in next generation intellectual property in the product, process and practice domain. The orientation of National Quality Campaign is to be appropriately changed to be competitive through quality management standards and quality technology tools to become competitive. The major areas that would be covered for suitable action requirements of the firm/cluster/industry are Manufacturing and engineering, Marketing, Financial and general management and Information Technology. Although their programme may involve IPR of materials research, specific research activities on new materials will not be covered. In addition, the policy framework has been announced in 2005-2006 budget, it is still in the planning stage. Hence, no relevant information on materials research has been found fit for inclusion in this report.

The Indian Council for Advancement of materials and Processing Engineeringwas founded in 1985 with Headquarters at Bangalore. It aims at establishing and fostering scientific and organized approach to advancement and application in the field of materials and processing through education, research, compilation, dissemination of information, training and interaction among professional of inter-disciplinary fields. In their website, there is information on various research activities in the area of new materials, such as Silica Tile System Development for Space capsule Recovery experiment, World of Smarts Systems, Bioplastics and Biocomposites in Automotive industry, Nanotube Composite Sandwich Material etc. These activities are mostly being carried out in organisations, located in Southern and Western part of the country. Since survey of this project is restricted to Kolkata and surrounding, details of these projects are not included here.

The data, thus collected, from R&D centres in and around Kolkata have been compiled and analysed in consistence with the objectives of the project.

3.1 Data Collection

Many organisations were visited and the interactions were made through questionnaires related to their R&D activities in the areas of materials and their outputs since 2000.

The interviewees are divided in the following categories.

A. Special individuals

B. Universities and autonomous institutions

C. R&D Laboratories

D. Industry.

A1 designates individual 1 in category A as given in Annexture I. Similarly B1.3 is for individual 3 in category B1. C4.1 is individual 1 in category C4. Double entries such as MM, HM, HH, etc. mean opinion of two individuals from the same institution.

The questionnaires for the interviewers, names of individuals and organisations along with summary of interview are given in **Annexure II** of this Final Report.

Three Tables are given to summarize their opinions as regards the following :

Table 3: Areas of interest for R&D in India today.

Table 4: Factors that motivate innovators to achieve.

Table 5: Factors that creates hurdles for technology transfer and commercialization of technologies.

Opinions collected from different institutions are indicated without identifying individuals as this is not so important. (The details as recorded originally are, however, in the records) Opinion that lacked conviction or seemed casual have been omitted.

The interviewees are labelled as A, B, C and D with suitable numbers as shown in Annexure I.

Table 3 : Areas Receiving Attention

Areas	**Institutions**												
		B				C						D	
	A1	1.3	3.1	4.1	5.1	1.1	2.1	3.1	4.1	4.2	4.3	1	2
Bio	√	√		√	√	√			√	√	√		
Electronic				√	√	√	√			√			
Energy					√								
Polymers						√							
Nano				√	√	√√	√	√	√	√		√	√
Metals & Alloys				√	√	√							
Ceramics				√	√	√							
Composites				√			√		√			√	
Others				2.3 Advanced Materials									

[A, B, C and D are different categories of persons A1, B1.3, B4.1 etc. denote people in different institutions in this category. See Annexure I.]

Table 4 : Factors that Motivate Innovators

Factors	**Institutions**													
	A	B					C						D	
High IQ	MM	MM	L	M M	H	L	L	H	M	H	M			M
Scientific knowledge	HH	HH	L	M H	H	H	M	H	H	H	H			H
Self Motivation	H	HH	M	H H	H	M	H	H	H	H	H			H
Inspiring Leadership	MH	MH	H	H M	L	M	H	H	H	H	M			H
Out-of-Box Thinking	HH	HH	H	L	-	-	-	M	-	H	M		H	M
Supportive infrastructure	MM	M	M	M H	H	M	L	M	M	H	H	H		H
Team support	MM	MM	H	M H	-	-	-	-	M	-	H		M	H
Laboratory discipline	MM	MM	L	- H	H	L	H		M	H	H			H
Rewards and recognitions	ML	ML	H	H M	H	H	L	L	M	M	M		M	M
Freedom of work	HM	HH	L	H M	-	-	M	H	H	H	L		H	H
High EQ	H	H	M	M L	-	-		M			M			H
Leadership qualities	L	L	-	- M	-	-				H	L			H
Big goals, well defined time frame	LL	LL	-	- M	-	-	H	H		M	L		M	M
Liberal funding	MH	MH	M	- H	-	-	L	H		M	H			

[H = High, M = Medium, L = Low in terms of importance]

[MM, MH etc. indicate two different persons in the same institution as indicated in Annexture I]

Table 5 : Factors that are Hurdles for Technology Transfer

Parameters	Institutions										
	A	B							C		D
Poor marketing		M		H	H	H	L	H	H		H
Incomplete technology		H	H	M	H	H	M	H			H
No. carrier chain		M	H		H			H H			H
Poor linkage with Indian work.	H	H	H	H	H	H	H	M			H
Absence of pilot plants		M	M	M	M	H	M	M H	H		H
Low credibility of Ind. work		M	L	L	M	M	L	H	H		H
Industries' reluctance for change		M	H	H	L	M	L	M H			H
Lack of Govt. support		M	H	H	L	M	L	M			M
Retirement of scientists		M	M	M		M		M			M
Post transfer service absent		M	M	M	M	H	M	M	L	H	
Easy imports		H	H	H	M	M	L	H	H		H
Budget components		M	M	M	L	M	M	L			H
No new ideas		M	M	M	M	M	M	M			H
Non recognition of efforts		M	M	H	M	M	M	H			H
Absence of clear goals		L	H		H			H			H
No mechanism for T^2			H		H						H

[H = High, M = Medium, L = Low in terms of importance]

The preceding tables clearly lead to the following observations:

a) The Maximum attention is on Bio and Nano- materials as the areas of research.

b) The most important parameters that motivate the innovators appear to be freedom at work, self-motivation and inspiring leadership. Rewards and recognitions are of secondary importance

c) Poor linkage with industry is considered to be the major hurdle for technology transfer.

As discussed in the Local Project Advisory Committee, the survey has been conducted in the organizations located in Kolkata and nearby areas. During the survey, it has been felt that there exists difference of understanding in the concept of innovation. Therefore, information regarding R&D activities of the organizations in the area of material research in general since the year 2000 has been collected for subsequent compilation and analysis. It has also been felt during initial survey that since it is a pilot study for Kolkata and surrounding regions, any restriction on area of research may not yield fruitful results. Therefore, relevant information on all types of materials have been collected for compilation and review.

3.1.1 Workshop on Materials Research

A Workshop, 'Indian Innovations in Materials Research: New Materials and Processes (IIMR)'was held during June 25-27, 2015 with the primary objective of evaluating the extent to which indigenous innovation mainly in the area of materials research has progressed. During the workshop, persons from research and academic institutes and industries had the opportunity of interacting among themselves and with experts in the fields. The workshop could also spread today's current need for innovation among the participants, mainly among the young generations. In the Workshop, one hundred and twenty papers were presented in different areas of materials research.

The complete programme of the Workshop is given **Annexure III**.

The aim of the Workshop was to invite experts in chosen scientific domains to speak on identified issues related to Innovations in general and on New Materials in particular. The Workshop was planned to cater to different segments of society which included senior scientists, professionals, students and members of the lay public.

The Welcome Address was delivered by Dr. R.N. Basu, Head Fuel Cell and Battery Division, CSIR-CGCRI. He spoke briefly about the scope of the Workshop and said that in all, about 40 posters, 24 Students oral presentations, 17 Contributory presentations, 29 Invited talks and 5 Plenary talks would be the highlight of the Workshop.

Shri Kamal Dasgupta, Acting Director, CSIR-CGCRI also warmly welcomed all delegates and guests. He said that IIMR-15 would help delegates understand the changes in science policy in the context of the nuances of innovation involved. He exemplified this by touching briefly upon the Dehra Dun Declaration. He said that any innovation in sync with the stated objectives as outlined in the Dehra Dun Declaration would get support and thus, help in making the nation's dreams to come true.

Prof. B. Das spoke on IAPQR's activities. Established in 1973, IAPQR is engaged in the pursuit, propagation and promotion of concepts, methods and practices to enhance productivity in manufacturing and service organizations through Quality and Reliability.

In his Key Note Address Chief Guest Dr. Srikumar Banerjee, DAE Homi Bhabha Chair Professor, Bhabha Atomic Research Centre, Mumbai, spoke about the Innovation Ecosystem. He succinctly pointed out that the meaning of Innovation did not lie in the words published in a dictionary but more in its application as evident in Google search for the same. He said Innovation is Competition-driven; Knowledge is Scholarship driven and Deployment is Market driven and the two-way dynamics among these three impacts societal development. Under innovation comes incremental innovation, radical innovation, large-system innovation, and innovation for inclusive growth. Protection of IPR and the challenges of technology transfer have to be addressed in this context. He spoke about the changing contexts of social challenges in India during 1950s to the 1990s during which period science delivered solutions to situations arising out of technology denial in the strategic sectors. Subsequently, Dr. Banerjee focussed on self-reliance in the era of techno-globalization and illustrated his talk with the story of nuclear reactor development in India. In the following years, social challenges including problems of Energy, Environment, Climate change, Water, Education, Affordable healthcare and increased Food production to feed the burgeoning population. Flow of solutions from science is therefore, global and wide-reaching.

The Vote of Thanks was delivered by Dr. A.K. Ray, Convenor, IIMR-15.

Spread over three days, the IIMR-15 comprised Plenary lectures, Invited talks, Contributory presentations, Poster session and a Panel discussion. A galaxy of distinguished delegates, guests and speakers from across India participated. Their presence alongside the exuberant young researchers and Summer Interns at CSIR-CGCRI added great value to IIMR-15.

The Plenary talks were: Nanostructured functionalised nanocomposites delivered by Prof. K.L. Chopra (IIT Delhi); Innovations in the context of STI Policy – 2013 by Prof. S.P. Mukherjee (IAPQR); Impacting Research Innovation and Technology - An MHRD Initiative for Self-Reliance in Engineering and Technology by Prof. Indranil Manna (IIT Kanpur); Science, Technology and Innovations in Leather Research by Prof. Dr. A. B. Mandal (Formerly Director, CSIR-CLRI) and Sustainability and Life Cycle Assessment of Materials by Dr. S. Srikant (CSIR-NML). Among the other dignitaries who delivered talks were: Prof. Ajay Ray (IIEST, Shibpur), Dr. Ashish Lele (CSIR-NCL), Prof. Anindya J. Bhattacharya (IISc, Bangalore), Prof. Rabibrata Mukherjee (IIT-Kharagpur) Dr. G. Padmanabham (ARCI), Dr. S.K. Bhadra (CSIR-CGCRI), Prof. B. S. Murty (IIT-Madras), Dr. Goutam De (CSIR-CGCRI), Dr. R.N Basu (CSIR-CGCRI), Sitendu Mandal (CSIR-CGCRI), Prof. H.S. Ray (Former Director, CSIR-RRL, Bhubaneshwar) and Dr. B. B. Jha (CSIR-IMMT) to name a few.

Dr. Srikumar Banejee was Chairman of the Panel discussion on The Role of Innovations in Make in India. The other distinguished Panellists were: Dr. K.Muraleedharan, Professor K.L. Chopra, Prof. S.P. Mukherjee, Prof. B.S. Murty, and Dr. A.B. Mandal.

Prof. Chopra initiated the discussion in his characteristic straightforward manner. He said that, we are a scientific civilization and health and wealth depend on Knowledge; on Science and Technology, which must be translated for the benefit of the citizens. He said that the Decade of Innovation as launched by the GOI calls for support at all levels and that Innovation and Entrepreneurship go together. According to him, the University system must recognize this and teach the art of entrepreneurship to its students as part of its curriculum. Universities and educational institutions must have Business incubator and /or Technology Parks. The ecosystem in an educational institute must support entrepreneurship.

Dr. K. Muraleedharan said that the lack of innovation in recent times must be addressed but not through slogans alone. He said that Make in India is an opportunity and all should play a role to make it a success. Make in India will usher in an era of resources, he said. He gave the example of Warship-grade steel that India used to procure from Russia. When laboratory scale production was successful as a result of indigenous research, his team approached Steel Authority of India (SAIL) which took up the challenge of production. Today, this steel is used to manufacture the first aircraft carrier at the Hazira plant. This was possible only because SAIL had the skillsets for manufacturing, which calls for different tools and doctrines as compared to laboratory-scale production.

Prof. Mukherjee emphasized that Make in India included design in India, develop in India and deliver in India (and globally!). He stressed the fact that designing in India was integral to the task of Make in India; it was not enough to simply develop and deliver using the abundant and cheap labour-force in the country. The word design too should not be taken in the narrow sense of assembly/manufacture in India. Goods and services must be designed to meet current, future and also, unmet needs. We need to design newer and better products/processes/controls he said. We must use our innovative minds for creativity; for using our knowledge of S&T for better design and services.

Prof. Murty focused on the people who innovate and how to educate them. He said that with the mushrooming of engineering colleges there are many with degrees in Engineering but they are not all, necessarily good engineers. There is a lack of various levels of strong educational backgrounds. Good quality education must reach all. There must also be a Faculty development programme. He discussed the difficulties inherent in reaching a large group of students and researchers spread over the country but insisted that with innovative thinking and novel use of technology, this could be made possible. He gave an example of how he was planning to set up a facility for a very expensive Atom Probe machine. Because it is so expensive, funding is not easy to come by. However, he has designed the facility to be capable of being remotely operated so that every contributor, no matter where geographically, is a partner with equal access to the machine. He said this was a new model. Such innovative models can be used to reach a large part of the population.

Prof. Dr. A. B. Mandal also spoke about the encouragement and support that researchers, scientists and entrepreneurs need at all levels.

There was a spirited discussion after the Panellists had expressed their views.

Shri Subrata Ghosh was the Session Chairman at the Manufacturers Presentation Session. Representatives from Phadke Instruments, Mumbai, Merck Life Science Pvt. Ltd., Mumbai, Alfatech Services, New Delhi, S.M. Scientech, Kolkata and ANTS Ceramics, Mumbai, and Techno-Scientific Co., Kolkata took part in this session.

The distribution of papers presented as per different areas covered are as follows:

General presentation on Invention and innovation	4
Nanoscience and Nanotechnology	30
Energy materials	15
Glass, Ceramics and Refractories	10
Sensors	10
Steel	8
Biomaterials	4
Photonics	2
Functional materials	2
Clays, innovative materials and some nanomaterials	1 each
Miscellaneous topics	32

A special interactive session with the young researchers was also arranged in the workshop. During interaction, the following ten questions were put to the participants :

1. What is innovation according to you?
2. What is the difference between invention and innovation?
3. Identify a few inventions in modern times (in the area of materials) that have real impact on society?

4. How does one assess the impact of an innovation?
5. Why many R&D centres focus more on publications than innovations?
6. Why our university system have little R&D focused on innovations? (Most universities do not bother about patenting)
7. What in your opinion will encourage young researchers to dream of innovations?
8. Can you suggest some innovative ideas for R&D on materials?
9. What factors discourage our researchers to become innovators?
10. Anything else to say?

The majority of the participants did not answer all the questions. The respondents were mainly JRFs from CSIR-CGCRI and Jadavpur and Calcutta Universities. A couple were from IMMT, Bhubaneswar. Their replies are summarized as follows.

Q. 1 and 2 : Almost all could differentiate between Invention and Innovation. The common refrain being Invention needs something extra to convert an idea to an usable product for the marketplace. It is the entrepreneurs who take that step. Thus :

Innovation → Invention + Implementation.

One quoted Grasty's Analogy saying throwing a pebble into the pond to generate waves is the invention and the ripples generated being used to generate energy is the innovation. At least the youngsters are avid readers!!

Q. 3 : The most common inventions mentioned were LEDs, LASERs, Graphenes, Fullerenes, Quantum Dots, Super alloys, biomaterials, photovoltaic materials etc. It appeared their responses reflect the specific areas they are researching in.

One reply stood out. It's the use of Thermo-electric jerseys to be used by footballers to spot tiredness due to high body temperature. Not sure if this is actually being used somewhere.

Q. 4. These replies were either blank or very vague. General refrain was if these help improve lives and fulfill human needs, they would be assessed as successful.

Q. 5, 6 and 7 : The general consensus was that because the researchers were all working for Ph.D.s, their primary focus was publications. Ever for junior scientists, publications in peer-reviewed journals were more necessary for career advancements. No wonder their guides and university authorities focus most on publications than patents.
It is only the R&D laboratories where there is focus on patents. But the fact that most patents remain on paper only is a big deterrent to young researchers.

Q. 8. Mostly left blank. One response was a touch-screen phone whose screen can also act as a solar cell battery. i.e., transparent materials which can act both as power supply and as a touch-screen.

Q. 9. Again the answers were vague. Factors identified were lack of instrumentation, low level of fellowship support and need to support families. Also lack of motivation from the institutions. Looks like a lack of faith in the top leadership.

Q. 10: Most did not reply.

Overall, it appears that the respondents could differentiate between inventions and innovations. They are mostly aware about what is going on not only in their own research areas but generally in the broad areas of materials science. However, the spark of inventiveness and innovativeness needs support from the R&D system including better career opportunities in India.

Dr. S. Srikant presided over the Valedictory Session marking the formal conclusion of IIMR-15.

The complete programme of the Workshop is given in **Annexure-III.**

3.2 Innovations

On the basis of information, collected through above resources, the research outcomes have been examined as innovative outputs in the light of STIP 2013. In this context, it is needless to mention that successful deployment in the society of an R&D output and the economy will require long time. The R&D output may have to pass through different stages of improvement on the basis of users' feedback. Therefore, the identified R&D outcomes are divided in the following three categories:

a) Technologies transferred to industries for benefit to the society
b) Technologies ready for transfer and
c) Technologies having potential for successful industrial application

3.2.1 Technologies Transferred to Industries for benefit to the society

The technologies developed in R&D laboratories generally fall under this category.

CSIR-NML, Jamshedpur

a) Synthetic Nanocrystalline Hydroxyapatite

A Synthetic Nanocrystalline Hydroxyapetite (HAP) is a common bone graft material widely used in industry. The technology of preparing the material synthetically using a novel biometric process technology been developed at CSIR-NML.

b) Synthetic Nanocrystalline Hydroxypatitle and Tricalcium Phosphate Composite

The autogenous bone grafts routinely used in dentistry for filling up bony defects are associated with various adverse factors including limited availability. The Synthetic bone grafts eliminate most of the adverse factors and are preferred by surgeons. The material has been developed at CSIR-NML.

For characterization of the above materials advanced technique using SEM / TEM / XRD /FTIR have been used. The salient features of the material are:

- Bio-compatibility as per EN ISO 10993 standards
- No BSE / TSE issues
- Non-toxic, non-allergenic and non-pyrogenic
- High porosity

- Bio-resorbable
- As a scaffold for bone formation and remodeling
- Can be molded into required shape
- Clinically proven
- Patented CSIR technology

Licenses have been granted to industries for commercialization of the technologies. It is expected that the developed technologies will be beneficial to the society mainly to the dentistry.

c) Technology for Production of uniform rare grade nano iron oxide from Waste Pickle Liquour

CSIR-NML in collaboration with Tata Steel developed a novel process for production of various shapes of uniform size and high quality monodispersed particles of hematite from waste pickle liquour. Very uniform size iron oxide in the range of 100-200 nm of different shapes and colours were produced. Different grades of oxide match with the colours of different standard high end iron oxide in the inter-national market such as red oxide 2097 of Akzo noble and Asthanano red oxide.

Huge quantity of acid pickle liquour is generated from the pickling process of steel industries rcontaining 100-150 g/l iron along with other minor impurities. The developed process takes care of the impurities and produce high purity iron oxide suitable for other high end applications in making soft ferrites, catalysts, sensors etc.

The technology has been transferred to industries for commercial scale production.

d) Technology for recovery of lead from Zinc Plant residue

Most of the Zinc processing units generate huge quantity of residue containing lead. As lead is one of the most toxic metals, industries generating such residue are usually under tremendous pressure for closure of the units. A very simple hydro-metallurgical process comprising acid treatment, brine leaching and crystallisaation, developed by CSIR-NML for recovery of lead in the form of marketable products but also generates a final residue almost free of lead can be dumpled safely anywhere. The process uses common salt for recovery of lead as lead chloride and operates in a close loop. No other solid or any liquid effluent is generated from the process and thus is environment friendly.

The technology has been transferred to industries for commercial production.

e) Technology for Production of Tungsten Metal Powder from Hard Carbide Scraps

Tungsten is a rare and strategic material that has critical applications in defence, energy and mining sectors. Its demand is met mainly through imports. However, number of secondary sources of tungsten are available in India.

An innovative technology has been developed at CSIR-NML to produce tungsten from scraps. The tungsten metal scraps are processed to produce highly pure Tungsten metal. The process involves acid treatment to recover pure oxide that is subsequently reduce tungsten powder. The process is superior to existing materials as it involves less number of unit operations and operates in closed loop with no solid/liquid effluent generation. It produces high tungsten recovery with simultaneous recovery of other metals.

The technology has been transferred to two industries for commercial production. Unit processing cost is about 40% less in comparison with the existing processes.

f) Technology for Nickel Recovery from Spent Catalysts

At CSIR-NML, a novel process has been developed for the recovery of nickel from the spent catalysts. Almost 100% dissolution of nickel has been made possible by the process in presence of a specially developed promoter. With addition of only 0.2% of the promoter more than 99.6% of nickel recovery has been achieved at 70^0 C and 3% sulphuric acid. The process was tested for variety of spent catalysts. The developed process got wide recognition and granted patents in 10 different countries.

The technology has been transferred for commercial production to an industry at Malaysia.

Recently CSIR-NML Jamshedpur has brought out a document that lists all the technologies ready for transfer and those actually commercialized already. The document lists salient features, environmental considerations major raw materials, major plant equipment/ machinery, technology, scale of development commercialization status and also techno-economics.

In addition to information on the preceding technologies, there is also information on the following for technologies transferred.

g. Wide metallic glass ribbon processing unit.
h. Magstar : A device for nondestructive evaluation of steel structure/component.
i. Microwave 1R : A noninvasive technology for iron ore compositional analysis.
j. Development of biphasic calcium phosphate block.
k. Paving blocks from flyash, blast furnace slag, steel slag, etc.
l. Recovery of gold from waste mobile phones and scraps of various equipment.

The relevant pages from CSIR-NML document are given in **Annexure-IV**.

CSIR-CGCRI

a) Ceramic membrane based pretreatment system for BRWO/SRWO plants

Activity on Ceramic membrane was initiated during 1993-1994 as an exploratory work. During this stage, the R&D activities were primarily focused on the development of low cost ceramic membranes in disc and tubular configurations including system design and development of prototypes for membrane based separation process. The milestone on upscaling and demonstration of the ceramic membrane was achieved in January 2002 when a pilot plant trial for treatment of arsenic contaminated groundwater was conducted successfully under the field condition. Development of low cost ceramic multichannel elements led to a step forward in application of ceramic based technology for iron removal and an experimental plant was installed in the residential complex of CSIR.

The process technology was transferred to industry to manufacture 'Arsenic and Iron removal plants'.

b) Ceramic Bio-medical implants

Conventional hip prosthesis comprises three components: accetabular cup of ultra high molecular weight polyethylene, a femoral head and a stem each made out of metal. It has limited life span and is not suitable for younger patients. CGCRI has developed an improved version which comprises accetabular cup, femoral head both made of ceramic material. The salient features of the product include reduced friction between femoral head and cup, less wear debris, improved mechanical properties, minimized revision strategies and longer life.

After successful completion of trials under simulated conditions, human trials on the implants have been done at Kalpataru Hospital, Barasat, West Bengal. Human trials are also being carried out at AIIMS, New Delhi.

It is expected that the products will have tremendous benefits for the society.

c) Hard and Abrasion Resistant Coating

CR-39 or polycarbonate grade plastics are of safe use for optical applications. The material can withstand high impact compared to glass but are not scratch resistant enough which deteriorates optical property fast. CGCRI has developed processes based on the organic-inorganic hybrid materials for scratch resistant coatings. The coatings are deposited on plastic ophthalmic lenses and PC sheets. The pencil hardness of the material is greater than 6H and has already passed ASTM tests.

Licenses of the technology have been granted to external agencies.

d) Special Glass Nodules for Nuclear Waste Immobilization

Under an Memorandum of Understanding with Nuclear Research Board, BARC and the Department of Atomic Energy (DAE), the CSIR-CGCRI has developed the seven component borosilicate glass beads to prove melter life and absorb fluctuations of sodium and iron in the

high level radioactive liquid waste for vitrification. CSIR-CGCRI has also optimized process parameters and carried out material characterization of the beads for bulk production.
The entire batch preparation including the processing of raw materials even mixing, charging of the mixed batch and the discharging of the melted frit was satisfactorily to several industries. License of the full scale technology has been transferred to industry. It will be beneficial not only for economic purpose but also be useful for the country's strategic sector.

e) Development of transparent, hard and protective coatings on CR-39® ophthalmic lenses and related plastics

At CSIR-CGCRI, this nanotechnology based process was developed for making sols (lacquers) for applying thermal-curable (<100°C) optically clear anti-scratch coatings on plastic (CR-39®, polycarbonates (PC), PMMA etc.) ophthalmic lenses, sheets and other shapes by dip-coating technique. The coating sol (long shelf-life) based on SiO_2 (silica)-PEO (polyethylene oxide) nanocomposite was developed using an inorganic-organic (I-O) hybrid approach. This sol can be applied on plastics as coatings, and after thermal curing a highly cross-linked interpenetrating nanocomposite hybrid network covalently bonded with silica nanoparticles have been formed and provide high abrasion and stain resistance. Transparent coatings, as shown below, having a refractive index value of 1.475±0.005 are appeared as homogeneous, crack-free and flawless with excellent adhesion to the substrates.

Salient Features:

- Coatings passed cross cut adhesive tape test (class 5B, ASTMD 3359);
- Pencil hardness value >6H, ASTM D3363;
- Passed abrasion test and Steel wool test
- Passed thermal and chemical durability tests.

The technology has been transferred to two industries for commercial scale production.
Currently the above process has been modified as a 'refractive index controlled hard-coating'. Refractive index of the resultant hard-coatings can be tuned in accordance with the refractive index of the plastic substrates. The uniqueness of this coating is that the previously scratched

plastics can be hard-coated, and scratches will be disappeared due to matching refractive index of coatings and substrates.

Durgapur Steel plant (DSP)

a) Micro alloyed BG Coaching wheels

DSP in association with IIT Kanpur and RDSO has developed micro alloyed BG coaching wheels keeping the following objectives in view:

- Reduction in in-service failures
- Withstanding higher axle loads without sacrificing safety
- Improvement in safety, reliability and enhancing carrying capacity without altering design

132 micro alloyed wheels have been manufactured, out of which 112 have been dispatched to Indian Railways for assembly and subsequent field trials. These wheels have shown excellent strength and hardness properties in comparison with conventional wheels.

In view of the necessity of high speed transport system of the country, these wheels will be beneficial for the society, specially the Indian Railways.

3.2.2 Technologies Ready for Transfer

The R&D activities of the academic institutes, like IIT – Kharagpur, IIEST, Presidency University, Calcutta University, Jadavpur University, IIM-Kolkata, Indian Cultivation of Science- Kolkakata,cover wide areas. It is observed that the Institutes and the universities have carried out extensive research activities for knowledge generation leading to publications in reputed journals. However, their main objectives are not aimed at real life applications in industries. Presently, they are not equipped with adequate infrastructure and expertise to convert generated knowledge into industrial applications leading to successful innovations as defined in STI Policy 2013. It is felt that with active participation of industrial organisations in the R&D programmes, the generated knowledge can be made more beneficial for the society.

The details of research areas and technologies, ready for commercialization of Indian Institute of Engineering Science and Technology, Sibpur, Indian Institute of Technology, Kharagpur, and CSIR-National Metallurgical Laboratory, Jamshedpur are given here.

Technologies Ready for Commercialisation

Organisation: IIT-Kharagpur

(* Technologies that deal with materials and their processing)

Biotechnology

1. A bio-process for sandalwood somatic seedling production
2. A Kit for use in Semi quantification of CRP Present in Whole Blood and a Process for Manufacture of the Same
3. A method for the preparation of lectin based immuno adjuvants
4. A Novel Biofuel Additive for Diesel Engines
5. A Process for the production of somatic seedlings of plants
6. An apparatus for Plant tissue culture
7. An improved process for the preparation of ethanol from starchy material
8. Development of a monoclonal antibody against cytoplasmic polyhedrosis virus infecting Indian saturniidae silkworms
9. Development of High Rate and Yield Hydrogen Production Process
10. Development of high yield hydrogen producing microbial strain enterobacter
11. Herbal Skin Nourishing Gel

Chemical Engg.

1. A device for cryogenic grinding of products such as spices, vegetables, food grains plastic and polymers.
2. * A process for the preparation of a Novel Polyurethan& its application as Membrane for Selective Separation of Organic Pollutants (Phenolic Compounds) from Aqueous Solutions by Pervaparation.

3. A Two Phase Double Vortex Atomizer
4. * Electric field assisted membrane separation of pectin
5. * Improved wet scrubber for simultaneous scrubbing of particulates and gaseous matters
6. * Membrane Based Water-Extraction of Polyphenols from Green Tea Leaves
7. Optical Probe for Multiphase Flow
8. * Synthesis and characterization of Hydroxyapatite (HAp)/poly (Vinyl alcohol phosphate) (PVAP) Nanocomposite biomaterials

Electrical Engg.

1. A clock controlled sun tracking system for solar photovoltaic and solar thermal collectors.
2. A new gate drive circuit for IGBTs and Mosfets for industrial electronics application
3. A Novel Automatic Slope (or Angle of Inclination) Detector
4. A novel bioreactor named "SEE-SAW" Reactor and design of instrumentation part
5. A novel position sensor using analogue electronic devices
6. A process sensing apparatus for transmitting optical signals corresponding to pressure and differential pressure
7. A speed controllable rotation floating disc device
8. An apparatus for non-invasive measurement of spatial parameters of a distant object
9. An auto start up and reversible speed control apparatus
10. Charging Circuit for a large SC Coil for SMES - UPS System
11. Electronic Circuits for protection of S. C. Coil against over-voltages and fast detections & protection of S. C. Coil against quench
12. Indigenously Developed Real Time Digital Simulator (POWERDRAW)

Electrical & Electronics Engg.

1. A Continuous soil moisture recorder
2. A Near Toll Quality Speech Coder at 2.4 Kbps
3. An Automated Irrigation System

4. An improved apparatus for Ultrasonography using a continuous wave Doppler system
5. An instrument for continuous non-invasive measurement of blood pressure
6. Automated Irrigation Controller
7. Current mode differential I/O buffer for high speed off-chip interconnect

Material Science

1. * A Composition for consolidation of Dense Ceramics and Metal Compacts
2. * A composition for forming porous bodies, in particular ceramic and metal forms and a process for the preparation thereof.
3. * A composition for use in gelation forming of ceramics
4. * A method of fused deposition with improved bonding strength through electro chemical discharges on a substrate
5. * A Novel Processing route to Fabricate Low Cost Fused Silica Ceramic Foam
6. * A Polymeric flocculent and its process for manufacture
7. * A process for the preparation of a graft copolymer for use as a flocculation agent
8. * A process for the preparation of a Novel Polyurethan& its application as Membrane for Selective Separation of Organic Pollutants (Phenolic Compounds) from Aqueous Solutions by Pervaparation.
9. * A process for the preparation of encapsulated metal nanoparticles
10. * A process for the preparation of fibrillised liquid crystalline polymer in a polyether etherketone
11. * A process for the preparation of graft copolymers for use as a flocclating agent
12. * A process for the preparation of graft Copolymers for use as a high performance flocclating agent
13. * A process for the preparation of pure metal from metal salts
14. * A process for the preparation of ultra-pure porous alumina powder
15. * A process for the preparation of ZnOnanopowder
16. * A process of preparation polymer coated glass fiber mat
17. * A process on Modification of Mat Grass for Improvement performance
18. * A Sensor system for detecting Presence of Deoxidizing Gases

19. * A Simple Environment Friendly Process for Fabrication of Highly Porous Materials

20. * A Stabilized t-ZrO2 and a Process for its Manufacture

21. * A Stable CrO2 Nanoparticles and a Process for its Manufacture

22. * A Starch Based Cationic Amylopectin

23. * A Starch Based Cationic Amylopectin

24. * A Transparent Amorphous AlO(OH).aH2O Glass and process for Preparation of the Same

25. * An Highly Stable g-Al_2O_3 Messoporous structure and its Process for Manufacture

26. * Carboxymethyl Cellulose Acrylate for Enteric coating and Sustained Release

27. * Carboxymethyl Cellulose Methacrylate for Enteric coating and Sustained Release

28. * Development of A Low Cost Equipment Spray - CVD for Deposition of Oxide Films

29. * Flexible Contact Tube for Rotation ARC GMA Welding

30. * Grafted amylopectin for use in sprinkler irrigation systems

31. * High performance flocculants based on hydrolysed and unhydrolysed guar gum-g-polyacrylamide

32. * High performance flocculating agents and viscosifiers based on hydrolysed grafted amylopectin and polycrylamide grafted carboxymethyl cellulose

33. * Polyamide Films and a process of preparing the same

34. * Process for the preparation of polysaccharide blended slow release urea

35. * Quick setting polymer composition

36. * Removal of p-chlorophenol and 2,4 dichlorophenol from water by pervaporation using polyurethane urea-PMMA IPN membrane

37. * Transparent Inorganic ZrO(OH)2.XH2O Polymer and a Process for Preparation of the Same

Mechanical Engineering

1. A Device for Making Shaped Products from Paste / Batter Such as Pulse Based Product/ BORI

2. A knee joint simulator

3. A method of maintaining the zone temperature in a single zone variable air conditioning (VAVAC)

4. A monodisperse virtual impactor type aerosol generator

5. * A monolayer abrasive tool used in surface grinding and a method of making the same

6. A Novel Automatic Slope (or Angle of Inclination) Detector

7. * A process for preparing ammonium salt coated Cu-X zeolites

8. A selective fused deposition modelling machine using electro-chemical discharge

9. An Electromagnetic Device based system for Fault Detection and Identification in Rotating Mechanical Components

10. An improved portable influsing pump

11. An improved torque amplification device using alternation flow hydraulics and orbital rotary piston motor principle

12. An improved voltage and current measurement system for sparks

13. CENTO DRIVE

14. Design and development of structured surface for the enhancement of boiling heat transfer

15. Optical Probe for Multiphase Flow

16. SYMBOLS2000

17. System for measuring Thermal Conductivity of Liquid/Nanofluids

Metallurgical &Material Engineering

1. * A Process for Preparation of Al - Ti - B Master Alloys for Grain Refinement of Aluminium and its alloys

2. * A process for preparation of master alloy for grain refinement of aluminium and its alloys

3. * A Process for production wear resistant cast iron by smelting reduction of waste products like red mud and sesilicated sand

4. * A process for the preparation of aluminium based ternary alloy

5. * A Process for the preparation of ferrous based composite

6. * Master Alloy for modification and grain refining of hypoeutectic AI-Si based foundry alloys and its process for manufacture

7. * Monel alloy resistant to stress corrosion crack in hydrofluoric acid

8. * Plasma sprayed ceramic coatings

9. * Virtual alloys (software)

Organisation: IIEST, Howrah

Aerospace and Underwater Systems

1. Underwater Lift bag
2. Rear projection balloon

Electrical and Electronics Engineering

1. * A non-invastive multi-sensor wireless system
2. Energy saving for bulk customers
3. Data logging and Remote Monitoring System for PV application
4. Gas Leak hunter
5. * Solar Lantern
6. Methano-Meter

Biotechnology

1. Subject specific customization of trip implant

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Among them, the technologies of IIT-Kharagpur in the area of materials that are ready for commercialization are mentioned here.

a) Master alloy for modification and grain refining of hypoeutectic Al-Si based foundry alloys and its process for manufacture

b) Monel alloy resistant to stress corrosion crack in hydrofluoric acid

c) A process for the preparation of aluminum based ternary alloy.

The details of technologies, which have been developed by CSIR-CGCRI and are ready for commercialisation, are available in their annual reports.

3.2.3 Technologies under Progress and having Potential for High Impact on Society and Economy

In the workshop, apart from review articles on status of innovation in material research in the context of STIP 2013, the participants presented their research findings in different areas of material development, processing and applications. Most of the research activities are oriented towards new knowledge generation or investigative studies. A few research findings, it is expected, can be converted to real life applications with suitable industrial participations. They identified research topics are

a) Science led innovations in advanced materials and processes required for the indigenous development and deployment of PEM fuel cells in India.

The CSIR-NCL, Pune and two other CSIR laboratories have been working for the development of indigenous technology for Polymer Electrolyte Membrane Fuel Cells for the last seven years and significant knowhow has been generated. With industrial participation, the generated knowhow can be converted to successful innovative products.

b) Production of Nickel from Chromite Overburden

CSIR-IIMT, Bhubaneswar developed a promising technology for producing Nickel and Chromium from indigenous resources and a demonstration plant was put up in the laboratory's

premises. The technology, if commercially utilized through industrial participation, will eliminate high cost of import of this metal of strategic importance.
There are also a few other research activities that show promising applications of existing technologies in new areas.

3.2.4 Development of Database on Innovation

The database of innovative technologies, listed under categories (a) and (b), has been developed in two groups as area-wise database and organization-wise database. The details of divisions are given here.

Examining the nature of innovations, identified during the survey and in consistence with the objectives of the projects, the areas of innovations have been divided in the following sectors:

1) Ceramic	2) Composites	3) Electronic and Photonic materials
4) Glass	5) Meta-materials	6) Metals & alloys
7) Nano-materials	8) Smart materials	9) Super materials
10) Others	11) Raw materials	

The organisations, considered in the survey in and around Kolkata region are listed here.
1) CSIR- Central Glass and Ceramic Research Institute, Kolkata
2) CSIR- Central Mechanical Engineering Research Institute, Durgapur
3) CSIR-Indian Institute of Chemical Biology, Kolkata
4) CSIR-National Metallurgical Laboratory, Jamshedpur
5) Durgapur Steel Plant, Steel Authority of India, Durgapur
6) Indian Institute of Engineering Science and Technology, Howrah
7) Indian Institute of Management, Kolkata
8) Indian Institute of Technology, Kharagpur
9) Jadavpur University, Jadavpur, Kolkata
10) Kolkata University, Kolkata
11) Saha Institute of Nuclear Physics, Kolkata

12) Variable Energy Centre, DAE, Kolkata

13) Tata Steel, Jamshedpur

The period of innovation, considered in the survey, is 2000 to 2015.

Separate database has been prepared for category (a), i.e., for Technologies transferred to industries and category (b), i.e, Technologies ready for transfer. Each database consists of three files as i) Main file that lists the complete list of areas and organisations, ii) areaswise innovation database is included in the second file and iii) organization innovation database is provided in the third file.

The softcopies of the files are recorded in a CD. The hard copy of the Database is given in Annexure-V. The user can open the files individually through EXCEL program or through the main file. The records can be accessed conveniently following the given instructions in the respective files.

In order to examine the overall standards, different aspects of the innovations, such as S&T content, benefits and costs and societal and economic impacts of the innovations are tabulated and shown in Table 6. Since the present pilot study is for short duration, market penetration and productivity of an innovation could not be examined and hence are not included here. However, since sufficient data are not available to use any mathematical formulation for awarding the grades quoted in Table-6, opinions have been obtained from different team members and experts in the field for computational purposes. While awarding numerical grades against each aspect of innovation in the scale of 1 to 10, a few basic criteria have been followed. For example, the maximum grade of 10 is considered equivalent to international standard for S&T content. Similarly, the maximum value of 10 is considered for high impact on the society and economy. In cases of Bio-materials, where commercialization needs approval from different agencies, economic impact is not yet visible but shows potential for high societal impact and the assigned grade is more than 5.

TABLE – 6 : GRADATION OF INNOVATIVE OUTPUTS OF DIFFERENT ORGANISATION

Organization	Title of Innovation	Area of Innovation	S & T Content	Benefits	Impacts on society and economy
CSIR-CGCRI	Ceramic membrane based pretreatment system for BRWO/SRWO Plants	Ceramic	5	5	6
	Ceramic Bio-medical implants	Bio-materials	7	7	7
	Special glass nodules for nuclear waste immobilization	Glass & Energy	6	7	7
	Development of transparent, hard and protective coatings on CR-39® ophthalmic lenses and related plastics	Nano-composites	7	6	6
	Hard and Abrasion Resistant Coating	Poltycarbonate based Plastics	5	5	4
CSIR-NML	Development of biphasic calcium phosphate block	Ceramic	5	6	6
	Paving blocks from flyash, blast furnace slag, steel slag, etc.	Ceramic	5	6	7
	Wide metallic glass ribbon processing unit	Glass	7	5	5
	Technology for recovery of Lead from Zinc Plant residue	Metals & Alloys	5	5	5
	Technology for Production of Tungsten Metal	Metals & Alloys	5	5	6

	Powder from Hard Carbide Scraps				
	Technology for Nickel Recovery from Spent Catalysts	Metals & Alloys	5	5	6
	Recovery of gold from waste mobile phones and scraps of various equipment	Metals &Alloys	6	7	7
	Magstar : A device for nondestructive evaluation of steel structure/component	Metals & Alloys	5	6	7
	Microwave 1R : A noninvasive technology for iron ore compositional analysis	Metals & Alloys	5	5	5
	Synthetic Nanocrystalline Hydroxyapatite	Nanomaterials	6	6	5
	Synthetic Nanocrystalline Hydroxyapatite and β- Tricalcium Phosphate Composite	-Do-	7	6	5
	Technology for Production of uniform of rare grade nano iron oxide from Waste Pickle Liquour	Nanomaterials	5	5	5
Durgapur Steel Plant	Micro alloyed BG Coaching Wheels	Metals & Alloys	6	5	4

Note :

(1) The maximum grade of 10 is considered equivalent to international standard for S&T content.

(2) The maximum grade of 10 for R&D benefits is assigned for high social benefits.

(3) The maximum value of 10 is considered for high impact on the society and economy.

(4) Limitations: The study is for short duration. So, the market penetration and productivity of an innovation could not be examined.

The Table shows that the majority of the innovations are on the development of new processes. The technologies related to strategic materials are common in both CSIR-NML and CSIR-CGCRI. It appears that the strategic sectors are more interested in indigenous research than the industrial sector. In terms of grades, Bio-medical implants have become the most important innovations among all other identified innovations.

3.3 Factors Affecting Innovations

There is no dearth of inventions in laboratories in India but rarely does an invention transforms into an invention. For this an innovation needs to be brought into the market place.

A technology coming out of a R&D laboratory needs to go through manufacturing and marketing to reach a user. This is Technology Push. On the other hand, Market Pull Innovation (i.e. a 'need' simulated invention) starts with market research and then an appropriate R&D and subsequent, manufacturing for the user. Generally, two-third of innovations need to be stimulated.

Technological innovations generally go through eight stages –

1. Basic Research – to increase understanding the laws of nature and generation of knowledge.
2. Applied Research – directed towards solving society's problem.
3. Technology Development – to convert knowledge and ideas into service through demonstration programme.
4. Technology Implementation – articles associated with introducing a product into the market place an ensuring successful commercial introduction of the product.
5. Production – activity associated with wide spread conversion of ideas into products and services.
6. Marketing – to ensure that consumers embrace the technology.

7. Proliferation – strategy that ensures wide spread use of technology and its dominance in the market place.

8. Technology Enhancement – maintaining a complete edge of the technology (new application of the technology, quality improvement, cost reduction, meeting customers' special needs and more to increase the life cycle of the technology).

Based on some selected technologies, NASA identifies the following Technology Readiness Levels (TRL).

Generic/Notional TRL Definitions

	Level	**Qualifier/Development Hurdle**
Basic Research	1	Basic scientific/engineering principles observed and reported
Feasibility Research	2	Technology concept, application, and potential benefits formulated (candidate system selected)
Feasibility Research	3	Analytic and/or experimental proof-of-concept computed (proof of critical function or characteristic)
Technology Development	4	System concept observed in laboratory environment (breadboard test)
Technology Development	5	System concept tested and potential benefits substantiated in a controlled relevant environment
System Development	6	Prototype of system concept is demonstrated in a relevant environment
System Development	7	System prototype is tested and potential benefits substantiated more broadly in a relevant environment
Operational Verification	8	Actual system constructed and demonstrated, and benefits substantiated in a relevant environment
Operational Verification	9	Operational use of actual system tested, and benefits proven

The periods needed for realizing the various levels are given as follows.

Sample statistics for twelve NASA Technologies Maturing from TRL 1 to TRL 9

Years to TRL 9 from TRL	Average (years)	Standard Deviation
1	16.3	11.4
2	14.5	10.9
3	13.1	10.6
4	11.3	10.6
5	9.7	10.7
6	7.0	5.6
7	5.0	3.9
8	2.2	3.1
9	0.0	0.0

It should be noted that several stages initially take many years and substantial financial investment. In fact, more money is required after the basic research. Moreover different teams with different expertise are needed at different stages.

Manufacturing Readiness Levels (MRI)

When there is a question of large scale manufacture and marketing then there is the issue of Manufacturing Readiness Level (MRL). Manufacturing starts after development of a technology and, therefore, there is a phase lag between TRL and MRL, the later starting somewhat later. We consider example of the automobile industry. A guide to recognized stages of development within the Automotive Industry in terms of Automotive Technology and Manufacturing Readiness Levels has been made available by the Low Carbon Vehicle Partnership in association with the Automotive Council in January 2011. Professor Richard Parry-Jones from the Technology Strategy Board writes the following.

'Good, clear communication firms the ground for exploring new ventures, common areas of interest and establishing new relationships. Within engineering sectors, communication is paramount to achieving high quality products and using resources most efficiently and effectively.'

Relationship between Technology Readiness and Manufacturing Readiness Level

Some Tables are reproduced from the report to compare TRL and MRL. There are ten stages of maturity for a product to :

- deliver its function (Technology Readiness)
- be produced (Manufacturing Readiness).

In any job problems faced are of two kinds, 'hard' and 'soft'. The word 'hard' does not mean difficult but means that the problem is well defined just as the contours of a solid are well defined. Two additional characteristics of 'hard' problems are that not the method of solution is known or can be found out and the solution is unique. By the word 'soft' one means that the problem is neither clearly well defined, nor is the solution very clear and the solution is not unique. While TRL's deal with 'hard' problems the MRL's essentially deal with 'soft problems'. These levels are staggered in the Table since advancing technological capability logically progresses ahead of manufacture. For each TRL the corresponding MRL is that which is usual. It should be noted, however, that some technologies can deviate from these levels.

Automotive Technology and Manufacturing Readiness Levels

TRL	Technology Readiness	MRL	Manufacturing Readiness
1	* Basic Principles have been ob served and reported. * Scientific research undertaken. * Scientific research is beginning to be translated into applied research and development. * Paper studies and scientific experiments have taken place. * Performance has been predicted.		
2	* Speculative applications have been identified. * Exploration into key principles is ongoing. * Application specific simulations or experiments have been undertaken. * Performance predictions have been refined.		* A high level assessment of manufacturing opportunities has been made.

3	* Analytical and experimental assessments have identified critical functionality and/or characteristics. * Analytical and laboratory studies have physically validated predictions of separate elements of the technology or components that are not yet integrated or representative. * Performance investigation using analytical experimentation and/or simulations is underway.	1	* Basic Manufacturing implications have been identified. * Materials for manufacturing have been characterized.
4	* The technology component and/or basic subsystem have been validated in the laboratory or test house environment. * The basic concept has been observed in other industry sectors (e.g. Space, Aerospace). * Requirements and interactions with relevant vehicle systems have been determined.	2	* Manufacturing concepts and feasibility have been determined and processes have been identified. * Producibility assessments are underway and include advanced design for manufacturing considerations.
5	* The technology component and/or basic subsystem have been validated in relevant environment, potentially through a mule or adapted current production vehicle. * Basic technological components are integrated with reasonably can be tested with equipment that can simulate and validate all system specifications within a laboratory, test house or test track setting with integrated components. * Design rules have been established. * Performance results demonstrate the viability of the technology and confidence to select it for new vehicle programme consideration.	3	* A manufacturing proof-of-concept has been developed. * Analytical or laboratory experiments validate paper studies. * Experimental hardware or processes have been created, but are not yet integrated or representative. * Materials and/or processes have been characterized for manufacturability and availability. Initial manufacturing cost projections have been made. * Supply chain requirements have been determined.
6	* A model or prototype of the technology system or subsystem has been demonstrated as part of a vehicle that can simulate and validate all system specifications within a test house, test track or similar operational environment. * Performance results validate the	4	* Capability exists to produce the technology in a laboratory or prototype environment. * Series production requirements, such as in manufacturing technology development, have been identified. * Processes to ensure manufacturability, producibility and

	technology's viability for a specific vehicle class.		quality are in place and are sufficient to produce demonstrators. * Manufacturing risks have been identified for prototype build. * Cost drivers have been confirmed. * Design concepts have been optimized for production. * APQP processes have been scoped and are initiated.
7	* Multiple prototypes have been demonstrated in an operational, on-vehicle environment. * The technology performs as required. * Limit testing and ultimate performance characteristics are now determined. * The technology is suitable to be incorporated into specific vehicle platform development programmes.	5	* Capability exists to produce prototype components in a production relevant environment. * Critical technologies and components have been identified. * Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated with components in a production relevant environment. * FMEA and DFMA have been initiated.
8	* Test and demonstration phases have been completed to customer's satisfaction. * The technology has been proven to work in its final form and under expected conditions. * Performance has been validated, and confirmed.	6	* Capability exists to produce integrated system or subsystem in a production relevant environment. * The majority of manufacturing processes have been defined and characterized. * Preliminary design of critical components has been completed. * Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on subsystems/systems in a production relevant environment. * Detailed cost analyses include design trades. * Cost targets are allocated and approved as viable. * Producibility considerations are shaping system development plans. * Long lead and key supply chain elements have been identified.
9	* The actual technology system has been qualified through operational experience. * The technology has been applied in	7	* Capability exists to produce systems, subsystems or components in a production representative environment.

	its final form and under real-world conditions. * Real-world performance of the technology is a success. * The vehicle or product has been launched into the market place. * Scaled up/down technology is in development for other classes of vehicle.		* Material specifications are approved. * Materials are available to meet planned pilot line build schedule. * Pilot line capability has been demonstrated including run at rate capability. * Unit cost reduction efforts are underway. * Supply chain and supplier Quality Assurances have been assessed. * Long lead procurement plans are in place. * Production tooling and test equipment design & development has been initiated. * FMEA and DFMA have been completed.
		8	* Initial production is underway. * Manufacturing and quality processes and procedures have been proven in production environment. * An early supply chain is established and stable. * Manufacturing processes have been validated.
		9	* Full/volume rate production capability has been demonstrated. * Major system design features are stable and proven in test and evaluation. * Materials are available to meet planned rate production schedules. * Manufacturing processes and procedures are established and controlled to three-sigma or some other appropriate quality level to meet design characteristic tolerances in a low rate production environment. * Manufacturing control processes are validated. * Actual cost model has been developed for full rate production.

10	* The technology is successfully in service in multiple application forms, vehicle platforms and geographic regions. In-service and life-time warranty data is available, confirming actual market life, time performance and reliability.	10	* Full Rate Production is demonstrated. * Lean production practices are in place and continuous process improvements are on-going. * Engineering/design changes are limited to quality and cost improvements. * System, components or other items are in rate production and meet all engineering, performance, quality and reliability requirements. * All materials, manufacturing processes and procedures, inspection and test equipment are in production and controlled to six-sigma or some other appropriate quality level. * Unit costs are at target levels and are applicable to multiple markets. * The manufacturing capability is globally deployable.

A few examples of time taken for development for some Indian technologies are as follows:

a. Production of Ni from nickel overburdened (abandoned in CSIR-IMMT Bhubaneswar after 15 years at level 7).
b. Production of Mg from dolomite (abandoned in CSIR-NML, Jamshedpur after some 25 years again around level 7 or 8).
c. Production of Ti from limonite –Technology transferred for in house production in DRDO for about 30 years
d. Production of Na and Mg at CSIR-NML (Level 3 or 4 after 5 years).

Technology Transfer, often referred to as T^2, is a process by which existing technology is transferred or transformed to fulfill the user's needs. It is the process by which research and other new technologies are transferred into useful processes, products and programmes. That is, it is a process by which a better way of doing something is put into use as quickly as possible.

The difficulties in T^2 include the following :

- People and organizations are naturally resistant to change.

- Personal contact – the human element – is the most important factor in innovation diffusion and adoption.
- The personal contact, through one – to – one technical assistance and special transfer agents, is expensive in the short run but may be immeasurably cost-effective in the long run.
- Effective communication of new ideas and techniques is best done through multiple channels – people, newsletters, case study reports, professional association networks and publications.
- Experience and endorsement of peers are very important elements in the widespread adoption of innovation an technology.
- Acceptance of a new technology takes time at lot of work and risk.

Some important T^2 activities are the following :

- Co-operative research projects
- Contract research
- Patenting, and
- Copy right and licensing.

Applied research, on the other hand adopts theory to practice – it demonstrates that an idea or concept has some practical application.

Why our R&D Centres do not have a satisfactory record of innovations?

We need to examine this question critically before attempting to suggest remedies. No doubt there have been outstanding achievements in Indian science and technology. A recent example is the Mangalyan which was accomplished by some 1000 scientists and engineers of ISRO working for a single mission for around three years with a budget of several hundred crores. Earlier ISRO put into orbit a satellites around the moon and several other satellites (GSLV) in space. These have made not only to add to the prestige and pride of the nation but also direct benefits to society. There has a great deal of participation of private industry which has produced high quality components with many spin offs. The GSLV satellites have revolutioned mass education, weather predictions and many other areas. However, there are not many such achievements in other agencies.

The answer lies in some of the following issues :

- *Time spent on active R&D by scientists in different R&D laboratories*

If one takes into account various kinds of leaves available to a scientist the total minimum number of days for a man would be around 140 only and for a woman even less around 110. Of course, there would always be exceptions of persons devoting much more time. But then rarely are scientists devoted to a single mission.

- *Research teams*

These are seldom exclusive and team members work in other areas too.

- *Originality of R&D*

Often the work undertaken is duplication of some earlier work. Because of poor record keeping often the details of earlier works are lost.

- *Poor marketing by R&D centres*

Not all laboratories have readymade literature on what all technologies they have developed for taking forward. Only very recently CSIR-NML, Jamshedpur has brought out a Technology Handbook listing all technologies that are ready for commercialization or have already been commercialized. Not many other CSIR Laboratories have such a document. In the universities even upto date Annual Reports of research results are not available. Potential investors find it difficult to get the information they seek. Even if the R&D centre presents some promising technology, the centre cannot provide much information on potential financial benefits i.e. return on investment because researchers are not trained to examine the economic aspects at all. The claims, therefore, are often vague and debatable.

- *Subjective horizon*

Some investors, specially Govt. agencies, often have a poor subjective horizon, i.e. they fail to see in the long term. This reflects the typical mind set of the bureaucracy.

- *Competition with imported technologies*

Many potential investors prefer to go for an off the shelf foreign technology rather than consider an indigenous alternative. There are several reasons for this not all of which are based on proper values and judgement.

- *Inadequate returns on efforts*

There are numerous examples where a researcher has spent many years developing a new material or process that has passed through rigorous examination also. Yet, for one reason or another it never went into the market. The frustrated scientist then prefers to switch to basic research which will yield publications and academic recognitions. These help them in their career growth.

In progressive industries R&D is focused on creating innovations and not on publications which may be considered secondary.

- *Laboratory records*

Many scientists assume R&D results to be in their private domain and leave no records in the laboratory for posterity. Laboratories often have no mechanism to ensure that they do.

- *Thrust on science*

In most R&D Laboratories there is more thrust on science and not on product and/or process development.

- *The university system*

In the university system researchers are mostly devoted to publications became these are useful in their promotions and recognitions. There is little effort towards product/process innovation and few universities have Pàtent Cells. These researchers simply cannot devote years on some missions that may not yield results useful in their career progress.

- *Sense of mission*

In most projects there is seldom a sense of mission that big, well defined goals bring forth.

- *Focus*

Generally there is a lack of focus and often projects can drag on for years with no well defined mile stones.

- *Lack of trust*

Researchers often do not enjoy 'trust' to deliver and there is too much monitoring far too frequently (by Research Councils, Technical audit, Parliamentary delegations, Vigilance for purchases etc.). This demotivates researchers and innovators. Many have found it safer not do take any risk.

- *Opposition*

There are established companies in India and abroad, which may oppose new developments.

- *Commitment*

Some of the observations given above lead to lack of commitment and inadequate analysis of efforts and failures. If there is no focus and no well defined time duration than commitment suffers.

- *Strict decision making*

Seldom there is a clear cut strategy and authority to close down projects that do not appear to be leading to fruitful results.

- *Networking of laboratories*

Today no R&D can be done in isolation. Individual modules must have connectivity and outputs of various models need to be additive.

- *Deliverables*

In projects undertaken often there are far too many activities and deliverables and consequently dissipation of time, energy, efforts and money.

- *Measures to take an invention forward*

One needs a carrier chain to take an invention forward with the help of different experts for different levels of TRL and MRL.

A laboratory seldom goes beyond TRL level of 3, whereas there are, necessarily several more levels to be reached for commercialization.

- *Relevance of projects*

Many projects are undertaken based on 'perceptions' of the industry but not calibrated with the actual requirements of the industry of the society.

- *Connectivity*

The users and industries often have no involvement with projects in R&D laboratory.

- *Partnership with engineering farms*

To take an invention forward one needs preparation of basic engineering package and TEFR. Often R&D projects fail because of absence of these.

- *Scale up*

Again, many inventions cannot go forward without scale up and demonstration plants. R&D labs are generally equipped with these.

- *Absence of clear mandate for innovations*

Many R&D laboratories do not have clear mandate to focus on innovations.

- *Cost of R&D*

For a CSIR laboratory today with a scientific man power of around 100 scientists and lab. Budget (including plan and non plan) of Rs. 50-90 crores and an effective 140 man day per year the per capita expenditure is a staggering figure which may be higher than international norms.

- *Bureaucracy*

The bureaucracy that is insensitive to needs of scientific R&D causes enormous delays in purchase, recruitment, travels etc. There is constant harassment of vigilance, Audit, Parliamentary and other delegations that supposedly monitor progress but actually demotivates.

- *Corruption*

Technology transfer and conversion of any invention to innovation necessarily has to go through several control points and corruption in these levels is not uncommon.

- *Problems with Patents*

Patents are often a step towards innovation. However, there are many hurdles for commercialization of patents.

a. Patents do not include Techno Economic Feasibility Report (TEFR). More often they remain on paper only.
b. The legal aspects of Patents i.e. IPR are formidable and often our R&D centres are not equipped to handle them.

The awareness of IPR issues was pioneered in this country by CSIR. Yet in CSIR itself priorities have been changing. In the last century there was initially emphasis on high quality publications (high SCI and IF). From the 90's there was emphasis on earnings from non-Governmental sources. Emphasis on Patents was initiated in the mid 90's because of which in many laboratories there was an increase in the number of patents filed and sealed. However, that was a temporary phenomenon and there is a decline in patents whereas the number of publications continue to rise in some laboratories. This is shown in the accompanying figures.

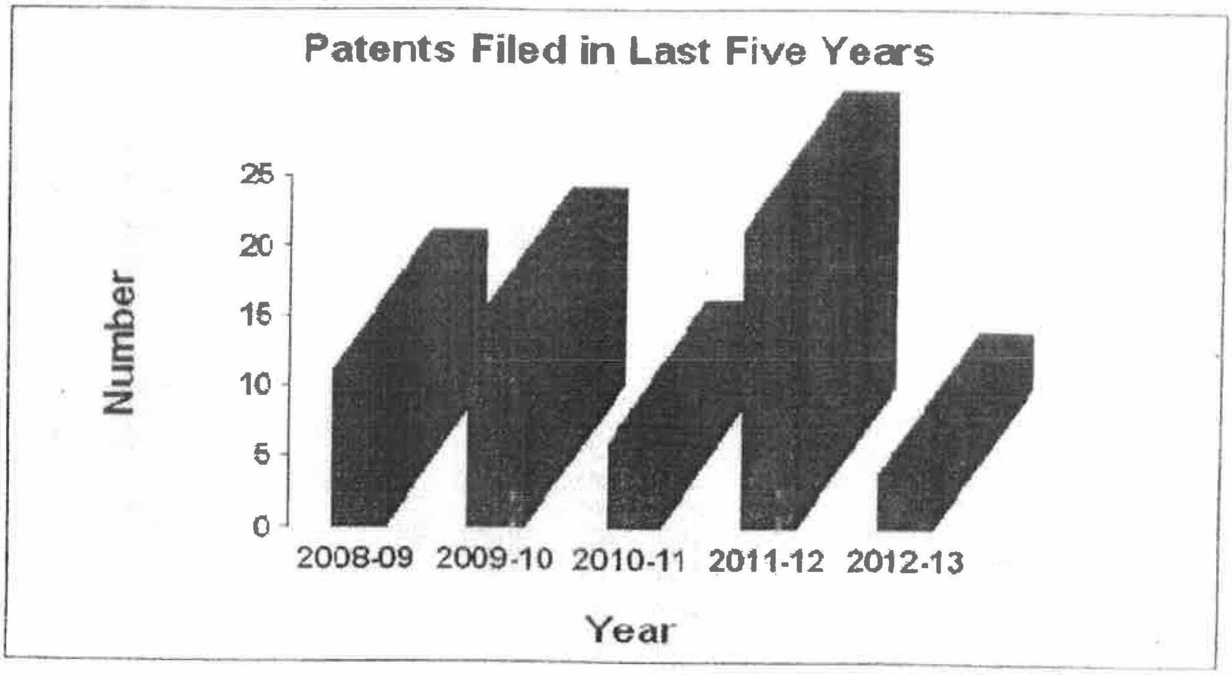

Figure 1 : Patents filed by CSIR-IICB during 2008-09 – 2012-13

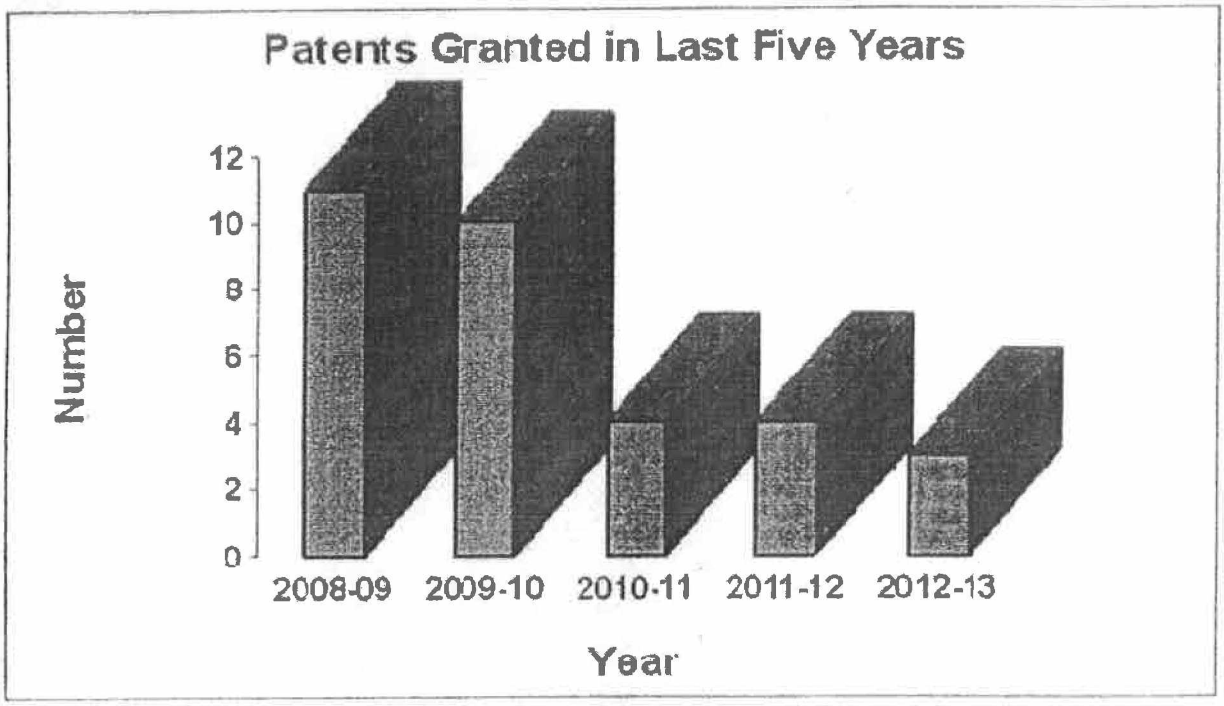

Figure 2 : Patents granted to CSIR-IICB during 2008-09 – 2012-13.

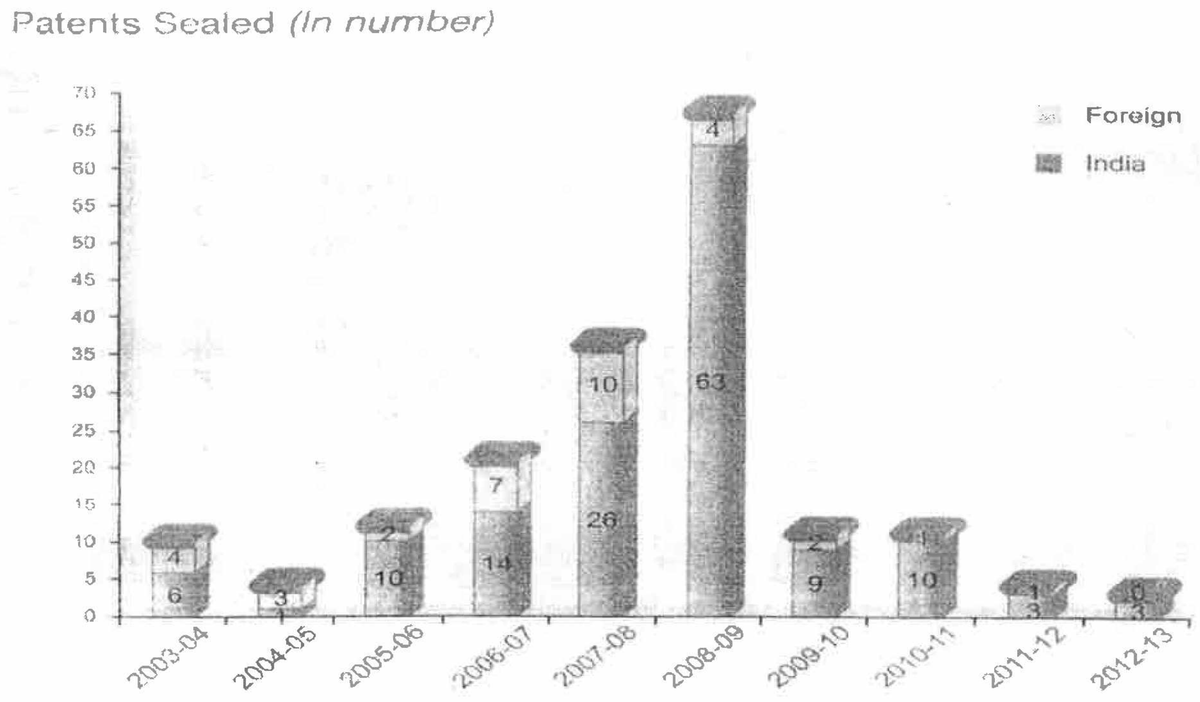

Figure 3 : Patents sealed for CSIR-CGCRI during 2003-04 – 2012-13.

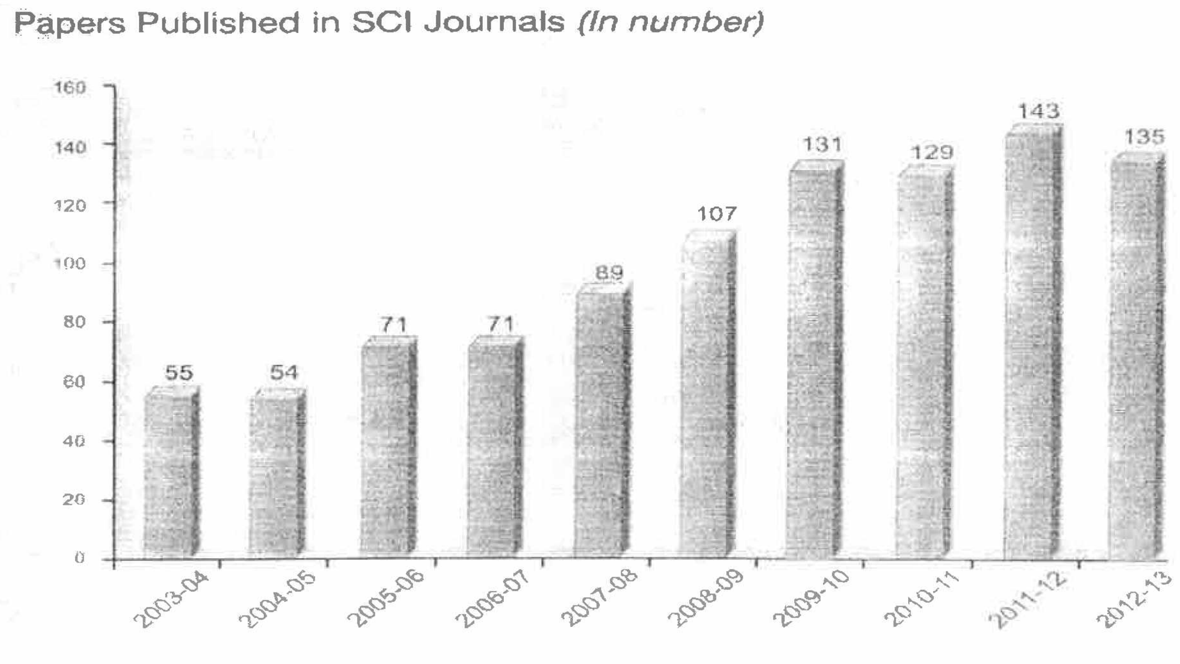

Figure 4 : Papers published in SCI Journals CSIR-CGCRI during 2003-04 – 2012-13.

Irrespective of whether it can immediately be put to use or not, an invention need nurturing. However, some discretion needs to be applied as some inventions may be really useless. There have been many exaggerated claims about certain inventions which are hyped as 'futuristic'. On the other hand, there are some truly promising ideas waiting for further development or for a shot at direct application. They may be called 'sleeping beauties that lie asleep waiting for the prince of industry to come and kiss to life. Yet we need to accept the unpalatable fact that not all good ideas end up as success stories.

Measures desirable to promote innovations

Some of the measures that should help in creating worthwhile innovations include the following :

a. Select R&D in priority areas for the maximum impact on the society.

b. Create high quality S&T mentors and Advisory councils.

c. Put in place proper evaluation procedures to measure efforts and success.

d. Create proper schemes for rewards and recognition and incentives for enhancing innovative R&D.

e. Create conditions for greater public support for R&D.

f. Reorient university research towards innovations.

g. Revamp bureaucracy for speedier decision making and making it more sensitive to the efforts of innovators.

h. Strengthen partnership of R&D laboratories with the industry.

i. Promote awareness of IPR and diffusion of innovations.

j. Facilitate commercialization of ideas.

k. Promote science and innovative spirit starting from schools.

l. Create a sense of mission and an atmosphere of trust to deliver.

m. Encourage researchers to take risk and recognition efforts even if a project becomes a failure (The famous 3M company has a motto, 'If a scientist does not fail he or she deserves to be fired).

It is well accepted that R&D and Innovations are necessary for development of the country. Our R&D centres, with some exceptions, are simply neither tuned for innovation nor capable to achieve them under the present conditions. In fact, the words 'technology' and 'innovation' are used rather casually, especially in the Universities. There is in general, no structured pressure on individual scientists or teams to deliver in that front and the fear of failure keeps people in the beaten tracks.

The major factors that affect innovations in the country have been identified from the survey include the following.

a) Manpower
b) Culture of innovation and awareness of STI Policy 2013
c) Funding on Infrastructure
d) Industry linkage with R&D programmes.

It is observed that the factors under (a)and (c) can lead to higher levels of knowledge generation that can be published in reputed journals. The knowledge becomes open and can be used by any technologist. In fact, most of the academic institutes are in this group.
These factors have also been compared with the similar factors for other countries.

According to a Report of The Boston Consultancy Group and CII Manufacturing Summit 2014[10]R&D professionals, i.e. full time researchers, in industry, academia and Labs. per million people of some countries are as follows[3] :
India – 160, Brazil – 710, China – 890, U.S. – 3,838, Germany – 3,950, Japan – 5,151.
India's share of high-technology exports in total manufacturing exports (%) is on decline: 2009- 9.1, 2010 – 7.2, 2011 – 6.9, 2012 – 6.6.

India's share of GDP spent on R&D is lower than peers and the Private Sector's contribution remains a matter of concern.

The Indian Research Infrastructure needs augmentation and improvement so as to achieve prominence in the field of High Technology Exports. There is some truth in the fact that our budget for science education and R & D remains small compared to many other nations and in spite of promises it does not increase. In fact, in the recent budget the hike is only about 3.4 per cent in real terms for Science and Technology compared to the previous year

The Boston Consultancy Group also says that overall R&D spending of some countries is as follows (in per cent of GDP).

Japan – 3.4, Germany – 2.19, U.S. – 2.8, China – 1.8, U.K. – 1.8, Brazil – 1.2, Russia – 1.1, Malaysia – 1.1, Turkey – 0.9, **India – 0.8**, Mexico – 0.4.

The private sector contributes to less than 40% of total R&D in India. This stands poorly in comparison to data elsewhere. The figures given in the report are as follows:

Country	Funding in Per cent		
	Academics	Industry	Government
India	**4**	**36**	**60**
U.S.	3	64	33
Japan	20	70	10
Germany	18	67	15
U.K.	28	62	10
China	8	70	16

It is obvious that there is urgent need of greater support for R&D funding, especially from the private sector. There are Government sources which also have brought out figures. The actual figures are not so relevant as the fact that contribution from private sector is far too low.

For successful innovations that can be beneficial to the society, culture of innovation and industry participation in R&D are essential and become main guiding factors.

3.4 Mandates for Innovative Work

While ISRO and DAE have well known mandates ths is not so far many other R&D organizations. During CSIR Director's conferences held during June 12-13, 2015 in CSIR-IIP Dehradun an attempt has been made to define some clear mandates as the following.

DEHRADUN DECLARATION FOR CSIR LABORATORIES FOR THE YEAR 2015-16

TEAM CSIR (CSIR Directors and through them all employees of all CSIR Institutions) today at Dehradun resolve :

To develop technologies for National missions like Swachch Bharat, Swasthya Bharat, Skill India, Smart Cities, Dgital India, Namami Ganga.

We also resolve to :

- Be a catalytic agent to evolve ndia into Samarth Bharat-Sashakt Bharat;
- Achieve global standars;
- Develop at least 12 game changing technologies every year;
- Catel to aspirations of common man and develop technologies beneficial to the poor;
- Focus on developing technologies for improving quality of life;
- Develop one technology for the strategic sector;
- Brng confidence to society about relevance of lab in terms of Social impact;
- ConductMid-term review of 2015-16 activity plan with clear milestones achieved;
- Make preparation for Platinum Jubilee celebrations beginning September 2016;
- Attempt for self financing of all labs in next 2-3 years;
- Develop a Revenue model in business-like manner with clear cost benefit analysis; and
- Develop Entrepreneurship in Small, Medium and Big industry.

The goals spelt out are definitely xxxxxxxx. Unfortunately, the road map and the necessary reorganization of the laboratories in terms of administration and R&D programmes remain unclear.

Some laboratories have initiated serious exercises in this direction. A Questionnaire circulated by CSIR-NML for collecting opinions of experts is given in Annexture V. All R&D Laboratories should undertake some such exercise and then decide what best to do and how. Perhaps it is time that universities also wake up.

4.0 CONCLUSIONS

From our study, we draw the following conclusions.

1) The common areas of materials research are Bio and Nano-materials. However, the full benefits of innovations in these areas are still small in the eastern region of the country.

2) Societal impacts are visible for the identified innovations. Examination of Economic impact will require long time.

3) Majority of R&D professionals are not aware of STI Policy 2013.The culture of innovation is lacking in academic institutions. Most of the research activities in such institutions are carried out for knowledge generation leading to publications.

4) The bureaucratic technology transfer procedure is the main hurdle to transfer R&D outcomes to the industries. Linkage among the industries, the R&D and academic institutions is missing.

5) The number of skilled R&D professionals is low in India in comparison with that of other developed countries. Inspiring leadership has been identified as an important factor that affects R&D activities and innovations.

6) Indian Research Infrastructure needs augmentation and improvement. It is also true that our budget for science education and R & D remains small compared with many other nations and in spite of promises it does not increase. The private sector contributes to less than 40% of total R&D in India.

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ANNEXURES

ANNEXURE I

Questionnaires of Interviews

Department of Science & Technology
(Government of India)
Project on Innovations in the area of New Material and Processing vis-à-vis STI-2013-A Pilot Study

Questionnaire

(To be filled by a senior scientist who is well informed. Preferably the Head of R & D Laboratory)

Organisation visited –

Discussion with (name and designation)____________________________________

Date of Discussion

____

Questions

1. How many innovations have been there in your organization since 2000 ?

2. Of the above
   a. How many have been patented ?
   b. How many have been transferred to the industry without patenting ?
   c. How many, patented/not patented, did not find any takers ?
   d. How many have been reported in journals ?

   N.B. : Answers to the above may be given as approx. percent

3. Since 2000, how many papers (bearing on Innovation in materials) have been published in reviewed journals (SCI journals, corps data base etc.)

4. Which of the in your organization belong to each of the following categories ?
   a. Incremental improvement
   b. Radically new development
   c. Attractive to the industry on commercial criteria
   d. Development with societal relevance

5. Which of the following (in percent) apply in case of your innovations ?
   a. New material
   b. Known material in new application

c. New procedure for inspection/testing
d. New device
e. Any other

6. Are all necessary material characterization techniques available in your laboratory ? If not do other organizations extend their co-operation readily ?

7. Which areas, in your opinion, are receiving maximum attention in India at present ? (Biomaterials, dectronic materials, nanomaterials, composites, ceramics, metals etc. etc.)

8. Which areas, receive maximum attention in your laboratory and why ?

9. Please give some details about other organizations that are collaborating with your laboratory in the area of New Materials. What are the areas ?

10. How important are the following in shaping the mindset of an innovator ? (Kindly use a 3 point scale- Highly important (H), of medium importance (M), Less important (L).
    a. High IQ
    b. Scientific knowledge
    c. Self motivation
    d. Inspiring Leadership that sets challenging goals
    e. Disruptive i.e. out-of-box thinking
    f. Supportive infrastructure and overall environment
    g. Good team support
    h. Discipline in the laboratory
    i. Rewards and recognition
    j. Freedom in work
    k. High Emotional intelligence
    l. Leadership quality
    m. Big goals and well defined time frame
    n. Liberal financial support
    o. Any other

11. How is a project assigned to an individual scientist/project leader in your organisation ? (Use 3 point scale)
    a. Assigned by Head of the Organisation/Department
    b. Chosen by the individual according to his/her expertise and availability of facilities
    c. Identified in consultation with colleagues
    d. Awarded by HQ/RC/some sponsoring agency
    e. Any other.

12. How often does an individual create facilities with his/her initiative for a chosen area of work with financial support of the laboratory and/or sponsored projects ?

    Very often/Sometimes/Rarely

13. In your organization is there any correlation between publications and patents ? If so please clarify.

14. Does your organization facilitate patenting ? If so, how ?

15. What, in your opinion, makes technology transfer difficult ?
    [Use 3 point scale. Highly important (H) of medium importance (M), of low importance (L)
    a. Poor marketing
    b. Technology not 100% complete
    c. Absence of carrier chain - Invention to Innovation
    d. Poor linkage between scientists and industry
    e. Absence of pilot plants
    f. Low credibility of indigenous technologies
    g. Reluctance of the industry to adopt new materials and processes
    h. Lack of sufficient government support
    i. Retirement/turnover of key scientists
    j. Poor post transfer services of the laboratory
    k. Easy availability of imported materials and technology
    l. Budget constraints
    m. Inability of whom to draw ideas from other areas
    n. Non-recognition of efforts when there is a failure
    o. Absence of challenging goals and fixed time frames
    p. Any other

16. What are the problems with patenting and patents ?

17. What can be done to make university teachers and laboratory scientists take more interest in patents and not focus almost exclusively on publications ?

18. STI-2013 states that
    Innovation is more than mere conversion of knowledge into a workable technology. It implies an S & T led solution that is successfully deployed in the economy or society. India has hitherto accorded little importance to this aspect.

    To what extent do you agree with this statement (strongly agree/Mildly agree/Do not agree)
    Please explain your answer

19. How important is the 'Science' content in the innovations in your laboratory ?

20. Please mention one or two success stories and one or two failure stories of your laboratory ? Please briefly mention what led to success and what essentially caused failures.

21. Please state in a few sentences what, in your opinion will promote the culture of innovation in our R & D Centres.

(Member of he Project Team)

ANNEXURE I (Contd.)

Names of Individuals Interviewed

Category A

1. Dr. Susil Kumar Mitra, Dy Controller of Patents and Design, Dept. of Industrial Policy and Promotion, Ministry of Commerce and Industry, Kolkata
2. Prof. A.K. Lahiri – Former Prof., Dept. of Metallurgy, IISc, Bangalore. Consultant Tata Steel
3. Prof. OmkarMohanty – Former Chief R&D, Tata Steel.

Category B

1. **Calcutta University**
   - 1.1 A. Maitra, Prof. Instt. Of Radio Physics and Electronics, Director, S.K. Mitra Centre for Research in Space Environment
   - 1.2 Dr. S. Chattopadhyay, Assoc. Prof., Dept. of Electronic Science.
2. **Presidency University**
   - 2.1 Dr.J. Mukhopadhyay, HoD, Geology Dept.
   - 2.2 Dr. Gandhi K. Kar, HoD, Dept. of Chemistry
   - 2.3 Prof. S. Ray Chaudhury, HoD, Dept. of Physics
3. **IIM, Kolkata**
   - 3.1 Prof. SaibalChattopadhyay, Director, IIM Joka, Kolkata
4. **IIT, Kharagpur**
   - 4.1 Prof.S. Das, Ex. Head, Met. & Mat. Engg. Dept.
   - 4.2 Prof. G.G. Roy, Head
   - 4.3 Dr. Tapas Banerjee, Asstt. Prof. (Also Asstt Prof. in School of Law, formerly with Patents Office, Kolkata)
5. **IIEST, Shibpur**
   - 5.1 Prof. S. Chatterjee, Director, R&D
   - 5.2 Prof. P.P. Chattopadhyay, Dean of Faculty
6. **Jadavpur University**

Dr. Siddharta Mukherjee, Prof. Dept. of Met. Engg. And Materials Science, Former Head, Chairman, IIM, Kolkata Chapter.

C. **R&D Laboratories**

1. CSIR-NML

1.1 Dr. S. Srikanth, Director

1.2 Dr. S.K. Pal, Head, PMD

2. CSIR-CGCRI

2.1 Dr. G. Banerjee, Chief Scientist

2.2 Dr. D. Bandyopadhyay, Head, PMD

3. CSIR-IICB

3.1 Dr. Ashish Choudhury, Principal Scientist

4. CSIR-IICB

4.1 Dr. Suresh Kumar, Principal Scientist

5. Ind. Association for cultivation of Science (IICS)

5.1 Dr. AmitavaPatra

D. Industry

D.1 Tata Steel, Dr. Sanjay Chandra, Chief R&D, Tata Steel

D.2 Durgapur Steel Plant (DSP), Dr. Asim Roy, Former GM, Durgapur Steel Plant (DSP)

Summary of Interviews

A 1.1 Sushil K. Mitra – There is a difference between invention and novelty. No patentability if there is no economic feasibility. A patent should deal with the non-obvious. Should not be obvious to scientists working in this area. There may be inventions not patentable due to ethical reasons.

Definition of invention differs under the US and European laws from the Indian law which differentiates between discovery and invention. In the U.S. any technical solution under the sun is an invention. Ex. : Prof. AnandaChakravarty's microbes eat up petroleum. There can be 50 patents for one product. One Japanese electric shaver has 52 patents – measures taken to ensure that even a component cannot be duplicated. In a process different steps can be patented.

This is called fencing to ensure monopoly

Sam Pitroda has 105 patents of which only 5 have been commercialized. The income from these 5 maintains the rest which have been done to fence the main 5. Patent is a negative right to stop others from exploiting the idea. Selling of a patent is exhausting the right. A patent does not give the right to manufacture. Quality control methods are not patentable. Instruments are patentable. IP systems should be stronger.

19th century was the age of Physics and Chemistry. Now new areas – Nanomedicine not yet successful. But 20th century is definitely the age of biology. Change of genes will cure sickness and give immunity.

Motivation for innovation needed are – Freedom, infrastructure, scientific motivation – ethical values, ambition.

Patents need good drafting for profession. Needs patents search to ensure there is no repetition. Innovation must spread in the country.

Interocular lens is not so popular because of cost – short supply – There are many products and options – where is the indigenous technology? We still go for the foreign lens and not the Indian lens because of Brand value.

Great innovations don't always need science. Look at wind mills in Netherlands and Denmark – great technology – Here weaker sections of society have benefitted more. Not much – science in Beet Sugar, Gobar gas plant.

There is always some science – amount of science is not always relevant. The ordinary Alpin is a great innovation, also Jaws clip, Coated clip.

Technology Transfer is weak in India. No breeding system – as good refining. Connect innovator and the industry.

Conduct the play well by good refining.

A 2 Prof. A.K. Lahiri : Innovation is some new product – not important whether marketed or not but has potential.

It involves making of something. Systematic research may lead to minor modifications but real innovation comes suddenly. Mind must be prepared to see it. Complete background knowledge is not essential – actually it can be detrimental. Vision becomes narrow with specialization.
Prof. Lahiri has some great ideas, based on actual experimentation, that he thinks can change the economics of Tata Steel. Yet he has still not been able to push through these because then there will be need for changes in present operational procedures.

Examples

1. His ideas on making coke from noncoking coal by blending different coal fractions (the development was accidental).

2. A mathematical model to control change distribution – essentially a remarkable marketable software for a mathematical model. But it is essentially an incremental improvement. Can be copyrighted. Needs engineering development.

In IIT's, IISc there is little innovation. There are only new findings.

Drug industry seems to dictate our R&D policy. There we know what is to be done for which there is a market. For materials this is not true. We are often not sure in the beginning about the application.

We have weakness in marketing.

In Tata Steel there are not many who understand the potential of new ideas to agree to invest money and try out things in full scale.
In product innovation marketing is more difficult; How to produce on a large scale; what is the demand, will that justify investment?

Example
The well talked about Metallic Glasses from rapid solidification does not have a single commercially viable product. Even after a lot of research we have failed to produce room temperature superconductors. Fuel cells have not yet not seen potential initially visualized.
Nanomaterials have stability problem.

Innovations may not have science component initially. This may come later when we want to go for 'understanding'. Closed societies have innovations. We have zero self confidence. Nano car – has a lot of indigenous innovation – not much sciene.

In drug development we proceed via science. In technology it is a different path.
Scientist and industry must work together. Ego clash will not help.

3. Prof. OmkarMohanty :There is a confusion about the word Innovation. Patents are a step towards innovation. He started a patent cell in Tata Steel from where initially 40-50 patents were filed every year initially. Now around 70.

Mere science is creation, invention. There are levels of innovation. In the western world they may or may not involve much science. IBM once sent 2,500 patents to University of California to add science and make more patents. In innovation there is application concept. There should be a change in practice of things in the society. e.g., hovercraft, sanitary towels, babies diapers, atom bomb. Innovation touches lives of people. If IPR is injurious to society then no patent is given.

Innovation is often interdisciplinary and out-of-box thinking. Many innovations come from persons who work at interfaces – not by people who are deep in one area.

Interfaces are lacking in India. There is priority for science. Many small innovations taking place are thrown into the dustbin by the management. Compared to Hovercraft, the sanitary towels, the diaper or the Hawaii chappal are greater innovations because the latter have touched the lives of many more. There is science of super absorbers in the towels and diapers.

Grass root innovations touch many lives. Industrial revolution proceeded science. Of course, after grasp of scientific principles things moved faster. Only about 8 metals were known till the 16^{th} century, then there was a flood - Davy alone discovering 22 more.

B 1.1 AnimeshMaitra : Their group has made 4 patents of which the technology for one (Antenna) has been transferred. The Dept. professors publish some 40 papers in SCI Journals every year and another 10 in non-SCI Journals.

Innovation is mostly incremental improvement of interest to the industry, there are few radical developments. The Antenna is good for Malls and other congested areas. 25-30% innovation involves new materials. University researchers are almost fully tuned towards publications which bring personal satisfaction as well as outside recognition e.g. awards, fellowships of Academies etc. There is no awareness about patenting and the mindset needs to change.

The Dept. does both theory and experiments. Areas – photonics, optical sources, sub cellular resolution optical coherence tomography, has developed devices and put up space telescope in Haringhata.

Projects are not assigned by head, individuals take initiative. Main support comes from DST and ISRO.

There is no facility for patenting. There is more science content in their innovations.
The Logo of Calcutta University says, 'Advancement of Learning' and the university has pursued the advancement for many decades now. They are not aware that the industry can also fund research but the industry wants Advancement of Earnings.

B 1.2 S. Chattopadhyay : The Dept. publishes 3-4 papers in SCI Journals per person per year. Interested in Nanomaterials, CuO, ZnO, TiO2, GeO.Feels the need of a patent cell.

Presently suffers from space crunch and lack of infrastructure and Labs. There are now World Bank Projects in 7 Depts. Emphasis on Electronics for biomedical applications, funding of 3 crore.

There is negative correlation between Patents and Publications. Science content is high in their research for innovations.

B 2.1 J. Mukhopadhyay : Geniuses set their own goals. Inspiring leadership is most important for many – everything follows from there. Support the mediocre. In the university nothing happens if nothing is achieved.

There is meanness in our character. Here everything is traditional.

Geology Dept. has done some good work and received BRNS funding in the area of exploration of minerals. The Dept. has done innovative work on how minerals exist in rocks – studies somewhat different from traditional work. The Dept. has shown that there may be a lot more iron ore hidden in sub surface.

Today Governance needs innovation.

The concept of LAN started in Presidency University from the Geology Dept. (2003-2004) First Cable network. First to start consultancy work during the time of earlier Vice-Chancellor (MalabikaSircar).

Support received from J.U. and IIT, Kharagpur. Every Dept. can earn through consultancy, even English Deptt.

Indigenous science suffers from lack of facilities for research. Publications are often not as good as those by others in advanced countries. Syllabus is obsolete. We lack self confidence. We need overhauling of teaching system starting from schools.

B 2.2 Dr. G.K. Kar : The Dept. has filled only 11 posts out of available 24. Research is difficult. Has not heard about STIP-2013. No concern with innovations by the university. The Dept. focuses on publications, some 30-35 every year in CI Journals. Promotions are time-bound and helped by publications only. Even research is difficult because of inadequate facilities.

There should be no reservation in higher education. Researchers need total freedom. Very frustrated because of experiences with the political set-up. From a very poor family, he has struggled all through. While posted in a village college he did research going to IIT, Kharagpur during weekends.

Innovation should result in an outcome – some product, selection of research scholars should be done properly. Integrated Ph. D. Programmes, even in IISc, Bangalore are not good. In his Dept. some cannot teach well even though they have good publications.

B 2.3 Prof. SomakRoychaudhury : Innovation results in some practical solution. We now need many materials of different classes.

Earlier in Presidency college research was mainly based on individual interests. Today the university is recruiting research oriented persons and students are being trained in laboratory research. The average age of the faculty in 15 depts. of the university is 36-37. Total 160 members. Those who had no research experience have been sent off. 90 of the 160 today had the last appointment abroad.

No big apparatus has come in the last 20 years. The university receives help from IACS, IIT, Kharagpur and Bose Instt. against payments from grants. The question is how much to spend on Blue Sky Technology which may not have any application now but may have in future.
The university today attracts around 750 application for 5 posts. The new Bio Science Dept. is drawing much attention.

For innovative research, skill is more important than IQ. People are interested in short term goals – do research, publish, get promotions and recognitions. Individuals grow with selfish motives – puts funds in areas of interest only. Research fields are inertia based – some go on and on with the same area. Individuals are reluctant to change fields.

There is no patent cell.

There is indigenous science in the area of pharmaceuticals, drugs, agriculture. In the area of Jute Fibers and Biomaterials there are lots of opportunities.

Not familiar with STIP-13.

There is work on grapheme in Physics Dept. There are seeds of innovation there. Other areas – Biomaterials, nanomaterials, advanced ceramics. Since 2000, some 600 papers in SCI journals. There is conflict between quality and quantity.

Motivation is desire to do something now – in a very selfish way. Most are not interested so much in recognitions and awards. Challenge from inspiring leadership is important.

Technology patent is not need based. Globally, there is Technology Pull. In Oxford research labs. Rolls Royce funds entire labs.

B 3.1 Prof. SaibalChattopadhyay : Has 'heard' about STIP-13 but does not know details. IIM has no patents.

For technology transfer one should have the Israeli model – R&D centres all have entrepreneurship wings that take innovations to the industry.

Innovation is invention plus commercialization, scalability not always essential (e.g. the computer technology).

IIM wants to promote affordable healthcare, education that is easily accessible, clean energy, specially renewable (e.g. solar energy). Always emphasizes business models, analytics and market needs.

Govt. policies on imported technologies are not deterrents.

IIM has an Innovation Centre Incubates for individuals/teams that propose ideas with a growth plan.

Entrepreneurship requires passion and risk taking ability.

IIM is 100% faculty dominated, even the Director cannot impose anything. There are 2 Deans, one for institutional academics and the other for external relations. Research projects taken are with individual initiative. Anything that does not come in conflict with the Institute's is allowed. Director comes into the picture if there is an apparent conflict. There are clear cut work norms and deliverables. If that is satisfied then the Institute cannot interfere.

B 4.1 and B 4.2 Dr. Tapas Banerjee and Prof. G.G. Roy, Prof. S. Das – R&D topics mostly chosen by individuals according to expertise and available facilities. 3 OR 4 persons in each Dept. have became self-sufficient by creating their own facilities.

No correlation between Patents and Publications.

To promote Innovations B.Tech. students should be invited to propose ideas.

One does not agree with definition of innovation as per STIP-13 (T.B.).

There is a proposal to promote work for innovations by equating one patent with three publications for assessment purpose.

Innovation is value addition. By IIT some 450 patents have been filed since 2000 of which 15 have been transferred to the industry. Dept. of Met. and Mat. Engg. has taken out 2 patents. Practically none for the industry. There have been some 1400 SCI Publications since 2000. Innovation is mostly incremental – Areas of attention – Nanomaterials, composites, electronic materials, biomaterials – the first two are important for the Dept. There are now Brokership firms which act as connectors to industry in intellectual ventures. They are operating in Bangalore.

B 5.1 and B 5.2

Dr. S. Chatterjee, Dr. P.P. Chattopadhyay : No clear data because of lack of records IIEST has become aware of the importance of IPR only since 3 or 4 years. Not aware of STIP-13. There may be some innovations. Since 1991 one said 10-12, the other 25-30. There have been perhaps 7/8 patents and 5 transferred to the industry. The university has done some good work for Tata Steel, ISRO and Pollution Control Board that has found actual application. Numerous publications.

Innovation is from concept to a successful product (SC) – successful means one that can replace an existing product. Innovation means implementation of a new idea in existing technological practice to achieve enhanced performance (PP) – **Not necessarily** a commercially successful thing which depends on many factors.

Radical developments are few, incremental developments are many. Documentation of R&D work has started only in 2007. No proper website yet. No accessible data base. Earlier to 2010 there was little concern for innovations.

New materials in innovation was 30-55%, new process – 20, new procedures, 10-12 new devices – rest.

Areas receiving attention – Nano, Bio Electronic, the best lower down – composites, metals, alloys ceramics.

No correlation between patents and publications. Applied work needs too much effort and has too little reward. Besides, industry does not always give feedback. Publications bring rewards. There is Industry-Academic problem. Innovation takes time but industry wants instant solutions. Sometimes the industry is not ready to spend any time to look at minor adjustments necessary. The industry finds it convenient to go for imports.

R&D problems are selected by individuals. Patents need competent legal support (PP). The small industry sector has completely shifted away from innovation SISI (Small Ind. Service Sector) has now become MOME (Med. And Small Scale Entrepreneurs) which in the last 25 years has seldom looked for anything new. The qualification of entrants is an engineering degree and they become administrators and provide commercial support only.

Ideas generated in the R&D Centre of Tata Steel are not utilized by the plant itself, so reluctant are people to introduce changes.

Some 80% innovations and only in the knowledge basket (PPC).

Do not agree with definition of innovation as given in STIP-13.

(PPC) It is wrong to assume that the same person will invent and innovate one needs a carrier chain

There are websites where one can dump ideas that can be picked up by others to work on innovations. These can be consulted by researchers.

B 6.1 – Prof. S. Mukherjee

4 Innovations since 2000, 1 patented, 2 transferred to the industry without patenting, 1 had no takers. Around 50 publications in SCI journals since 2000. The Dept. has done work of social relevance and has worked on known materials in new applications. They receive ready co-operation from other institutions.

Believes that apart from steel, nano materials are receiving maximum attention – materials processing and characterization.

Has collaborated with CSIR-NML, CSIR-CGCRI and RDCIS mainly. Projects are generally chosen by individuals in consultation with colleagues and sometimes by sponsoring agencies. Seldom assigned by head. Individuals very often create his/her facilities.

There is no correlation between Patents and Publications. In Jadavpur University there is no facility for IPR schemes.

As regards what motivates an innovator? Most factors listed in the Questionnaire are to be rated as High except. IQ(M), Leadership (M), Rewards and Recognition (M) and big goals (M), Leadership Quality has Low (L) value. Believes that a deterrent to Technology Transfer is absence of carrier chain, absence of pilot plants and reluctance of the industry to adopt new materials and processes (all High).

Believes 'Science' content is important. **Mildly** agrees with definition of Innovation in STIP-13. Believes that there should be greater involvement of industry with the academia.

C 1.1 and C 1.2 Dr. S. Srikanth and Dr. S.K. Pal : 260 patents since 1991, 50 technologies transferred without patenting. Industries have also been provided with many innovative solutions. 80% Product/Process have not found takers. 1800 publications in SCI journals since 1991. One needs a big goal and a fixed time to achieve innovations* (SS).

Tata Steel has given to CSIR-NML an project on Patent Analytic Services for patentability students, write space mapping of total landscape, patent density, preferable ideas for investment, business possibilities etc. (16 lakhs per year + services) DSIR has also sponsored project on Space Mapping.

Dr. Srikanth believes in cycles or development, MRL's and TRLs (see Report for the First Quarter).

That innovation must have a commercial value is well accepted now.
Most laboratories do not have innovations (SS) 85% patents have been published after a period in journals.

Patent needs novelty in process/product, inventive step, industrial utility.

S. Srikanth believes that a patent is the first step towards innovation.

A Laboratory does only idea generation, process some concept, in selected cases go to pilot scale and commercialization - In subsequent levels of TRL/MRL people/time required expand exponentially (The terms TRL/MRL have been explained in the Second Quarterly Report).

In NML, Mg, Na at present is only a large sale development – Level 6.DMRL Ti technology is Level 8.

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* This matches with the saying that to achieve anything important one should have not enough time and not enough funds!

Because benefits of investment are yet to be proven. Level beyond and needs participation of the industry. Lab cannot give some of the answers. Atomic Energy and Space organization can because they are going all the way.

Making, sharping, treating, packaging all are needed. Labs are restricted because they do not go beyond 3 or 4 stages.

Nano research has thrived in India because it is science. Nanotechnology has not flourished because we cannot proceed to next levels.

SS – Mangalyan is right on top in international scale – Level 10 – From concept to Landing – 2 years. Govt. approval in 13 months – 1000 engineers on one project – Biggest motivation – a big goal.

SS – We need partnership with the stakeholder from the beginning – Involve all three – Developers, manufacturers and users.

SS – Drug development needs more stages.

Identity of individual active molecule, then clinical trials, ethical considerations, Govt. policies, huge investments.

Collect information on how much time is spent on doing core R&D.

There are tentative calculations that indicate that time spent is too small to achieve anything big.

Most innovations are incremental, radical – few, many have promise of economic benefit and are industrially attractive. A few have social relevance. Very few are ahead of time. Most innovations deal with improved process techniques.

Areas receiving attention – Bio, electronic nano, composites, ceramics, metals and alloys.
We need to change from publish or perish to patent and prosper.

C 2.1 and C 2.2 Dr. D. Bandhyopadhyay and D.G. Banerjee : Since 2000 there have been approx. 20 innovations – mostly published later. 1000 SC journal publications since 2000. Innovations are mostly incremental, some 80% are attractive for the industry. 60% of CSIR-CGCRI innovation has significant social relevance.

Areas of attraction – Nano, energy.

R&D projects are taken based on individual initiative, (Note : The well known Sol-Gel Division was established by Dr. D. Ganguly – a geologist, after the then Director Dr. Kumar practically pushed him into that area.). Often projects are assigned by HQ/RC, national and social needs are also kept in mind.

Publications are increasing but patents are going down. The former are more easily 'delivered'. There is little recognition for patents (GB). Patents have high science content (GB). People should cut across disciplines.

There are many success stories –
Ceramic based water purification, optical glass, radiation shielding glass, glass beads for nuclear waste immobilization etc. some failures in the area of defence armaments and traditional ceramics (DB).

C 3.1 CSIR-CMERI
Asish Choudhury : Not familiar with STIP-2013. The Instt. has 3 innovations since 1991 – Epoxy concrete, ADI, MM Processing. 2 have been copyrighted, 2 transferred to industry. Some innovations did not have any taker. Publications are very small in number (3). Innovation is modification of existing processes with new ideas. It leads to growth of technology and knowledge gain.

Innovation (in percent) : incremental (25), radical (5), with economic promise (30), industry acceptance (20), societal relevance (20).

New materials is 10%, new technique – 90%.

Areas of interest – Nano materials processing, composites, metals and alloys.

No correlation between patents and publications.

It is difficult to change attitude and mindset of people. Industry is also not willing to accept new technologies by modifying existing product line.

In CMERI scientists prefer to go for patents.
Innovations have medium science but a good deal of technology.

50% projects undertaken are suggested by Research Council, 30% by internal brain storming. Some 20% come from the industry.

C 4.1 Dr. Suresh Kumar - Few innovations at CSIR-IICB but many publications. There has been a radically new development of Prostalyn for prostate cancer. IICB works on new materials and molecules. Interested in Biomaterials, enjoys collaboration with CSIR-CDRI, CSIR-IGIB, CSIR-IMT.

Projects are mostly selected by individuals, weak correlation between patents and publications. There is organizational facility for support but technology transfer is difficult. Patents receive low priority compared to publications.

Due credit should be given for patents. Strongly agrees with STIP-2013 definition of Innovation. In the work in the Instt. the science contest is high.

Innovation demands freedom.

C 5.1 Prof. AmitavaPatra : No innovations in IACS. 4 Patents, approx 2000 SCI journal publications since 2000. Maximum attention in India is for Energy Materials and Bio-related materials.

Individuals choose R&D topics and often create facilities.

D 1. Sanjay Chandra : Not familiar with STIP-2013. In Tata Steel there have been some 1000 innovations since 1991 of which 600 have been patented. No question of transferring know how to other industries.

More that 50% of the patents have been later published in SCI journals.

They need an Innovation Cell.

Innovation is achievement of a certain result not in the usual manner. If there is no consumer then it is merely a creative work.

50% innovations are incremental, radically new may be – 25%, 10% promise major economic benefit, industrially accepted would be 90%, 10% may have social relevance.

Innovation is something new that is for the first time. Must have practical use.

Mostly about new processing technique (7%), new procedure for inspection is small, new device – negligible, new material – not many.

Areas of interest : Nano materials, composites

It is necessary to lay down a clear cut direction specially when there is a large mass. Industry looks for sure shot, has no time to experiment with an incomplete technology offered. They cannot take the burden of exploring. If something is available abroad then they do it here. Cost of research in CSIR Labs is very high. But elsewhere cost of research is still very very low in India. Some outstanding experts (e.g. Dr. Baldev Raj should be asked to define national priorities).

ANNEXURE II

Programme of Workshop on 'Indian innovation in Materials Research' held during June 25 – 27, 2015

Plenary Session -1 (Chairman: Prof. H.S. Ray)	
Nanostructured functionalisednanocomposites (A-1)	K.L. Chopra (IIT Delhi)
	Anil Gupta (IIM Ahmedabad)
Science, Technology & Innovations in India – Past, Present & Future (Chairman: Prof. Anil Gupta)	
Innovations in the context of STI Policy - 2013 (A-2)	S.P. Mukherjee (IAPQR)
Indian Innovations - Whose Science? Whose Technology? (A-3)	Subrata Ghosh (Ex. CSIR-CGCRI), ChandanaPatra (CSIR-CGCRI)
Innovation and Growth under British Colonial Rule and Its Impact on Research Environment in India (A-4)	SankarGhatak (CSIR-CGCRI)
Approach towards transforming inventions into innovations leveraging Technology Transfer Mechanism in the light of STI-2013 (A-5)	A. Bhar (IBM India Pvt. Ltd)
Technical Session-1: Nano Structure-1 (Chairman: Prof. Indranil Manna)	
	Ashish Lele (CSIR-NCL)
Utility of Carbon in Energy Storage (A-6)	Aninda J. Bhattacharya (IISc)
Spin Dewetting: a novel versatile method for rapid nano fabrication with different Soft Materials (A-7)	Rabibrata Mukherjee (IIT Kharagpur)
Plenary Session -2 (Chairman: Prof. K.L. Chopra)	
	Prof. Indranil Manna (IIT Kanpur)
	S.K. Bhattacharya (CSIR-CBRI, Roorkee)

Panel Discussion: The Role of Innovations in Make in India	
PANELLISTS: Dr. Srikumar Banerjee (Chairman) Prof. K.L. Chopra Prof. S.P. Mukherjee Dr. K. Muraleedharan Dr. A.B. Mandal Sushim Banerjee	
Technical Session 2 – Laser, Photonics & Fiber Optics (Chairman: Dr. RanjanSen)	
Innovative materials processing with pulsed lasers (A-8)	G. Padmanabham (ARCI)
Photonic Crystal and Photonic Bandgap Optical Fibers: Realization of Technology (A-9)	S.K. Bhadra (CSIR-CGCRI)
Make in India – Polysilicon production for Solar Photovoltaics (A-10)	D.N. Bose (St. Xaviers College)
Ultrafast Active Terahertz Metamaterials (A-11)	Dibakar Roy Chowdhury (Mahindra Ecole)
Technical Session 3 – Nano Structure -2 (Chairman: Prof. D.N. Bose)	
Designing band engineered P-type transparent conducting oxides and its nanostructures as emerging functional material (A-12)	K.K. Chattopadhyay (JU)
New Approaches to Synthesize Functional Nanomaterials of Current Interest (A-13)	Goutam De (CSIR-CGCRI)
Design and Development of Al-based nanocomposites reinforced with garnet and multi-wall carbon nanotubes (A-14)	M. RaviathulBasariya (CSIR-NML), V.C. Srivastava (CSIR-NML), N.K. Mukhopadhyay (IIT BHU)
Imparting functionality to clays by manipulating the interlayer chemistry (A-15)	Koushik Dana (CSIR-CGCRI)

Technical Session 4- Power & Energy (Chairman: Dr. Probal Das)	
Development activities in high power CW lower hybrid current drive system (A-16)	Pramod K. Sharma (IPR, Gandhinagar)
Challenges in Technology for Processing of Nano-crystalline Ultra soft Magnetic Alloy Ribbons Used for Energy Savings Applications (A-17)	BhaskarMajumdar, D ArvindhaBabu and S V Kamat (DMRL)
Role of Innovations in Materials Development and Processing of Solid Oxide Fuel Cell (A-18)	R.N. Basu (CSIR-CGCRI)
Recent Advances in Pb-Acid Battery Development for Micro & Mild Hybrid Vehicles (A-19)	DebasishMazumdar, Ashwini Kulkarni, Avichal (Exide Industries Ltd.)
Nanogenerators –the necessary device in the next decade (A-20)	ShrabaneeSen (CSIR-CGCRI)
Technical Session 5 – Metallurgy-1 (Chairman: Dr. A.K. Ray)	
Novel and Innovative Thermo-Mechanically Treated Bars (A-21)	Saral Dutta (Ex. SAIL)
Innovations in Automotive Steels :Focus on Forging Grades (A-22)	O.N. Mohanty (TAI, Bhubaneswar)
Nano Materials with exceptional properties developed through Top - Down Approach (A-110)	B.S Murty (IIT Madras)
Accelerating weathering mechanism of Weather Resistant Steel to prevent Corrosion Loss: A Tool for Structural Engineers (A-23)	Jayanta K. Saha (INSDAG), Amit Sarkar (INSDAG), P K Mitra (JU)

Gray Taguchi method to improve quality of SAE 1080 carbon steel strip by optimization of heat treatment process parameters in rolling plant (A-24)	Vijay Shankar Kumawat (Manipal Univ., Jaipur), M. L. Mittal (MNIT,Jaipur)
Technical Session 6 – Sensors & Actuators (Chairman: Dr. A.B. Mandal)	
	Ajoy K. Ray (IIEST)
Development of Advanced Magnetostrictive Materials for Magneto-mechanical Stress Sensor Applications (A-25)	Dibakar Das (Univ. of Hyderabad)
Development of engineered ceramic oxide gas sensing system for air quality monitoring (A-26)	Subhasish Basu Majumder (IIT Kharagpur)
PPM level acetone vapour detection by γ-Fe2O3 containing mixed oxide nanocomposite sensors (A-27)	SushmitaKundu (CSIR-CGCRI)
Metal oxide capacitive sensor for pulmonary function testing (A-28)	DebdulalSaha (CSIR-CGCRI)
Technical Session 7- Ceramic materials (Chairman: Dr. Swapan Das)	
Materials and Manufacturing Innovations at CSIR-CGCRIfor Orthopaedic Implants (A-30)	Vamsi Krishna Balla (CSIR-CGCRI)
Silicon carbide: a novel ceramic material for advanced applications (A-31)	Bhaskar P Saha (ARCI)
Specialty Borosilicate Glass Bead for Nuclear Waste Immobilization: Technology Development and Commercialization (A-111)	SienduMandal, Alok Roy Chowdhury, DipaliKundu, RanjanSen (CSIR-CGCRI)

Photocatalytic activity of TiO2 coatings on ceramic tiles by Raman spectroscopy (A-32)	Samar Kumar Medda, Srikrishna Manna and Goutam De (CSIR-CGCRI)
Fluroapatite based bioactive glass-ceramics for biomedical applications (A-33)	Sumana Ghosh (CSIR-CGCRI),N. Dandapat (IIEST, Kolkata), V.K. Balla (CSIR-CGCRI)
Event	
Technical Session 8 – Material Development, Characterization & Application -1 (Chairman: Dr. R.N. Basu)	
Science, Technology and Innovations in Leather Research (A-34)	A.B. Mandal (CSIR-CLRI)
Two dimensional confinement of electrons in nanowall network of GaN leading to high mobility and long phase coherence time (A-35)	SubhabrataDhar (IIT Bombay)
Custom designed Bioactive Ceramic materials for Clinical applications (A-29)	H.K. Varma (SCTMST, Trivendram)
Innovations for Efficiency Enhancement in Thin Film Solar Photovoltaics (A-36)	DipayanSanyal (CSIR-CGCRI)
How pH affects the metal dispersion on silica HMS, MCM-41 and SBA-15 supports (A-37)	Shyamal Roy (JU)
Formation and microscopic aspects of ceramic nanostructures on aluminium by anodization (A-38)	M. Mubarak Ali (C N College, Erode), V. Raj (PU, Salem)
Technical Session 9 – Material Development, Characterization & Application -2 (Chairman: Dr. Arup Ghosh)	
Rational design of functional materials based on crystallographic concepts and novel synthesis protocols (A-39)	A.K. Tyagi (BARC)

Light Harvesting in Nanoscale Systems (A-40)	AmitavaPatra (IACS)
Fabrication of GinatMagentoresistance (GMR) based magnetic field sensing element and their applications (A-41)	Prasanta Chowdhury (CSIR-NAL)
Residual life assessment of high temperature components (A-42)	B.B. Jha (CSIR-IMMT)
Synthesis and development of transition metal oxide-kaolin composite pigments for potential application in paint systems (A-43)	Swagata Roy, SubrataKar, Sukhen Das (JU)
Development of an effective biosorbent material from industrial sludge for toxic heavy metal remediation (A-44)	LataRamrakhiani, SwachchhaMajumdar, Sourja Ghosh(CSIR-CGCRI)
Technical Session 10 -Metallurgy - 2 (Chairman - Saral Dutta)	
	Dr. S. Srikant (CSIR-NML)
Production of nickel from chromites overburden – a promising technology of a Laboratory of the Council of Scientific and Industrial Research (CSIR) that has not been commercialized (A-45)	Prof. H.S. Ray (IAPQR)
Event	
Manufacturers Presentation Session (Chairman - Subrata Ghosh)	
MP-1	Phadke Instruments, Mumbai
MP-2	Merck Life Sciences Pvt. Ltd., Mumbai
MP-3	Alfatech Services, New Delhi
MP-4	S.M. Scientech, Kolkata
MP-5	ANTS Ceramics, Mumbai
MP-6	Techno-Scientific Co., Kolkata
Student Session 1: *Innovations in Young Minds* (Chairman: Prof. S. Basu Majumdar; Co-Chairman: Dr. B.B.Jha)	

Influence of side-chain interactions on the self-assembly of discotictricarboxyamides: a crystallographic insight (A-46)	ArpitaPaikar, DebasishHaldar (IISE)
Indian magnesite: Processing to improve its refractories properties (A-47)	P. Kumar, A. Ghosh, H.S. Tripathi (CSIR-CGCRI)
Hierarchically Structured ZnO-GrapheneNanocomposite for Different Applications (A-48)	SusantaBera, Sunirmal Jana (CSIR-CGCRI)
Effect of carbon nanotube incorporation on the dry wear characteristics of structural silicon carbide prepared by spark plasma sintering (A-49)	Kaushik Sarkar, Soumya Sarkar, Sumantra Basu and Probal Kr. Das (CSIR-CGCRI)
Cross-linked interconnected powder morphology obtained by filter paper templating method for application as oxygen separation ceramic membrane (A-50)	QuaziArif Islam (CSIR-CGCRI),Mir Wasim Raja (SFSC), RajendraNath Basu (CSIR-CGCRI)
Effects of Rare Earth on thermal and Mechanical Properties of Mica Glass-ceramics in SiO2-MgO-Al2O3-K2O-B2O3-F System (A-51)	MrinmoyGarai, BasudebKarmakar (CSIR-CGCRI)
Student Session 2: *Innovations in Young Minds* (Chairman: Dr. O.N. Mahanty; Co-Chairman: Dr. P. Sujatha Devi)	
Misfit layered Cobalt oxide as Thermoelectric material (A-52)	Avinna Mishra (ACIR), LaxmidharBesra(CSIR-IMMT), Bimal P. Singh (CSIR_IMMT), SaramaBhattacharjee (CSIR-IMMT)

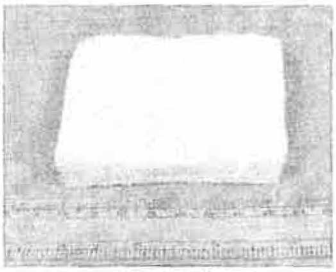
Simultaneous adsorption of Metanil Yellow and Indigo carmine from wastewater onto Chitosan - Graphene Oxide nanocomposite: Optimisation, characterisation, modelling and toxicity evaluation (A-53)	Priya Banerjee (CU), AniruddhaMukhopadhayay (CU, Papita Das (JU)
Preparation and characterization of tulsi mediated iron nanoparticles impregnated pH responsive PVDF-co-HFP membranes (A-54)	PiyalMondal, M K Purkait (IIT Guwahati)
Trimethylsilyl functionalized durable superhydrophobic ZnO-SiO2 films on glass (A-55)	Indranee Das, Manish Kr Mishra, Samar K Medda, Goutam De (CSIR-CGCRI)
Studies on 'A'-site Nonstoichiometry in Sr-doped Lanthanum Ferrite and its Effectivity with Cobaltite-based Composite Cathode: Application of Intermediate Bi-Layer for SOFC Stability (A-56)	Koyel Banerjee, JayantaMukhopadhyay. Rajendra N. Basu (CSIR-CGCRI)
Effect of urea on facet development of Fe-Co bimetallic oxides: Application as Arsenic sensor (A-57)	Priyanka Mukherjee, MamataMohapatra, ChinmayaSarangi, GeetikamayeePadhy, Kali Sanjay (CSIR-IMMT)
Student Session 3: *Innovations in Young Minds* (Chairman: Prof. S. Basu Majumdar; Co-Chairman: Dr. B.B. Jha)	
Amine Functionalized Graphite Nanosheets and its Application in Controlled Drug Release and Catalysis (A-58)	Amrita Chakravarty, KoushikBhowmik, Arnab Mukherjee, Goutam De (CSIR-CGCRI)
Facile Synthesis of Polyaniline/Ag Nanocomposite and its Applications (A-59)	SanjoyMondal, Sudip Malik (IACS)

Biosorption of nickel from aqueous solution using dry biomass of Bacillus cereus M116 (A-60)	AnimeshNaskar, Lalitagauri Ray (JU)
Biogas Compatible Anode Cermets for Solid Oxide Fuel Cell Application (A-61)	RajshreeKonar, JayantaMukhopadhyay, Rajendra N. Basu (CSIR-CGCRI)
Fabrication of Multi-length Scales Wrinkles by Buckling of Metal Thin Film on Viscoelastic Polymeric Substrate (A-62)	Anuja Das, Aditya Banerjee, Rabibrata Mukherjee (IIT Khragpur)
Gas sensing characteristics of composite oxide thin films (A-63)	Abhisekh Ghosh, S. B. Majumder (IIT Kharagpur)

Student Session 4: Innovations in Young Minds
(Chairman: Dr. O.N. Mahanty; Co-Chairman: Dr. P. Sujatha Devi)

Ordered surface texturing of silica-zirconia thin film: A soft lithographic approach (A-64)	Saswati Sarkar, Hasmat Khan, SomjoytiBasak, Sunirmal Jana (CSIR-CGCRI)
Sol-gel based new nanocomposite: An efficient and reusable photocatalyst (A-65)	Moumita Pal, SusantaBera, Sunirmal Jana (CSIR-CGCRI)
Bimetallic Nanocatalysts for Room Temperature Hydrogen Generation (A-66)	DeboleenaBhattacharjee, KaustabMandal, SubrataDasgupta (CSIR-CGCRI)
La0.65Sr0.3MnO3 Nanorods as Solid Oxide Fuel Cell Cathode (A-67)	Debasish Das, Rajendra N. Basu (CSIR-CGCRI)
Soft Lithographic Fabrication of Topographic Meso-scale Patterns with Tunable Feature Height (A-68)	Nandini Bhandari, Rabibrata Mukherjee (IIT Kharagpur)
Mixed Matrix Membrane for Separation of CO2/CH4 from Simulated Landfill Gas (A-69)	MitaliSen, Nandini Das (CSIR-CGCRI)

ANNEXURE III



Uses

Synthetic Bone Graft

Scale of Development

Process demonstrated at 100 gm/batch scale

Commercialization Status

The know-how transferred to M/S G. Surgiwear Ltd, Shajahanpur

Techno-economics

For 100 gm/batch scale Capital cost ~ RS. 3.0 Lakhs (excluding land & shed)

MST 010

Biomimetic Polymer based Hydroxyapatite Block

Salient Features

The product is novel three dimensional load bearing polymer-hydroxyapatite nanocomposite. It has been synthesized through biomimetic route. The process is *in situ*, simple and cost effective. It does not involve any toxic cross linker and works at near ambient conditions. The application of the nanocomposite is as a load bearing synthetic bone graft. The compressive mechanical strength of the nanocomposites is in the range of 2-12 MPa.

Patent Application No: 3438DEL2014

Environmental Consideration

Not applicable

Major Raw Materials

Calcium salt and phosphate salts, ammonium solution NH_3, Distilled water and polymer

Major Plant Equipment/Machinery

Magnetic stirrer (rpm): 1000/min, pH meter, Mould made of perspex sheet (15 cm × 15 cm × 10 cm) & Distilled water plant

Technology Package

(a) Process Know-how, (b) Details of equipment, (c) Plant Layout and (d) Quality Assurance Methods. Assistance in setting up the plant on separate terms.

CSIR-NML Jamshedpur

MST 009

Development of Biphasic Calcium Phosphateblocks

Salient Features

The product novel three dimensional load bearing biphasic calcium phosphate nanocomposite is osteoinductive. It can induce the stem cells to differentiate into new bone forming cells. So the nanocomposite can be used as bone healing & synthetic bone graft. The mechanical compressive strength of the 3D BCP is in the range of 6-26 MPa analogous to cancellous bone.

Patent Application 2009DEL2013

Environmental Consideration

Not applicable

Major Raw Materials

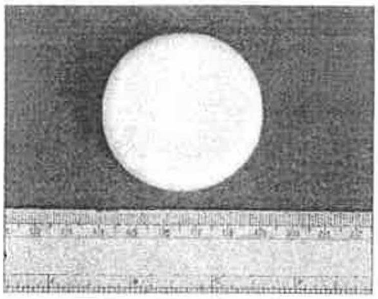
Calcium salt and phosphate salts ammonium solution NH_3, Distilled water, polymer

Major Plant Equipment/Machinery

Magnetic stirrer (rpm): 1000/min, pH meter, Mould made of perplex sheet (15 cm x 15 cm x 10 cm) & Distilled water plant Muffle Furnace

Technology Package

(a) Process-Know-how, (b) Details of equipment, (c) Plant Layout & (d) Quality Assurance Methods. Assistance in setting up the plant on separate terms.



Uses

Synthetic Bone Graft/Scaffolds

Scale of Development

Process demonstrated at 100 gm/batch scale

Commercialization Status

The know-how transferred to G. Surgiwear Ltd, Shajahanpur

Techno-economics

For 100 gm/batch scale Capital Cost ~Rs. 5.0 Lakhs (excluding land & shed)

MST 001

Wide Metallic Glass Ribbon Processing Unit

Salient Features

25mm wide 25-50 micron thick continuous glassy ribbon can be prepared by planar flow casting method using melt spinning system. It uses 1kg (for ferrous alloy) capacity induction furnace. The liquid metal is poured on water cooled Cu-wheel which can rotate at a speed of 1000 -3000 rpm. The system can be operated in normal and controlled atmospheres. The type of alloys that can be prepared through this melt-spinning system are:

- Glassy magnetic alloys: Fe-Si-B , Fe-Ni-B, Co-Si-B
- Nanostructured magnetic alloys: Fe-Nb-Cu-Si-B,Fe-Co-Nb-Si-B
- Brazing alloys: Cu-Ni-Mn, Ni-Fe-Cr-B-Si
- Ferromagnetic shape memory alloy: Ni-Mn-Ga, Co-Ni-Al

Patent Application No: 352/DEL/2007

Environmental Consideration

No hazardous gas emitted.

Major Raw Materials

(i) Fe, Co, Ni, Cr, Nb, Cu, Si,B, Al, Mn, Ga depending on the type of alloys to be produced

(ii) Excel grade argon gas

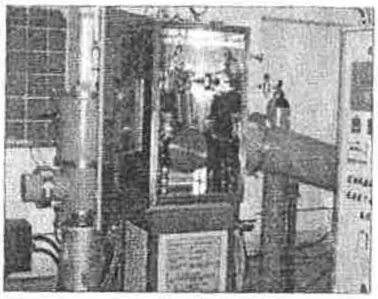
(iii) Chilled water

Major Plant Equipment/Machinery

Electric Arc Furnace, Induction melting unit coupled with water cooled rotating copper disc

Technology Package

Equipment details, process description, Cost estimation & product specification, Assistance in setting up the plant on separate terms.



Uses

Rapidly solidified material processing unit for

- Magnetic alloys: Transformer core, magnetic sensor applications, saturable reactors, choke coils, core materials for circuit breaker etc.
- Brazing Alloys: Joining materials for heat-exchanger for automobile and aircraft industries

Scale of Development

Single unit can produce 500g alloy/ batch leading to 50kg/ month capacity

Commercialization Status

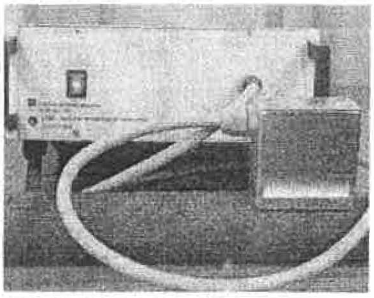
Licensed for manufacturing to M/s Vacuum Techniques Pvt. Ltd., Bangalore, on non-exclusive basis

Techno-economics

Rs. 1 Crore (excluding land & shed) per unit & Recurring Expenditure depends on type on raw material used

MST 002

MagStar: A portable magnetic hysteresis and Barkhausen emissions based electromagnetic device for non-destructive evaluation of steel structure/component



Uses

(i) Evaluation of microstructural changes during heat-treatment/ ageing,
(ii) Determination of ferrite volume fraction,
(iii) Evaluation of ferromagnetic phases and its correlation with mechanical properties and
(iv) Residual stress analysis

Scale of Development

Portable Laboratory based device and scope for automation for in-service operation

Commercialization Status

Licensed for manufacturing to M/s Technofour, Pune, on non-exclusive basis

Techno-economics

Cost: Rs. 20 Lakh/unit, Additional Sensor: Rs. 2.0 Lakhs/unit

Salient Features

The developed electromagnetic NDE device works by exciting the sensor by an alternating current source. The sensor is to be placed on test body to get signal corresponding to the characteristics of the test objects. The output signals from the sensor are the measure of the magnetization, coercivity and magnetic noise (Barkhausen emissions) which change with microstructure and stress state of the materials. The salient features of the device are as follows:

Magnetic Hysteresis Loop (MHL) measurement

Frequency Range : 20mHz to 200Hz
Excitation : 0-1500 Oe
Wave Shape : Sinusoidal / Trianguler

Magnetic Barkhausen Emissions (MBE) measurement

Frequency Range : 10Hz to 200 Hz
Excitation : Up to 1500 Oe
Number of cycles 3 to 10
Gain 0 to 20 dB in steps of 1 dB

Filter setting 10KHz to 300KHz independently variable Low pass and High pass.

Power Requirement : 230V, 50Hz, 200VA
Weight : 3.25Kg

Control, Display and Analysis : External laptop /notebook/ personal computer

Patent Application No: 2545DEL2006

Environmental Consideration

Not Applicable

Major Raw Materials

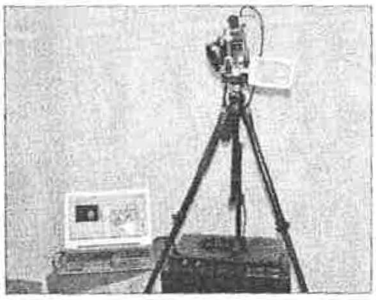
Electronic components, Soft magnetic core materials

Major Plant Equipment/Machinery

Sensing probe, power source, amplifier, Data acquisition & analysis system

Technology Package

(a) Details of equipment, (b) Operating Manual and (c) Quality Assurance Methods.



Uses

- Detection of alumina, silica, iron in iron ore
- Alumina in bauxite
- Moisture in coke

Commercialization Status

Implemented at Noamundi mines. On belt analysis is also possible.

Techno-economics

Capital Cost:~ Rs. 5 Lakhs

MST 008

Microwave-IR SORT: A rapid, reliable, non-invasive technology for iron ore compositional analysis

Salient Features

Fast, Reliable non-invasive technique to detect alumina/Fe in iron ore. This technology relies on the conversion of microwave energy to heat energy based on the dielectric properties of the mineral constituents of iron ore. Thermal behavior of the ore is imaged using Infra-red camera with high temperature sensitivity and the average temperature rise is related to the wt% of alumina/Fe in iron ore.

- IR camera: Long range
- Temperature Resolution: 0.1°C
- Microwave power: 650 - 700 Watt
- Iron ore size: -10mm
- Time of estimation: 30 secs/sample

Patent Application No: 854/KOL/2014

Environmental Consideration

Not applicable

Major Raw Materials

Iron Ore/ Coke/ Bauxite

Major Plant Equipment/Machinery

Computer controlled IR camera, Microwave, Laptop

Technology Package

(a) Process-Know-how, (b) Details of equipment & (c) Assistance in setting up the plant on separate terms and (d) Software

CSIR-NML Jamshedpur

MEF 007

Paving Blocks from Fly Ash, Blast Furnace Slag, Steel Slag, etc

Salient Features

These Paving blocks are produced from the geopolymerisation of industrial waste such as fly ash, granulated blast furnace slag, steel slag and red mud in different combinations.

- Meets IS 15658:2006 specification
- Can be produced in different shapes and sizes with properties equivalent to M15 - M35 grade concrete.
- Uses ambient temperature synthesis and generates 30% less CO_2, 35% low embodied energy than conventional equivalent product

Patent Application No: 1509/KOL/2011

Environmental Consideration

The product meets USEPA 1311 specification for toxicity. Also due to 35% low CO_2 emission and 35% less embodied energy, it falls in the category of green. Due to use of waste and byproduct, it qualifies for 1 point in LEED certification for green building.

Major Raw Materials

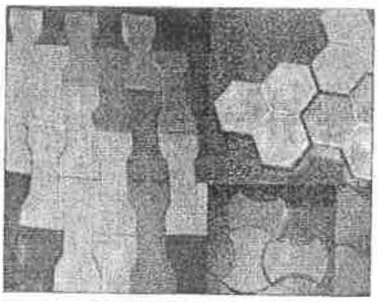
- Fly ash conforming to IS 3812, and/or
- Ground granulated blast furnace slag conforming to IS 12089:1987, and/orSteel slag with low free lime and metallic iron
- Chemical admixture as per IS 9103
- Commercial grade Alkali hydroxide/ silicate

Major Plant Equipment/Machinery

Hopper, Batch weighing system, Pan mixer, Vibro-hydraulic press, Curing tanks, Conveyor belt, Dust collection systems, etc.

Technology Package

(a) Process-Know-how, (b) Details of equipment, (c) Plant Layout, & (d) Quality Assurance Methods. Assistance in setting up the plant on separate terms.



Uses

The process produces pavement blocks of different shapes and sizes, and different colours and designs. These paving blocks can be used in pavement, patio, lounge, garden, park, petrol pumps, etc and are suitable for light to medium load.

Scale of Development

10 tons/day

Commercialization Status

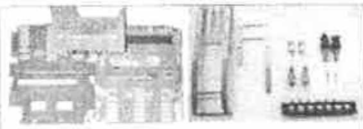
Technology transferred and commercialized.

Techno-economics

Minimum viable plant size: 50 tons/day

Capital cost: Rs. 40 Lakhs (Excluding land and building)

Cost of product: Rs. 320-400/ square meter



Scraps containing gold

Uses

Gold is a versatile metal and is used for various purposes like in jewellery, electrical and electronic equipments, dentistry, medical diagnosis, aerospace, glassmaking etc.

Scale of Development

1 Kg to 10 Kg (Lab Scale)

Commercialization Status

Transferred to M/S ADV Metal Combine Pvt. Ltd., New Delhi

Techno-economics

Capital Cost ~Rs. 10 Lakhs

Recurring Cost ~Rs. 2 Lakhs/ Year

MEF 016

Recovery of Gold from Waste Mobile Phones and Scraps of various Equipment

Salient Features

A process is developed for the dissolution of metal from the PCBs of waste mobile phone, small parts of various equipments containing gold on outer layer. Chemical leaching followed by adsorption/ cementation with subsequent heat treatment was used to recover 99% gold.

Environmental Consideration

20 to 25 L effluent generated is recycled after proper treatment. The solid residue will be utilized as non hazardous filling material in various applications

Major Raw Materials

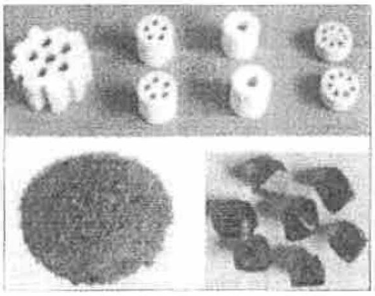
Mobile phone PCBs, scrap parts of various equipments, leachant, adsorbent, etc.

Major Plant Equipment/Machinery

Leaching reactor, hood, filter press, pH meter, balance, glassware, safety appliances, etc.

Technology Package

(a) Process Know-how, (b) Details of equipment & (c) Quality Assurance Methods. Assistance in setting up the plant on separate terms.



Uses

Nickel sulphate is extensively used in electroplating, organic chemical synthesis, metal coloring, dye mordant, manufacturing other nickel salts, Ni-Cd battery

Scale of Development

Process developed on 1 kg scale with overall recovery of 96% nickel

Commercialization Status

Process demonstrated on 1 kg scale and transferred to M/s SMC Technology, Malaysia

Techno-economics

For a 10 MT/month capacity plant; Capital cost is ~Rs.75 Lakhs (excluding land & shed). Recurring Expenditure - Rs. 3.5 Lakhs/month (excluding spent catalyst cost).

MEF 002

Production of Nickel Sulphate from Spent Nickel Catalyst

Salient Features

Nickel catalysts used in various operations become spent after several cycles of use, for which a very simple and innovative process is developed at NML for recovery of nickel. The processing step consists of direct acid leaching in presence of a promoter followed by impurity removal to produce nickel salt/metal. The novelty of the process is that, it gives very high nickel recovery (99%) under the moderate conditions in presence of a little quantity of a promoter without which it is found to be very poor even at higher temperature and acid concentration. High purity alumina is produced from the process as a part of leached residue.

Environmental Consideration

Only CO_2 is produced from the process if the catalyst is contaminated with oil/ghee and the quantity will depend on the organic content in the spent catalyst. About 10-20 kg per ton of iron hydroxide residue is generated.

Major Raw Materials

Spent nickel catalyst, sulphuric acid, alkali, Promoter

Major Plant Equipment/Machinery

Roaster, Grinding and sieving apparatus, leaching reactors, promoter, filtration unit, pumps, crystalliser etc.

Technology Package

(a) Process Know-how, (b) Mass Balance, (c) Details of equipment, (d) Plant Layout and (e) Quality Assurance Methods.

Assistance in setting up the plant on separate terms and condition

MST 013
PABI : Portable Automated Ball Indentation System

Salient Features

The device has the ability to estimate hardness, yield stress, yield ratio, tensile strength, strain hardening constant and fracture toughness- all in just one test. Other features of the device are (i) Ball impression is less than an mm in diameter making it nearly non-destructive test, (ii) hardness mapping of non-uniform samples like weld zone and HAZ, (iii) adaptor for bench testing of small sample, (iv) adaptor for field testing of large components, (v) stress or strain controlled test modes, (vi) estimation of multiple properties with one run and (vii) software controlled operation and analysis

Patent Application No: 0549DEL2012

Environmental Consideration

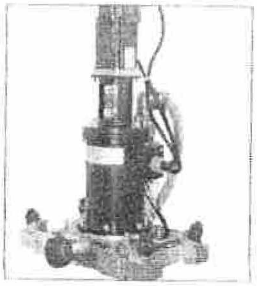
Not applicable

Major Plant Equipment/Machinery

Electronic components, load cell, LVDT, power source, amplifier, Data acquisition & analysis system, PC etc.

Technology Package

(a) Details of equipment, (b) Operating Manual, (c) Quality Assurance Methods, (d) Training & (e) data for validating the systems



Uses

To evaluate key mechanical properties of metallic components/ materials

Scale of Development

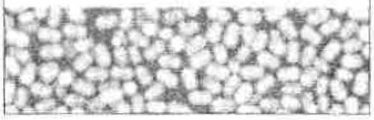
Portable Laboratory based device and scope for automation for in-service operation

Commercialization Status

Commercialized by M/s Ducom Instruments, Bangalore

Techno-economics

Cost: Rs. 25-30 Lakhs/unit depending upon nos. of attachment.



Uses

Hematite has variety of application as photosensitive material, catalyst, high quality pigments, and cosmetics besides its major use as magnetic materials mainly for producing both soft and hard ferrites

Scale of Development

Developed and demonstrated on 1 kg Scale

Commercialization Status

Transferred to M/s Tata Pigments Ltd.

Techno-economics

Chemical requirement cost is about Rs. 30,000 against product cost of about Rs. 1,25,000 per ton of iron oxide production.

MEF 004

Production of Ferrite and Pigment grade high purity Monodispersed iron Oxide from Waste Chloride Pickle Liquor and other Iron Rich Sources

Salient Features

High purity mono dispersed hematite particles of very uniform sizes and shapes have been produced by low temperature aqueous synthesis route in large quantities with a yield of almost 100% starting from very inexpensive and impure iron sources such as blue dust, scraps, pickle liquors, crude iron oxide, high iron containing residues etc. Low temperature aqueous synthesis method produce very uniform size and shapes of iron oxide from very inexpensive and impure iron sources. The mono dispersed hematite particles of different shapes such as cubic, spindle, ellipsoidal, spherical, peanut type particle can be produced by this method. Different shapes of uniform size mono dispersed hematite particles of size ranging from 200 - 2000 nm can be produced.

Environmental Consideration

The liquid effluent generated from is treated for regeneration of alkali and recovery of marketable grade salt. Only about 50 kg of nontoxic residue is generated per ton of iron oxide production.

Major Raw Materials

Waste Chloride Pickle liquor, Blue dust, scrap iron, High iron containing waste

Major Plant Equipment/Machinery

Oxidation column/leaching reactor (optional) Precipitation Reactors, Filter press, storage tanks, alkali regeneration setups, evaporator/crystallizer

Technology Package

(a) Process-Know-how, (b) Details of equipment, (c) Plant Layout and (d) Quality Assurance Methods. Assistance in setting up the plant on separate terms.

MEF 005

Yellow Tungsten Oxide (YTO) and W-powders from WC-hard Metal Scraps

Salient Features

Recovery of high pure products (YTO, W-metal powders & other metal salts/powders) from waste/end of life WC-hard metal tool bits/drill bits/inserts etc., and heavy metal alloy scraps/swarf. The salient features of the process are:

- Purity of YTO & W powder is >99.9%
- High pure cobalt salt is a by-product
- Process recovers all the metals from WC scraps with >95% recovery efficiency
- Processing cost ~ Rs. 400/kg of tungsten powder (excluding scrap cost).

Environmental Consideration

- No solid/liquid effluent generated
- ~0.25MT of CO_2/MT of W powder.
- Storage & handling of flammable H_2 gas.

Major Raw Materials

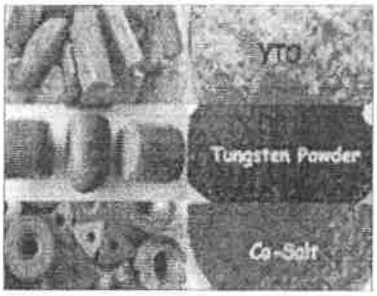
(i) WC scraps, (ii) commercial mineral acids, (iii) EXCEL Grade N & H gasses.

Major Plant Equipment/Machinery

(i) FRP/rubber-lined leaching reactors with heating & condensation facilities, (ii) high temperature oxidation furnace(~1000°C Max), (iii) Filter press with PP/FRP MOC with suitable slurry handling pumps, (iv) Pusher type reduction furnace (~1000°C Max), and (v) Drying oven (150°C, Max).

Technology Package

Complete flow-sheet with mass balance, Equipment details, Process description, Equipment flow-diagram, Cost estimate & Product specification, Assistance in setting up the plant on separate terms.



Uses

Tungsten has numerous critical applications in defense, energy, mining etc. sectors

Scale of Development

Process demonstrated at 1kg/batch scale

Commercialization Status

The process has been licensed to

(i) M/s Bharat Futuristic Corporation, Bangalore and

(ii) M/s Minestone Minerals Ltd., Mangalore

Techno-economics

For a 5MT/month capacity plant; Capital 65.0 Lakhs (excluding land & shed) & Recurring Expenditure Rs. 18.0 Lakhs/month (excluding scrap cost).

ANNEXURE - IV

CSIR-National Metallurgical Laboratory

December 11, 2015

Subject : Policy & Roadmap document on CSIR-NML's Vision, Mission, Mandate, Goals, Structure, Core Areas and Deliverables in the Short, Medium and Long Term

The questionnaire has essentially four components:

Part A is lays emphasis on Vision, Mission and Mandates. PART B focuses on the structure and constitution of our laboratory including human resources, research areas and constraints. Part C deals with planning for the future in terms of our core activities. PART D deals with our efforts on obtaining new business and redefining our business models.

I request you to provide your valuable inputs based on your assessment of the national and international R&D scenario in the domain of Minerals, Metals & Materials, expertise and vast experience . I will be grateful if you can provide your on-line response latest by 20th Dec.

S.Srikanth

Director, CSIR-NML

A. Vision, Mission and Targets

A.1. What should be the Vision statement of CSIR-NML [Tick any one or provide yours]

	To become a global leader and an internationally benchmarked laboratory in mineral and metallurgical research and development (present documented vision statement)
	Globally acclaimed self-sustained technology centre (vision as projected by Director, NML over the past six years)
	Any other (Please give your Vision statement below in not more than 20 words)

A.2. What should be the Mission and mandate of CSIR-NML ? (Not more than 30 words each)

A.3. What should be NML's Goals and targets for 2020? [Provide up to 5 goals for each area]

Area	Goals	Targets
In Knowledge creation and dissemination		
In technology creation and translation		
In Social and Strategic services		

Present targets of CSIR-NML for 2016 are:

- 50 % budget from Industrial sources [Annual budget of NML for 2014-15 was ~Rs 60 crores (Rs 33.6 crore CSIR grant, Rs 9.4 Cr from LRF & rest projects) without pension] & ECF was Rs 30.2 Cr (Rs 20 Cr from Industry & rest from GAP)
- 80% direct utilization of man-power & major equipments
- Commercialization of 5 technologies with lasting impact
- 5% of operational budget from IP licensing & technology transfer
- Paperless CSIR-NML
- One major national mission project
- 150 SCI papers/Yr with Av Citation/Paper of 10; Generate 20 Phds/year under AcSIR

B. Structure & Constitution

B.1. The macro structure of the R&D and service divisions should be

Indicate your choice	Macro-structure
	As it is today [4 verticals (Mineral Processing, Metal Extraction & Forming, Materials Science & Technology, Corrosion & Surface Engg. - R&D Divisions) + 5 Horizontals (Analytical Chemistry, Research Planning & Business Development, Information Management & Documentation and Information & Communication Technology - Service units)]
	Broadly as it is today with merger of a few sub-critical units
	Based on industrial sectors, each department catering to one or two broad sectors (Steel, Strategic sector, Chemicals, Oil & Gas, etc)
	Fluid, with only administrative units, groups form as and when required, based on projects
	Other (Indicate here)

B.2. What should be the core research areas of the laboratory *(In order of preference, "1" being the highest priority, please rank the below areas)*

Rank	*Area*
	Advanced materials and their applications (synthesis, evaluation and processing)
	Materials Characterization and Evaluation (including NDT)
	Structural Integrity and Structural Health
	Metals Extraction, melting and casting
	Mineral Processing
	Metals forming, joining and post processing
	Corrosion and wear
	Rare metals and alloys
	Waste utilization
	Energy and environment
	Coal & Coke
	Applied/Analytical chemistry
	Integrated Computational Materials Engineering (ICME) including materials & process modeling
	Life Cycle Assessment of Materials (LCA)
	Any others [Please specify below]

B.3. Human Resources Profile [Scientists:Technical Officers (Gr. 3 & 2 only):Rest] of CSIR-NML- *tick your preference (present ratio based on sanctioned position is 170:157:377)*

As it is today (121:81:170)		**1 : 1 : 1**	
1 : 0.5 : 1		**Any other (Please specify ratio here):**	

B.4. Indicate what should be the optimum time involvement of scientists/technical officers in various activities (*Put values from 1-100 so that it totals to 100 for each category*)

Category	**Research & Technology Development**	**Science & Technology Management**	**Administrative Functions**	**Teaching & Mentorship**
Senior officers (G/F or equivalent)				
Middle level (EII/EI or equivalent)				
Junior Officers (C or equivalent and lower GP)				

B.5. In your assessment, what are the major systemic and other constraints in CSIR labs especially NML? *(Please Rank the following, 1 being the most constraining)*

Administrative Procedures (including Finance, Purchase, etc.)	
Scientific Inertia	
Mentorship vacuum	
Lack of quality manpower	
Lack of ownership and commitment by employees	
Lack of quality facilities	
Lack of leadership	
CSIR's lack of direction and purpose	
Financial resource constraints	
Industrial apathy to R&D	
Sufficient time not available for R&D,Technology Development	
Locational Disadvantage	
Any others (please specify)	

B.6. Assessment of NML's capabilities - *Indicate your opinion on NML's capability with regards to research and technologies by ticking appropriate box)*

Capabilities or lack thereof	High	Medium	Low	Nil
NML is capable of high value translations (technologies/products)				
NML is capable of High Sciences				
NML is capable of providing High value services				
NML is capable of high quality testing and analysis				
NML is capable of running high quality academic program				

C. Plans and deliveries

Indicate how the profile of CSIR-NML's research should be for optimum effectivity

(Indicate as percentage, totaling to 100)

Broad research	% Manpower Wise		% Fund generation wise
	Gr IV	Gr III	
High-end Knowledge based Services			
Development of New Products and Technologies			
High Quality Science			
Societal Mission			
Skill Development			

C.1. High – end Knowledge based services

What should be the major programs of CSIR-NML?

C.1.a. Short term (Delivery within 6 -18 months)

	Rank ("1" highest)	Deliverables (List 3 max per category)	Specific Constraints (List 3 max per category)
Contract research through sponsored projects			
Testing and industrial solution provision			
Industrial consultancy, Environment & energy Audits			
Exploratory research projects with definite future			
Technical Trainings & Skill Development Programs			
Any other (Please specify)			

C.1.b. Medium term (Delivery within 2-3 year)

	Rank ("1" highest)	*Deliverables (List 3 max per category)*	*Specific Constraints (List 3 max per category)*
Government grant projects (ARDB, DST, BRNS, etc)			
On-site industrial solutions/Contract Research			
Technology Development & translation			
Any other (Please specify)			

C.1.c. Long term (Delivery beyond 3 years)

	Rank ("1" highest)	*Deliverables (List 3 max per category)*	*Specific Constraints (List 3 max per category)*
Creation of centres of excellence in conjunction with sponsors			
International Knowledge Warehouse (in collaboration with international institutes) and data mining			
Large inter-laboratory projects targeting technology development			
Customer needed database, knowledge base creation (e.g. Microstructure Atlas, Corrosion Map, etc.)			
Technology development for industrial, strategic & social sectors identified in consultation with stakeholders			
Any other (Please specify)			

C.2. Development of New Products and Technologies

C.2.a. Differentiating our products: *Indicate how we can build an effective USP (Unique selling proposition) for our products and technologies (Rank with "1" as highest priority)*

#	Strategy
	Providing basket of technologies for an application or for a sector
	Collaborating with our cluster CSIR laboratories to produce robust and comprehensive technologies
	Developing products/technologies targeting mass markets/ multiple clients
	Developing products/technologies targeting niche markets/ few clients
	Product/technology to be endorsed only after rigorous trials certified by non-developers, including third party or round robin tests
	Improve after-sale service and free or first use of improved versions
	Any others (please specify

C.2.b. Existing Technology areas *Indicate the areas in which NML should concentrate for technology proliferation by ticking appropriately after adding any other technologies)*

Technology Areas	Short term	Long term	Discontinue
Waste recovery & Value Additions			
Inhibitors			
Coatings			
Recycling (including e-waste)			
Sensors & Devices for Structural Health Monitoring			
Lean ores beneficiation			
New Materials (bio-, Nano-, etc.) development			
Process intermediations (e.g. improved pelletization, briquetting, synthetic flux, etc.)			
New Products			
New Energy efficient & Environment friendly Processes			
Any other			

C.2.c. NewTechnology areas *Indicate at least 3 new areas in which NML should concentrate*

Technologies to be developed in the short term	Technologies to be developed in Long term

C.3 High Quality Science

C.3. a. Please prioritize the outcome of High sciences (Rank with "1" as highest priority)

#	Outcome
	High impact publications
	International recognition
	High citations
	Editorship/ Key readership
	Higher Brand Value
	More business

C.3.b. Please indicate what should be the Metrics for high sciences at NML

Metric	Value
Minimum Av Impact factor of publications (Av IF for 2013 was 2.2 and 2014 was 1.9)	
Citation per journal	
Verified Downloads	
Citations per paper (present C/P is 10.99 Google Sch)	
Any Other (Please specify)	

C.3.c. Please indicate in your opinion the areas in which NML has the facilities and expertise for high sciences (Tick appropriate Box)

Area	High	Medium	Low	Nil
Materials Evaluation				
Materials Characterization				
Bio-materials				
Non-destructive analysis				
Waste Utilization and Value addition				
Non-ferrous				
Ferrous				
Forming				
Minerals Processing				
Corrosion and surface engineering				
Analytical/applied chemistry				

C.4. Skills Development

Please provide Five Technical Areas/topics in which NML can carry out skills development annually and on a sustainable basis (financially and technically) & provide certificate courses

1	
2	
3	
4	
5	

C.5. You, the scientist/technologist..................

As a leading scientist/technologist, name 1 dream research project or technology development that you would like CSIR-NML to take up.

Dream Work (Give topic/ name)	Why you want to do it	How it will help other Indians	Do you and NML have the expertise and facilities (tick)		Fund quantum needed
			Yes		
			Can be developed soon		
			Can be developed over a period		
			No and Never		

D. Finance and Economics

D.1. Indicate the revenue share that NML should strive for by 2018 (for 2014-15, the revenue share was Rs 7.94 Cr from Govt bodies, Rs 19.82 Cr from Industry, Rs 2.21 Cr from Testing & Analytical Services (including Rs 1.14 Cr from equipment leasing), Rs 21.67 lakhs from Technology Transfer and Royalty/Premia). CSIR-NML's annual budget is about Rs 60 Crores (without pension)

Values	Sale-ables				
	Technical Services (Testing/ Calibration, etc.)	Technologies (Licensing and transfer)	Contract Research	Skills development	Assets utilization (facilities, space, etc.
Amount (in Crores)					
%					

D.2. Business Model

What Business Model would best suit NML *(tick one or more below)*

D.2.a. Inre Knowledge marketing

Tick(1 or more)	***Business Model***
	External agents to obtain contract research, freeing up all scientists to execute
	An internal group of senior scientists dedicated to obtaining contract research
	Free for all, everyone strives to get contract research
	Develop outreach centers (abroad if necessary)
	As is practiced today (what falls in our laps)
	Use the knowledge and facilities strength of our engineering cluster and market comprehensive knowledge through inter-lab collaborations
	Any others (Please specify)

D.2.b Inre Technologies

Tick(1 or more)	***Business Model***
	Through external agent
	Involve venture capitalists
	Start by incubation, development of vendor and then proliferation at larger scales
	Use the knowledge and facilities strength of our engineering cluster and develop and market comprehensive technologies
	As is practiced today : bench scale - get an industry interested - up scale if required – sell
	Develop technology baskets (e.g. for Structural Health Monitoring) for flexible marketing
	Any others

D.3. Identifying the markets:

D.3.1. Indicate the top three industrial sectors/sub-sectors that are likely to fund research in areas of expertise of NML immediately

1	
2	
3	

D.3.2. Indicate the three sectors/ sub-sectors which are most likely to fund research in the future (2018 onwards)

1	
2	
3	

D.3.3. Indicate the two industrial sectors/sub-sectors which NML should vacate due to low or no returns

1	
2	

D.4. Entrepreneurship development

Please prioritize the following as means of entrepreneurship development by and at NML

#	Entrepreneurship development means
	Setting up of Incubation Center
	Tie-up with reputed NGOs
	Tie-up with small and medium scale established entrepreneurs
	Through Venture Capitalist
	Create spin-offs through Company 25 norms
	Promote technology transfer with relatives of employees

Annexure V

Areas and Organisations for Survey of Innovations Transferred to Industries

Areas of Innovation:

[click to access area-wise database file]

1) Ceramics	2) Composites	3) Electronic and Photonic materials	4) Glass
5) Meta-naterials	6) Metals & Alloys	7) Nanomaterials	8) Raw materials
9) Smart materials	10) Super materials	11) Others	

Organisations, included in the survey:

[click to access organisation-wise database file]

1) CSIR- Central Glass and Ceramic Research Institute, Kolkata
2) Jadavpur University, Jadavpur, Kolkata
3) Kolkata University, Kolkata
4) Indian Institute of Engineering Science and Technology, Howrah
5) Indian Institute of Technology, Kharagpur
6) CSIR- Central Mechanical Engineering Research Institute, Durgapur
7) Durgapur Steel Plant, Steel Authority of India, Durgapur
8) CSIR-National Metallurgical Laboratory, Jamshedpur
9) Indian Institute of Management, Kolkata
10) Saha Institute of Nuclear Physics, Kolkata
11) Variable Energy Research Centre, DAE. Kolkata
12) CSIR-Indian Institute of Chemical Biology, Kolkata
13) Tata Steel, Jamshedpur

Period of innovation: 2000 to 2015

Areawise Database of Innovations Transferred to Industries

Areas of Innovation:

1) Ceramics 2) Composites 3) Electronic and Photonic materials 4) Glass
5) Meta-naterials 6) Metals & Alloys 7) Nanomaterials 8) Raw materials
9) Smart materials 10) Super materials 11) Others

[click area-name to jump to corresponding record and click Back to return]

Areas of innovation	Organisations involved	Title of innovation	Nature of innovation	Source of information
Ceramics	CSIR-CGCRI	Ceramic membrane based pretreatment system for BRWO/SRWO Plants	New application	Annual report
	CSIR-CGCRI	Ceramic Bio-medical implants	Development of implants	Annual report
	CSIR-CGCRI	Development of biphasic of calcium phosphate block	Material development	Annual report
	CSIR-CGCRI	Paving blocks from fly ash, blast furnace slag etc.	New application	Annual Report
Composites	NIL	NIL	NA	Survey report

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Electronic & Photonic materials	NIL	NIL	NIL	Survey report	Back
Glass	CSIR-CGCRI	Special glass nodules for nuclear waste immobilization	New application	Annual report	
	CSIR-NML	Wide metallic glass ribbon processing unit	Device development	NML Technology Document	Back
Meta-materials	NIL	NIL	NA	Survey report	Back
Metals and Alloys	CSIR-NML	Technology for recovery of Lead from Zinc Plant residue	Metal recovery technology	NML Technology Document	
	CSIR-NML	Technology for Production of Tungsten Metal Powder from Hard Carbide Scraps	Production technology	NML Technology Document	
	CSIR-NML	Technology for Nickel Recovery from Spent Catalysts	Metal recovery technology	NML Technology Document	
	CSIR-NML	Recovery of gold from waste mobile phones and scraps of various equipment	Metal recovery technology	NML Technology Document	

	CSIR-NML	Magstar : A device for nondestructive evaluation of steel structure/component	Device development	NML Technology Document
	CSIR-NML	Microwave 1R : A noninvasive technology for iron ore compositional analysis	Device development	NML Technology Document
	Durgapur Steel Plant	Micro alloyed BG Coaching Wheels	Product development	Survey report
Nanomaterials	CSIR-NML	Synthetic Nano crystalline Hydroxyapatite	Material development	NML Technology Document
	CSIR-NML	Synthetic Nano crystalline Hydroxyapatite and β- Tricalcium Phosphate Composite	Material development	NML Technology Document
	CSIR-NML	Technology for Production of uniform of rare grade Nano iron oxide from Waste Pickle Liquour	Production technology	NML Technology Document

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	CSIR-CGCRI	Development of transparent, hard and protective coatings on CR-39® ophthalmic lenses and related plastics	Material development	Annual report	Back
Raw materials	NIL	NIL	NA	Survey report	Back
Smart-materials	NIL	NIL	NA	Survey report	Back
Super materials	NIL	NIL	NA		Back
Others	CSIR-CGCRI	Hard and Abrasion Resistant Coating	Polycarbonate based Plastic	Annual report	Back

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Areas and Organisations for Survey of Innovations Ready for Transfer to Industries

Areas of Innovation:

[click to access area-wise database file]

1) Ceramics	2) Composites	3) Electronic and Photonic materials	4) Glass
5) Meta-naterials	6) Metals & Alloys	7) Nanomaterials	8) Raw materials
9) Smart materials	10) Super materials	11) Others	

Organisations, included in the survey:

[click to access organisation-wise database file]

1) CSIR- Central Glass and Ceramic Research Institute, Kolkata
2) Jadavpur University, Jadavpur, Kolkata
3) Kolkata University, Kolkata
4) Indian Institute of Engineering Science and Technology, Howrah
5) Indian Institute of Technology, Kharagpur
6) CSIR- Central Mechanical Engineering Research Institute, Durgapur
7) Durgapur Steel Plant, Steel Authority of India, Durgapur
8) CSIR-National Metallurgical Laboratory, Jamshedpur
9) Indian Institute of Management, Kolkata
10) Saha Institute of Nuclear Physics, Kolkata
11) Variable Energy Research Centre, DAE. Kolkata
12) CSIR-Indian Institute of Chemical Biology, Kolkata
13) Tata Steel, Jamshedpur

Period of innovation: 2000 to 2015

Areawise Database of Innovations
Ready for Transfer to Industries

Areas of Innovation:

1) Ceramics 2) Composites 3) Electronic and Photonic materials 4) Glass
5) Meta-naterials 6) Metals & Alloys 7) Nanomaterials 8) Raw materials
9) Smart materials 10) Super materials 11) Others

[click area-name to jump to corresponding record and click Back to return]

Areas of Innovation	Organisations involved	Title of innovation	Nature of innovation	Source of information
Ceramics	CSIR-NML	Geopolymer Cement	Material development	NML Technology Handbook
	IIT, Kharagpur	Electric field assisted membrane separation of pectin	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Improved wet scrubber for simultaneous scrubbing of particulates and gaseous matters	Product development	www.iitkgp.ac.in
	IIT, Kharagpur	Membrane Based Water-Extraction of Polyphenols from Green Tea Leaves	Process development	www.iitkgp.ac.in

	IIT, Kharagpur	A Composition for consolidation of Dense Ceramics and Metal Compacts	Material development	www.iitkgp.ac.in
	IIT, Kharagpur	A composition for forming porous bodies, in particular ceramic and metal forms and a process for the preparation thereof.	Material development	www.iitkgp.ac.in
	IIT, Kharagpur	A composition for use in gelation forming of ceramics	Material development	www.iitkgp.ac.in
	IIT, Kharagpur	A Novel Processing route to Fabricate Low Cost Fused Silica Ceramic Foam	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Plasma sprayed ceramic coatings	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A process for the preparation of ultra-pure porous alumina powder	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A Stabilized t-ZrO2 and a Process for its Manufacture	Process development	www.iitkgp.ac.in

	IIT, Kharagpur	A Highly Stable g-Al2O3 Messoporous structure and its Process for Manufacture	Process development	www.iitkgp.ac.in	
	IIT, Kharagpur	A process for preparing ammonium salt coated Cu-X zeolites	Process development	www.iitkgp.ac.in	
	IIT, Kharagpur	Plasma sprayed ceramic coatings	Process development	www.iitkgp.ac.in	Back
Composites	IIT, Kharagpur	A Process for the preparation of ferrous based composite	Process development	www.iitkgp.ac.in	Back
Electronic & Photonic Materials	IIEST	A non-invasive multi-sensor wireless system	Product development	SURVEY REPORT	
	IIT, Kharagpur	A Sensor system for detecting Presence of Deoxidizing Gases	Product development	www.iitkgp.ac.in	Back
Glass	IIT, Kharagpur	A process of preparation polymer coated glass fiber mat	Process development	www.iitkgp.ac.in	

	IIT, Kharagpur	A Transparent Amorphous AlO(OH).aH2O Glass and process for Preparation of the Same	Process development	www.iitkgp.ac.in	
	IIT, Kharagpur	A Transparent Amorphous AlO(OH).aH2O Glass and process for Preparation of the Same	Process development	www.iitkgp.ac.in	Back
Meta-materials	NIL				Back
Metals & Alloys	CSIR-NML	Yellow Tungsten oxide and Tungsten Metal Powder from Heavy Alloy scraps	Recovery technology	NML Technology Handbook	
	CSIR-NML	Synthetic Flux and a process for dephosphorisation of steel in induction furnace	Process development	NML Technology Handbook	
	CSIR-NML	Ferrosilicon from BHQ, BHJ and low reactive Coal	Material development	NML Technology Handbook	

	CSIR-NML	Production of directly reduced iron (DRI) High metallised low sulphur directly reduced iron from iron ore slime and rejected/middling coal	Material development	NML Technology Handbook
	CSIR-NML	A process for production of highly metallised low sulphur directly reduced iron (DRI) in Tunnel Kiln	Process development	NML Technology Handbook
	CSIR-NML	Highly metallised low sulphur directly reduced iron (DRI) from ironore slime and rejected/middling coal	Material development	NML Technology Handbook
	CSIR-NML	Recovery of gold from waste mobile phones and scraps of various equipment	Recovery technology	NML Technology Handbook
	CSIR-NML	Recovery of cobalt from discarded Li-ion batteries of mobile phones	Recovery technology	NML Technology Handbook

	CSIR-NML	Recovery of Neodymium as a value added production from waste hard disk of personal computers	Recovery technology	NML Technology Handbook
	CSIR-NML	Energy efficient coke based brass and bell metal melting furnace.	Process development	NML Technology Handbook
	CSIR-NML	High quality magnesite	Process development	NML Technology Handbook
	IIT, Kharagpur	A process for the preparation of pure metal form metal salts	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Flexible Contact Tube for Rotation ARC GMA Welding	Product development	www.iitkgp.ac.in
	IIT, Kharagpur	A Process for Preparation of Al - Ti - B Master Alloys for Grain Refinement of Aluminium and its alloys	Process development	www.iitkgp.ac.in

	IIT, Kharagpur	A process for preparation of master alloy for grain refinement of aluminium and its alloys	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A Process for production wear resistant cast iron by smelting reduction of waste products like red mud and sesilicated sand	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A process for the preparation of aluminium based ternary alloy	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Master Alloy for modification and grain refining of hypoeutectic Al-Si based foundry alloys and its process for manufacture	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Monel alloy resistant to stress corrosion crack in hydrofluoric acid	Material development	www.iitkgp.ac.in

	IIT, Kharagpur	Virtual alloys (software)	Software development	www.iitkgp.ac.in	
	IIT, Kharagpur	Synthesis and characterization of Hydroxyapatite (HAp)/poly (Vinyl alcohol phosphate) (PVAP) Nano composite biomaterials	Process development	www.iitkgp.ac.in	Back
Nanomaterials	IIT, Kharagpur	A process for the preparation of encapsulated metal nanoparticles	Process development	www.iitkgp.ac.in	
	IIT, Kharagpur	A process for the preparation of ZnOnanopowder	Process development	www.iitkgp.ac.in	
	IIT, Kharagpur	A Stable CrO2 Nanoparticles and a Process for its Manufacture	Process development	www.iitkgp.ac.in	Back
Raw materials	CSIR-NML	Separation of quartz and feldspar	Process development	NML Technology Handbook	
	CSIR-NML	Pellets from iron ore fines/slimes	Process development	NML Technology Handbook	

	CSIR-NML	Sintering of iron ore with high percentage of micro-fines	Process development	NML Technology Handbook	
	CSIR-NML	Briquetting of ore fines	Process development	NML Technology Handbook	
	CSIR-NML	Column floatation technology	Process development	NML Technology Handbook	
	CSIR-NML	Specific, selective & green reagent for the beneficiation of ores, minerals and coals	Process development	NML Technology Handbook	Back
Smart materials	NIL				Back
Super materials	NIL				Back
Others	CSIR-NML	Ferrite and Pigment grade high purity monodispersed Iron Oxide from waste Chloride Pickle Liquor and other iron rich sources	Recovery technology	NML Technology Handbook	
	CSIR-NML	Pellet-sinter composite agglomerate (PSCA) of iron oxide fines for use in blast furnace	Material development	NML Technology Handbook	

	CSIR-NML	Cold bonded carbon composite pellets for utillisation of iron ore micro-fines and carbon bearing fines	Material development	NML Technology Handbook
	CSIR-NML	Flux sintered through micro-pelletization	Process development	NML Technology Handbook
	CSIR-NML	Beneficiation of low-grade barite ores	Process development	NML Technology Handbook
	CSIR-NML	Beneficiation of low grade iron ores	Process development	NML Technology Handbook
	CSIR-NML	Beneficiation of Tungsten ores	Process development	NML Technology Handbook
	CSIR-NML	Clean coal from coking/non-coking coals/coal slurry	Process development	NML Technology Handbook
	CSIR-NML	Copper concentrate from copper ores	Process development	NML Technology Handbook
	CSIR-NML	De-ashing of high-ash thermal coal	Process development	NML Technology Handbook
	CSIR-NML	Phosphate concentrate	Process development	NML Technology Handbook
	CSIR-NML	Beneficiation of dumped low-grade iron ore fines for iron and steel making	Process development	NML Technology Handbook

	CSIR-NML	Ferrite and Pigment grade high purity monodispersed Iron Oxide from waste Chloride Pickle Liquor and other iron rich sources	Recovery technology	NML Technology Handbook
	IIT, Kharagpur	A process for the preparation of a Novel Polyurethan & its application as Membrane for Selective Separation of Organic Pollutants (Phenolic Compounds) from Aqueous Solutions by Pervaparation.	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A method of fused deposition with improved bonding strength through electro chemical discharges on a substrate	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A Polymeric flocculent and its process for manufacture	Process development	www.iitkgp.ac.in

	IIT, Kharagpur	A process for the preparation of a graft copolymer for use as a flocculation agent	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A process for the preparation of a Novel Polyurethan& its application as Membrane for Selective Separation of Organic Pollutants (Phenolic Compounds) from Aqueous Solutions by Pervaparation.	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A process for the preparation of fibrillised liquid crystalline polymer in a polyether etherketone	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A process for the preparation of graft Copolymers for use as a high performance flocclating agent	Process development	www.iitkgp.ac.in

	IIT, Kharagpur	A process on Modification of Mat Grass for Improvement performance	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A Simple Environment Friendly Process for Fabrication of Highly Porous Materials	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	A Starch Based Cationic Amylopectin	Material development	www.iitkgp.ac.in
	IIT, Kharagpur	Carboxymethyl Cellulose Acrylate for Enteric coating and Sustained Release	Material development	www.iitkgp.ac.in
	IIT, Kharagpur	Development of A Low Cost Equipment Spray - CVD for Deposition of Oxide Films	Equipment development	www.iitkgp.ac.in
	IIT, Kharagpur	Grafted amylopectin for use in sprinkler irrigation systems	Material development	www.iitkgp.ac.in

	IIT, Kharagpur	High performance flocculants based on hydrolysed and unhydrolysed guar gum-g-polyacrylamide	Material development	www.iitkgp.ac.in
	IIT, Kharagpur	High performance flocculating agents and viscosifiers based on hydrolysed grafted amylopectin and polycrylamide grafted carboxymethyl cellulose	Material development	www.iitkgp.ac.in
	IIT, Kharagpur	Polyamide Films and a process of preparing the same	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Process for the preparation of polysaccharide blended slow release urea	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Quick setting polymer composition	Process development	www.iitkgp.ac.in

	IIT, Kharagpur	Removal of p-chlorophenol and 2,4 dichlorophenol from water by pervaporation using polyurethane urea-PMMA IPN membrane	Process development	www.iitkgp.ac.in
	IIT, Kharagpur	Transparent Inorganic ZrO(OH)2.XH2O Polymer and a Process for Preparation of the Same	Process development	www.iitkgp.ac.in
	CSIR-NML	Beach sand heavy minerals	Process development	NML Technology Handbook

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