Nanoelectronics

Abstract: Nanoelectronics refer to the use of nanotechnology on electronic components, especially transistors. Although the term nanotechnology is generally defined as utilizingtechnologyless than 100nm in size, nanoelectronics often refer to transistor devices that are so small that inter-atomic interactions and quantum mechanical properties need to be studied extensively. As a result, present transistors (such as CMOS90 from TSMC or Pentium 4 Processors from Intel) do not fall under this category, even though these devices are manufactured under 90nm or 65nm technology.

This paper is all about the use of nanotechnology in electronics The aim of Nanoelectronics is to process, transmit and store information by taking advantage of properties of matter that are distinctly different from macroscopic properties. The relevant length scale depends on the phenomena investigated: it is a few nm for molecules that act like transistors or memory devices, can be 999 nm for quantum dot where the spin of the electron is being used to process information.

Microelectronics, even if the gate size of the transistor is 50 nm, is not an implementation of nanoelectronics, as no new qualitative physical property related to reduction in size are being exploited. Introduction: Nanoelectronics: fig no: 1 nanoelectronics Nanoelectronics are sometimes considered as disruptive technology because present candidates are significantly different from traditional transistors. Some of these candidates include: hybrid molecular/semiconductor electronics, one dimensional nanotubes/nanowires, or advanced molecular electronics.

The sub-voltage and deep-sub-voltage nanoelectronics are specific and important fields of R&D, and the appearance of new ICs operating near theoretical limit (fundamental, technological, design methodological, architectural, algorithmic) on energy consumption per 1 bit processing is inevitably. The important case of fundamental ultimate limit for logic operation is the reversible computing. Although all of these hold immense promises for the future, they are still under development and will most likely not be used for manufacturing any time soon. This is the future f nanotechnology. What is Nanoelectronics? Semiconductor electronics have seen a sustained exponential decrease in size and cost and a similar increase in performance and level of integration over the last thirty years (known as Moore's Law). The Silicon Roadmap is laid out for the next ten years. After that, either economical or physical barriers will pose a huge challenge. The former is related to the difficulty of making a profit in view of the exorbitant costs of building the necessary manufacturing capabilities if present day technologies are extrapolated.

The latter is a direct consequence of the shrinking device size, leading to physical phenomena impeding the operation of current devices. Quantum and coherence effects, high electric fields creating avalanche dielectric breakdowns, heat dissipation problems in closely packed structures as well as the non-uniformity of dopant atoms and the relevance of single atom defects are all roadblocks along the current road of miniaturization. These phenomena are characteristic for structures a few nanometers in size and, instead of being viewed as an obstacle to future progress might form the basis of post-silicon information processing technologies.

It is even far from clear that electrons will be the method of choice for signal processing or computation in the long term - quantum computing, spin electronics, optics or even computing based on (nano-) mechanics are actively being discussed. Nanoelectronics thus needs to be understood as a general field of research aimed at developing an understanding of the phenomena characteristic of nanometer sized objects with the aim of exploiting them for information processing purposes.

Specifically, by electronics we mean the handling of complicated electrical wave forms for communicating information (as in cellular phones), probing (as in radar) and data processing (as in computers). Concepts at the fundamental research level are being persued world-wide to find nano-solutions to these three characteristic applications of electronics. One can group these concepts into three main categories: 1. Molecular electronics Electronic effects (e. g. electrical conductance of C60) Synthesis (DNA computing as a buzz word) 2. Quantum Electronics, Spintronics (e. g. quantum dots, magnetic effects) 3.

Quantum computing Currently the most active field of research is the fabrication and characterization of individual components that could replace the macroscopic silicon components with nanoscale systems. Examples are molecular diodes , single atom switches or the increasingly better control and understanding of the transport of electrons in quantum dot structures. A second field with substantial activity is the investigation of potential interconnects. Here, mostly carbon nanotubes and self-assembled metallic or organic structures are being investigated. Very little work is being performed on architecture.

Furthermore, modeling with predictive power is in a very juvenile stage of development. This understanding is necessary to develop engineering rules of thumb to design complex systems. One needs to appreciate that currently the best calculations of the conductance of a simple molecule such as C60 are off by a factor of more than 30. This has to do with the difficult to model, but non-trivial influence of the electronic contact leads. The situation in quantum computing is somewhat different. The main activities are on theoretical development of core concepts and algorithms.

Experimental implementations are only starting. An exception is the field of cryptography (information transportation), where entangled photon states propagating in a conventional optical fiber have been demonstrated experimentally. Approaches to nanoelectronics: Nanofabrication: For example, single electron transistors, which involve transistor operation based on a single electron. Nanoelectromechanical systems also falls under this category. Nanofabrication can be used to construct ultradense parallel arrays of nanowires, as an alternative to synthesizing nanowires individually. Nanomaterials electronics:

Besides being small and allowing more transistors to be packed into a single chip, the uniform and symmetrical structure of nanotubes allows a higher electron mobility (faster electron movement in the material), a higher dielectric constant (faster frequency), and a symmetrical electron/hole characteristic. Also, nanoparticles can be used as quantum dots. Molecular electronics: Single molecule devices are another possibility. These schemes would make heavy use of molecular self-assembly, designing the device components to construct a larger structure or even a complete system on their own.

This can be very useful for reconfigurable computing, and may even completely replace present FPGA technology. Molecular electronics is a new technology which is still in its infancy, but also brings hope for truly atomic scale electronic systems in the future. This is one of many possible ways in which a molecular level diode / transistor might be synthesized by organic chemistry. A model system was proposed with a spiro carbon structure giving a molecular diode about half a nanometer across which could be connected by polythiophene molecular wires.

Theoretical calculations showed the design to be sound in principle and there is still hope that such a system can be made to work. Other approaches: Nanoionics studies the transport of ions rather than electrons in nanoscale systems. Nanophotonics studies the behavior of light on the nanoscale, and has the goal of developing devices that take advantage of this behavior. Nanoelectronic devices: Radios: Nanoradios have been developed structured around carbon nanotubes. Computers: Nanoelectronics holds the promise of making computer processors more powerful than are possible with conventional semiconductor fabrication techniques.

A number of approaches are currently being researched, including new forms of nanolithography, as well as the use of nanomaterials such as nanowires or small molecules in place of traditional CMOS components. Field effect transistors have been made using both semiconducting carbon nanotubes and with heterostructured semiconductor nanowires. Energy production:

Research is ongoing to use nanowires and other nanostructured materials with the hope of to create cheaper and more efficient solar cells than are possible with conventional planar silicon solar cells.

It is believed that the invention of more efficient solar energy would have a great effect on satisfying global energy needs. There is also research into energy production for devices that would operate in vivo, called bio-nano generators. Medical diagnostics: There is great interest in constructing nanoelectronic devices that could detect the concentrations of biomolecules in real time for use as medical diagnostics, thus falling into the category of nanomedicine. A parallel line of research seeks to create nanoelectronic devices which could interact with single cells for use in basic biological research.

These devcies are called nanosensors. What needs to be done ? First, nanoelctronics is a wide open field with vast potential for breakthroughs coming from fundamental research. Some of the major issues that need to be addressed are the following: 1. Understand nanoscale transport! (closed loop between theory and experiment necessary). Most experiments and modeling concentrate on DC properties, AC properties at THz frequencies are however expected to be relevant. 2. Develop/understand self-assembly techniques to do conventional things cheaper.

This has the future potential to displace a large fraction of conventional semiconductor applications. One needs to solve the interconnect problem and find a replacement of the transistor. If this can be done by self-assembly, a major cost advantage compared to conventional silicon technology would result. 3. Find new ways of doing electronics and find ways of implementing them (e. g. quantum computing; electronics modeled after living systems; hybrid Si-biological systems; cellular automata). Do not try and duplicate a transistor, but instead investigate new electronics paradigms!

Do research as a graduate student in this field and lay the foundation for the Intel of the New Millenium. Objective: The last few decades has seen an exponential growth in microchip capabilities due primarily to a decrease in the minimum feature sizes. The resulting doubling of processor speed every 18 months (known as Moores Law) is, however, expected to break down for conventional microelectronics in about 15 years for both fundamental and economic reasons . The search is on, therefore, for new properties, paradigms and architectures to create a novel nanoelectronics. Conculsion:

Finally, there is a third direction in nanoelectronics which will receive more attention in the future. This new field is called " spintronics". Spintronics is concerned with electromagnetic effects in nanostructures and molecules caused by the quantized angular momentum (the spin) that is asscociated with all fundamental particles like, for example, the electron. The magnetic moment of a particle is directly proportional to its spin. Hence, if we learn to manipulate not only charge, but also spin on a single electron level, information may be stored and transported in the form of quantized units of magnetism in the future.

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