Report of

DeitY Innovation Council

On

Nanoelectronics

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Department of Electronics & Information Technology

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New Delhi - 110003

DeitY Innovation Council on Nanoelectronics

Department of Electronics and Information Technology, MCIT has formed a sectoral innovation council in order to promote innovation in the area of Nanoelectronics. The council consists of the following members:

1. Prof. V. Ramgopal Rao, Indian Institute of Technology Bombay, Mumbai. (Chairman)
2. Prof. Navakant Bhat, Indian Institute of Science, Bengaluru. (Member)
3. Dr. A.S. Rao, Director- Innovation, Centre for Innovation Incubation and Entrepreneurship(CIIE), Indian Institute of Management (IIM), Ahmedabad. (Member)
4. Shri P.S. Narotra, Scientist G, Industry Promotion Division, DeitY. (Member)
5. Dr. Praveer Asthana, Director, Nano Mission Council, Department of Science and Technology, New Delhi. (Member)
6. Prof. Bodh Raj Mehta, Physics Department, Indian Institute of Technology Delhi. (Member)
7. Rep. MSME, New Delhi. (Member)
8. Mr. Kapil Bardeja, Co-Founder, M/s NanoSniff Technologies Pvt. Ltd., Mumbai. (Member)
9. Dr. Kota Murali, Chief Scientist & Progamme Director, Nanotechnology, IBM India, Bengaluru. (Member)
10. Dr. Chandrasekhar Nair, Director, Bigtek Labs, II Floor, SID Entrepreneurship Center, Indian Institute of Science Campus, Bengaluru. (Member)
11. Shri T.K. Sarkar, Ex- Senior Director & GC (R&D in Electronics), DeitY, MCIT, GOI (Member)
12. Dr. G. V. Ramaraju, Group Coordinator, R&D in IT, DeitY, MCIT, GOI
13. Mr. Ramesh Chand, DeitY, MCIT, GOI. (Convener)

The Council deliberated on various issues related to the Nanoelectronics innovation. The following points and recommendations emerged out of these deliberations for furthering the innovation activities in the country in the core area of Nanoelectronics.

Scope & Definition

For the purpose of innovation, following the IEEE Electron Devices Society definition, Micro/Nano-electronics is defined in the following way:

“Micro/Nano-electronics is the field of interest which encompasses all aspects of engineering, physics, theory, experiment and simulation of electron and ion devices involving insulators, metals, organic materials, plasmas, semiconductors, quantum-effect materials, vacuum, and emerging materials. Specific applications of these devices include bioelectronics, biomedical, computation, communications, displays, electro and micro mechanics, imaging, micro actuators, optical, photovoltaics, power, sensors and signal processing."

The scope of the Nanoelectronics Innovation Council therefore includes the entire electronics systems hardware infrastructure enabled by Nanoelectronics technology. In addition to the above definition, the focus is also on integrated circuit chips, packaging and electronics systems. This will facilitate the entire electronics hardware ecosystem to prosper in the country which would create a significant impact on the society.

Background

In the last seven decades, electronics has been at the forefront of enabling the economic growth of developed economies such as USA, Europe, Japan and Korea. According to a European Commission study, the growth rate of the electronic industry is twice as fast as the world GDP. Today, the electronics industry is the largest and the fastest growing manufacturing industry representing a market of $7 trillion in 2009. Through miniaturisation, microelectronics created “intelligent chips”, and the impact of this industry cut across the entire industrial ecosystem. As an example, about 50% of the cost of an automobile today is in electronics and this will continue to increase as the automobiles become more “intelligent”. Electronics hardware has in general created platforms for inclusive growth, by providing opportunities to access knowledge and information. For example revolution in mobile phones technology led to communication access to the remote parts of the country while the photovoltaics modules have helped provide lighting to remote corners of the country where the grid would not reach. Hence it is very important that we strive for self reliance in this important and crucial technology segment. Nanoelectronics, as distinct from the underlying fundamental nanoscience and the broader but fuzzy nanotechnology, is specifically targeted to the use of small-dimension devices for electronics applications. Besides their obvious but important use in integrated circuit chips, these devices have many other applications in sensors, photonics, lighting and photovoltaics.

Nanoelectronics is also a highly multi-disciplinary and a specialized area. As the demand for electronic products grows, there is a continuous need for development of cheaper, power efficient, high performance, and innovative products. As the Complementary -Metal-Oxide-Semiconductor (CMOS) scaling powered by the Moore's Law fuelled the growth of Micro/Nano-electronics for the past 4 decades or so, the continued scaling of the transistors has given rise to a host of issues which is currently affecting the growth of this sector. The solution to the CMOS scaling problem calls for a holistic solution in terms of novel device structures, processes, new materials, novel ways of integration, innovations at the circuit and system level and finally the packaging. Also, using silicon CMOS technologies the products still become restrictive in terms of their usability. For example, there is a crying need for innovation to realize electronics and displays that are foldable/flexible, integration of the sensor technologies alongside the CMOS dies (More than Moore Era), and ultra low voltage/low power operation. Innovative product design fuels demand, as shown by iphone/ipad kind of applications. The nanoelectronics companies that innovate in terms of their products (such as Apple) and technologies (such as Intel) tend to drive the development of future growth opportunities.

India can play a major role in fuelling the Nanoelectronics growth, if we can focus on 'frugal innovation' involving the Nanoelectronics technologies/platforms, and produce products and services that are affordable by more people at low levels of income, without a compromise on the quality. The innovation paradigm however needs to focus on inclusive innovation for the people at the bottom of pyramid. The mantra for Nanoelectronics innovation in India therefore needs to be based on the concept of "high technologies at affordable costs addressing the societal needs".

Proposed Application Areas

India took a major initiative in the 11th Plan to start and strengthen many activities in nanoelectronics, including creation and support of several Centres of Excellence in Nanoelectronics and a nation wide Indian Nanoelectronics Users' Programme. This should be scaled up multi-fold through the innovation council, with emphasis on nanoelectronics to cater to India's expanding requirements in consumer, societal, security, strategic, energy and agricultural areas, and thereby gain technology leadership and economic maturity with more than 10% GDP growth target.

Some of the application areas where the Nanoelectronics innovation can have a significant impact are:

1. ***Societal Electronics:*** There are many new applications of low-cost nanoelectronics which can transform Indian society, including smart cards (UID), low cost medical diagnostic devices, pathogen sensors, water purification, environmental sensors, sensors for agriculture and distance education through smarter phones. One needs to realize that, more than half of

India's population is under the age of 25, and one million people a month are expected to join the labour force over the next decade. Therefore we need to develop technologies that help youth excel & acquire skills, which is a pressing need in the country. It could be low cost tablets, training material, distance education tools, IT, or learning aids.

2. ***Rural Electronics***: India's massive agricultural sector employs about 60% of the population, yet accounts for only about 17% of total GDP. We need to use innovation/technology as a vehicle to improve productivity in our agricultural sector. It could be by way of sensor networks for agricultural applications or assisting the farmer with low cost easy to use sensor technologies for soil health monitoring. Food security is emerging as the foremost consideration for the inclusive growth of India. The needs in this sector are very specific to our environment and circumstances and the solution should emerge indigenously. Applications of Nanoelectronics in Agriculture is a completely unexplored territory worldwide. An example application is soil health monitoring sensor network which would have a real time sensing and remedial action to assess soil moisture, micronutrients etc. There are several potential applications in enhancing the growth and productivity of this sector.

3. ***Medical Electronics:*** Healthcare is a major concern in India and rural health infrastructure is hardly existent. For example, 14 million persons are infected with TB in India and more than 300,000 deaths occur every year; about 2 million cases of malaria are recorded every year, by 2015 close to 5 million infected with AIDS; 17.1 million lives are claimed by cardiovascular diseases, with 82% of deaths occurring in low- and middle-income countries like India. India is home to about 40 Million diabetic patients. Add to this: 42% Indians live on $1.25 per day & 22 Million population pushed below poverty line annually due to healthcare expenditure. We need low cost medical diagnostic technologies, medical equipment, point-of-care systems to address these pressing needs.

4. ***Consumer Electronics:*** The large and growing Indian markets in telecom, computers, automobiles and entertainment make it possible to envisage nanoelectronics fabrication in India at the large scales required. The presence of such a sector will also provide the capability of chip fabrication for strategic applications.

5. ***Strategic Electronics:*** Security is such a major concern in India. There are hardly any technologies that can prevent recurrence of terrorist attacks, the type that happened in the recent past. The technologies that are protecting our airports are vastly inadequate. Vapour phase or stand-off detection of explosives, sensor networks for explosive detection covering the vital installations, protection of transport systems, detection of chemical warfare agents are all problems that are currently looking for a solution. Nanoelectronics can play a vital

role in providing a solution to these problems. Besides explosive detection, there are important requirements for IR detectors and imaging, high-speed and high-power electronics, and lasers, all of which are critical in defence, space and homeland security applications. *In addition, strategic requirements often mandate that chip fabrication be in a secure domestic foundry*.

6. ***Energy Electronics:*** Compound semiconductors offer solutions for high speed electronics, semiconductor lighting, optoelectronics etc. where silicon based solutions are inadequate or not available. Energy is an area where innovation can create a profitable playing field in the solar PV marketplace. India is a fertile testing ground for many of these technologies and offers huge markets, if there are cost effective solutions. This could be by way of developing the new nano-based photovoltaic cells that will be critical for the National Solar Mission, or through the widespread use of smart energy meters, and efficient lighting, including white light emitting diodes and organic LEDs.

Approach and Strategies

All the above application areas will receive significant support from a co-ordinated development of nanoelectronics. This development should focus on several related aspects:

(1) Research and manpower training Infrastructure: The state of the art research facilities should be created and sustained in major educational research institutes with a large manpower training target (for example, producing 500 PhDs per year in the Nanoelectronics area should be a goal to gain worldwide leadership in this area). The lessons learnt from the two state-of-the-art centres at IISc Bangalore and IIT Bombay can be leveraged and another 10 institutes can be identified to facilitate such centres. Each of these resource centres can create a network of users (similar to the Indian Nanoelectronics Users Program) and aim for massive human resource training and research program in this area.

(2) Industrial silicon foundry Infrastructure: We still depend on foundries abroad to get any state of the art chip manufactured. This is big lacuna in self reliance. (Even China has launched a focussed program in this area with a massive US$10 Billion funding support in the last 10 years: http://www.theregister.co.uk/2011/02/25/ict_godson_3b_chip/) We need to have focussed efforts in creating cutting edge silicon technology foundries in the country, possibly collaborating with established industrial players in this field. These foundries should necessarily be targeted towards commercial production. This is already happening to a small extent in silicon photovoltaics area. This should be further strengthened and expanded to create the foundries for IC chip manufacturing, LEDs, flat panel displays etc. The highly trained manpower coming out of afore-mentioned research infrastructure will also be able to run such facilities.

(3) Innovation and Incubation Infrastructure: One of the biggest enablers in nanoelectronics technology is to enable and incubate innovative companies. Most of the revolutionary developments in the last couple of decades, worldwide, have happened because of agile start up companies. Although USA has established technology leadership in the last couple of decades, the US government actively provides financial and other support to incubate new companies under SBIR program (http://www.sbir.gov/). Similar initiatives are run in several other developed countries. We can learn from such initiatives and evolve a similar program in large scale. This would be efficiently utilized by highly trained manpower in this area, and also the research outputs produced in the aforementioned R&D centres can be taken to their logical conclusion to create a societal impact. Lack of government funds for start-ups and absence of the eco-system for venture capital funding is currently hampering the growth of start-up culture in India, which needs to be addressed immediately.

(4) Policy Changes for Encouraging Entrepreneurship: Government policies in terms of Intellectual Property rights are also not conducive for start-up growth in the country. For example, with many government agencies, the funding agency holds the rights to all the intellectual property generated out of a government funded project, which is a major deterrent for starting of new companies.

Action Items

(1) Create advanced research and development centers in nanoelectronics such as the Centres of Excellence in Nanoelectronics (CENs) at IITB and IISc with basic common facilities and advanced complementary facilities. The common infrastructure can be jointly funded through public-private partnerships, which can be opened to users/industries through pay per use program. The facilities that need to be further developed should cover areas like device design, process technologies, computational, packaging, testing, and characterization technologies. The innovation in Nanoelectronics would require technology platforms that can only be developed in sophisticated facilities and through advanced training. The grass root level of innovation in Nanoelectronics would utilize these platform technologies developed in the CENs and then focus on the applications.

(2) Fund projects that align with the semiconductor fab and related areas with tangible objectives that include government/academia/industry partnership.

(3) Fund projects in areas of national interest to academia and industry on development of advanced devices & systems. The projects must have a system level focus with product as a deliverable addressing the need in a particular sector. Project funding should be for tangible goals and aligned with commercialization in identified areas.

(4) The projects focussed under the Nanoelectronics innovation council must have a comprehensive policy for their final deployment. Therefore, the inputs of concerned ministries/industry are of utmost relevance.

(5) Set up computational nanoelectronics infrastructure for accelerating innovation and manufacturing in all the above areas. As the costs and time associated with innovation and manufacturing at the nanoscale is increasing, computational technologies should go hand in hand with experimental technologies to reduce the costs and time associated with nanoelectronics innovation and manufacturing.

(6) Incubation: The innovation council needs to promote commercialization of nanoelectronics innovation related to Electronic System Design & Manufacturing (ESDM) technologies that are of national and societal benefit. There must be a provision for loans/funding to start ups, small and medium scale industries for developing commercial products. There must be regional level innovation centres that seek application related ideas and match them with the technology platforms developed in the Centres of Excellence in Nanoelectronics (CEN). The proposed regional incubation centres must scout for IP developed in academic institutions and package the IP in a way that will generate interest in the industries. One may look at Small Business Innovation Research (SBIR), US (http://www.sbir.gov/) kind of a model for funding small scale industries/start-ups and Industrial Technology Research Institute (ITRI), Taiwan (http://www.itri.org.tw/eng/) kind of a model for setting up a business incubator. All the CENs in the country must be encouraged to set up business incubators and must be judged based on the number of technology start-ups they help incubate. Establish IP creation and licensing cells within the CENs to take forward ideas generated through nanoelectronics innovation council funding. The IP cell needs to be on a constant look out for opportunities to promote commercialization of innovation coming out of the council funding. Government policies also need to be simplified in order to encourage individual innovators to incubate companies. Risk free funding in the form of grants, non collateral unsecured loans need to be given to deserving start-ups, with higher grant limits than presently available (50 Lakhs), in phases. To create excitement in this line and develop CAN DO feel, there is also a need to support few short duration (6 to 12 months) industry oriented projects on priority. Those projects aim to take existing R&D results to the market. The focus will be on prototyping with `fast to market' strategy.

(7) Establish awards for innovators funded through the innovation council for promoting the culture of innovation in nanoelectronics.

(8) Human Resource Development: Introduce modern courses in nanoelectronics as a part of EE, physics, materials sciences, and chemistry in universities. We also need to incentivise faculty achievements through salary top-ups, fellowships, travel grants for one/two international conferences every year and encourage funding for exchange programs for joint work with Government/industry/university research centers.

(9) Introduce field trips for Ph.D students to expose them to the local needs. Since the problems will be defined top-down in this programme, it will help students formulate the problem through interactions with the end users, which must be done from the very beginning. For example, if a student is taking up a project related to agricultural sensors, he/she must spend sufficient time with the farmers understanding the field requirements/needs. Students who join the innovation programs must get higher stipends through joint government/industry funding, travel grants for one/two international conferences and field trips every year, exchange program funding for joint work with Government/Industry/Academia.

(10) One of the key ingredients missing in the incubation scenario in India is availability of sufficient competent technical resources (Masters, Ph.Ds) in nanoelectronics areas who are willing to take up the start-up route. Any exposure to start-up culture during their educational tenure would help ignite some fire in them. As part of the curriculum, introducing an industry summer training module may be useful, wherein the students will get an opportunity to work in a start-up company aligned with their research areas, in India or abroad for 3-6 months. This will help them in confidence building to take up the challenges as an entrepreneur and give them some exposure to the start-up culture.

(11) Joint funding for collaborations with industry. Nanoelectronics area requires sophisticated approach to realization of a product from basic science to system level. This requires collaboration between academia and industry without which it is difficult to realize field deployable systems. Funding should be made available for advanced R&D for both academia and industry to work together to take concept to a real product.

(12) Academic-industry research interface: It is important to have a strong interface between academic institutes and industry to carry forward the academic research output to the next level of technology and device development. This important step of S&T transition requires expertise normally not available with academic departments and research institutes. In a number of universities it has been observed that the presence of technology development manager in different departments and close interaction with Ph.D students and researchers help in enhancing the technology transition. Similar experiment at Univ of Twente, Netherlands has been quite successful. It is proposed that trained technology development manpower should be appointed in the major research centers funded by DeitY.

(13) Workshops and conferences need to be conducted at regular intervals to create awareness for nanoelectronics research, societal requirements, product development and manufacturing.

(14) Learning from best practices: DeitY may identify the international best practices in the R&D innovation and incubation specially in the area of Nanoelectronics and suitably adopt the same for the Indian conditions.

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