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RECENT TRENDS IN NANOTECHNOLOGY: NANOELECTRONICS APPLICATIONS AND DEVELOPEMENT

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Abstract: In this paper we have studied the recent trends in nanotechnology, especially applications and development in nano-electronics. Here we have also studied the difficulties and opportunities for nano-technology. This study will help to build an understanding of basic concepts behind some of the latest nanoelectronics research.

Keywords: Nanotechnology, Electronics, Nanoelectronics developments.

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INTRODUCTION

Nanotechnology is the study, design, creation, synthesis, manipulation, and application of functional materials, devices, and systems through control of matter at the nanometer scale (1–100 nanometers, one nanometer being equal to 1×10^{-9} of a meter), that is, at the atomic and molecular levels, and the exploitation of novel phenomena and properties of matter at that scale. The origins of nanotechnology go back to 1959, when Richard Feynmann, winner of the Nobel Prize for Physics, addressed the American Physical Society in a lecture entitled "There's Plenty of Room at the Bottom". In his lecture, he examined the possible benefits for society of being able to catch atoms and molecules and put them down in given positions, and to manufacture artifacts with a precision of a few atoms. Nanotechnology research and development is directed towards understanding and creating improved materials, devices and systems that exploit these properties as they are discovered and characterized.

2. Nanoelectronics Applications and Development:

The electronics industry has long been immersed in a process of miniaturization. Moore's Law, formulated in 1965, states that the number of transistors in the average computer will increase approximately twofold every 18 months. The law still holds today, but the limit of silicon-based technologies is over. In this miniature world, the laws of quantum physics become more and more relevant. Quantum physics says that the way electrons operate is based on probabilities. The nanotechnology is still at an early stage, nanoelectronics is still piggy-backing on its immediate predecessor: microelectronics.

Nanoelectronics is defined as the research, manufacture, characterisation and application of functioning electron devices of less than 100 nanometres in size. This would make it possible to use quantum properties, which, once controlled, could offer benefits such an increase in processing speed and storage capacity and a considerable reduction in the size of any technological component or equipment. It is generally believed that any development involving multiple applications could spark a new industrial revolution. Processing time and the size of devices will be considerably reduced, and there will be an increase in the power of computers and transistors for use in microprocessor-controlled telephones, cars, domestic appliances and industrial machinery.

2.1. Nanoelectronics Applications:

Nanoelectronics is currently in the process of entering our society, even if we are not always aware of the everyday devices in which we are using it. The following are a number of developed technologies which illustrate the current status of nanoelectronics.

Brighter, lighter, more energy-saving screens: OLED (Organic Light-Emitting Diode) technology, is already available on the market, allowing brighter images, in lighter devices, with lower energy consumption and wider angles of vision. It is used in screens for laptop computers, cinemas, mobile phones, automobile dashboards, GPS systems and digital cameras.

Direct Methanol Fuel Cell: Recently, Toshiba (2005) presented two revolutionary models of MP3 player, capable of operating without batteries, by using nanoscale fuel cells. This new technology, called DMFC (Direct Methanol Fuel Cell) is also used in mobile phones and laptop computers.

Faster Computer Chips: IBM in 2002 announced the creation of carbon nanotube transistors that outperform even the best prototype transistors available. Transistors are the elements from which computer chips are built. The new technology eliminates the problem of the excessive heat today's chips generate when they operate above a certain speed; It also gives higher speeds as the data has to travel very short.

Memory cards the size of a postage stamp with the capacity of 1 Tb: The scientists of IBM managed to create a system with a storage density of one terabit (a trillion bits) per square inch.

Communications Devices: Nanoscale mobile phones are now being developed. The *nanophones* consist of radio transmitters less than the diameter of a human hair in size. Because the radio frequency amplifiers now being used in mobile phones are hot tungsten filaments with an efficiency of only 10%, researchers are looking to replace them with high efficiency carbon nanotubes, which would consume less energy. **Communication Networks:** The data through the internet can be processed incredibly faster by means of a silicon chip that efficiently controls the beam of light carrying the information. The light, through the optic fibres, has proved to be the best alternative to transmit huge amounts of information at a great speed.

Quantum Computing: Today's electronics codes computer data using a binary system of ones and zeros, depending on whether an electron is present or not. In principle, however, the rotation of an electron (in one direction or another) could also be used as information. This means that spintronics could enable computers to store and transfer twice the amount of data per electron. This technology is closely related to quantum computing; scientists are researching the possibility of using the electron spin for future quantum computers, in which this rotation would act as a *qubit* or *quantum bit.* This will be the new generation of computers known as "quantum computers".

2.2. Nanoelectronics Development:

The nanomaterials are characterized, not just by structure size, but also by the degree to which they are "engineered" for specific combinations of properties. Recently, nanomaterial for potential electronic applications is graphene, the subject of the 2010 Nobel Prize in Physics. Graphene is a single atomic layer of graphite (an allotrope of carbon), in various shapes and orientations. Graphene has amazing properties, in part, stemming from a band structure that exhibits linear, rather than the usual quadratic, dependence of energy on momentum. Its potential uses include ultracapacitors [Stoller et al.,2008], transparent conductive electrodes for PV (replacement for expensive indium tin oxide) [Wilson,2010 and Bae et al.,2010], various forms of transistors, and many more. Although cost reduction would be the major benefit of using a nanomaterial in some cases, enhancement of material properties is generally the primary objective. Another electronics-industry example of the latter is improving the electrical and thermal conductivity of bonding materials, such as in packaging applications [Wakuda et al., 2010].

In 2003, the Semiconductor Industry Association (SIA) formed a Nanoelectronics Working Group, which recommended that industry and government partner to sponsor increased university research in nanodevices nanomanufacturing that would allow the industry to dramatically depart from the increasing capital and operating cost trends. These recommendations were presented both to the President's Council of Advisors on Science and Technology (in 2003) [Doering,2003] and to the SIA Board of Directors. In March of 2005, six of the SIA member companies, AMD, Freescale, IBM, Intel, Micron, and Texas Instruments, responded by forming the Nanoelectronics Research Initiative (NRI), a consortium activity that funds university research as a part of the Semiconductor Research Corporation (SRC). In 2010, the corporate members of NRI are AMD/Global Foundries, IBM, Intel, Micron, and Texas Instruments. NRI is also currently supported by the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and several state and local governments. Thus far, the NRI research has identified quite a few possible approaches to "beyond CMOS" devices, which are currently at various stages of theoretical and experimental evaluation. A first pass has also been made at estimating their performance against a consensus "ultimate CMOS," which is currently equated to what is popularly called "the 15nm technology node." Details of this initial comparison have been submitted for publication [Bernstein et al., 2010]. The biggest challenge in replacing the basic field-effect transistor (FET) as a switch is that it is already extremely good and further scalable! As long as its materials properties can be improved and the manufacturing technology/cost is up to the feature-scaling task, the conventional FET theoretically approaches performance and energy efficiency close to physical limits imposed by the uncertainty principal, equilibrium thermodynamics, and electrodynamics, at least for devices based on individual charged-particle (e.g., electron) behaviour.

The history of studying these limits goes back to Von Neumann and was well summarized by Meindl a decade ago [Meindl et al., 2001]. This recognition has prompted much of the early NRI research to focus on information state variables that are alternative to "the amount of electrical charge on FET gates" employed by CMOS logic. It has also encouraged some study of non-equilibrium operation and "thermal-phonon engineering." Despite the just-mentioned excellence of scaled/materials-enhanced FETs, NRI research indicates that several forms of tunnel FETs (TFETs) may use less power at a given speed. An enabler for such TFETs could be graphene-nanoribbon channels [Zhang et al., 2008]. In fact, many of the currently-studied NRI switches are based on using graphene in some part of the nanostructure. Thus, it’s possible that "carbon nanoelectronics" may at least augment silicon CMOS at some point in the future. Of course, we are a long-way from volume manufacturing of integrated circuits with graphene. However, NRI process/materials research has already produced a promising breakthrough in CVD of large-area graphene layers [Li et al., 2009], which could have many uses, including the manufacturing of TFETs and more-exotic devices, as well as the previously-mentioned transparent electrode application. Another graphene-based switch being studied in NRI is the Veselago device [Cheianov et al., 2007], which is designed to manipulate electron wave functions as if they were electromagnetic waves (i.e., analogously to optics). Such devices take advantage of the focusing properties of p-n junctions in graphene and have been estimated to have the potential for very high speed. Note that the devices previously discussed all still use "quantity of electric charge" as the logic state variable. Of course, in hard-disk and some other memories, atomic-spin orientation has long been used to represent information. So far, commercial spin-based memories have all employed spin in the form of magnetic domain orientation. NRI research has shown that magnetic states can also be used to perform "nanomagnet logic" (NML) [Alam et al., 2010]. Like most of the NRI spin-based devices studied thus far, NML seems to fit best with applications requiring very low power at modest speed. NRI also conducts research on devices based on electron-spin transport [Behin-Aein et al., 2010].

3. Challenges and Approach to Nanotechnology:

i) Producing the nanomaterials in large enough volumes, with consistent quality, at acceptable costs.

ii) Supplying the nanomaterials in a form (such as proper particle size, surface chemistry, dispersion capability, compatibility with various media, etc.) that would allow integration into the process.

iii) Engineering and customizing the nano-based system to local requirements.

iv) Addressing environmental, health and safety concerns in the use and disposal of nano products.

v) The gap between basic research and application is another challenge in nanotechnology, like several other technologies. There are poor labs with lack of skilled manpower that could provide linkages between the technology and commercial domains.

vi) One of the main challenges is terms of the interdisciplinary nature of nanotechnology and the scope of its applications, which lead to significant overlaps in the areas for R&D support identified by different agencies.

vii)To make a balanced approach between technology development and addressing risk issues we have to argue that research related to toxicity and risk assessment must be undertaken once the applicability of specific nano-applications are ascertained, especially when the prototype of the product has been developed and is available for field testing.

viii)The main challenges faced by regulatory institutions currently relate to the regulatory capacity, information asymmetry and absence of interagency coordination.

4. Conclusion:

In this paper we have studied the recent trends in nanotechnology, especially applications and development in nanoelectronics. Here we have also studied the difficulties and opportunities for nanotechnology. This study will help to build an understanding of nanotechnological research. We can conclude that there is a good future for nanotechnology**.**

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