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Extended Abstract

The Future of Nano-electronics- A Critical Analysis- D S Grewal Emeritus, Eternal University, Baru Sahib, Himachal Pradesh

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Abstract

Nanotechnology is now well embedded in scientific minds and societal needs. Its branch, nanoelectonics, has been leading and developing 'more than Moore's' predictions. The nano-mateial like CNTs, nanowires, quantum dots, graphene and xene, have led towards fabrication and manufacturing smarter, stronger, miniaturized, reliable quality products which are not only cheap and consume less energy but also occupy least space. Stretchable, wearable, flexible nano-products have increased their portability and security, giving a new meanings to the requirement of development of nanoelecronics. Graphene, an allotrope of carbon, is likely to become a dominant material in flexible electronics in future. Because of its superb electrical conductivity, flexibility and physical strength it will replace other carbon products in the Nano field. Nano-marketing is now over $1 trillion globally and the major countries of the world are alive to its developmental needs.

Since the development of nanotechnology needs huge funds beyond the capability of an individual research or institution there is an urgent need of setting up centrally funded, well equipped nano-laboratories spread all over making them approachable to all researcher with least cost to make it a marketable product. The major corporate houses must rise and assist nano-research and to introduce nanoproducts on their production lines to take the advantage of trillion dollar global market in nanomaterial and products. Nanotechnology and specially the nanoelectronics can build any country's future if the research and manufacturing are encouraged by their governments and research planners. The future of mobile electronics lies in stretchable or flexible electronics. The potential applications may include wearable electronic devices, biomedical uses, compact portable devices and robotic devices.

The first discussion of molecular nanoelectronics was the proposal by Aviram and Ratner in 1974 to produce a rectifier from organic molecules. The first example of a single molecular electronic device did not appear until 1990, the major problem relating to the difficulty of making individual electrical contacts to molecules which may only be a few nm in size.

The development of the scanning tunneling microscope (STM) basically enabled the first measurements in this field to be started and has remained one of the major tools in electrically characterising single molecules.Some of The first demonstrations of electronic properties of single molecules by Purdue University included Coulomb blockade and Coulomb staircase when a STM tip measured the conduction through gold nanoparticles self-assembled with SAMs.

A second set of experiments at IBM, Zurich, demonstrated a STM tip deforming a C60 bucky ball. The resulting mechanical deformation modifies the resonance tunneling bands of the molecule and produces electromechanical amplification. Hitachi demonstrated a molecular abacus where a STM tip was used to move 0.25 nm high C60 molecules along monoatomic steps and then counted by imaging with the STM tip. While all these devices demonstrate functionality that may be used in circuits, the scaling to the level of present CMOS circuits would be impossible.Another approach to molecular electronics is the use of organic molecules. A collaboration between Yale and South Carolina Universities demonstrated the conduction through a benzene molecule attached to two gold electrodes using thiol groups to bind the molecule to the gold. Benezene rings have delocalized Π-electrons out of the plane of the molecule through which electrons can be transported when an appropriate bias is applied across the molecule. Carbon–carbon double and triple bonds provide similar orbitals out of the plane and therefore combinations of these polyphenylene molecules create conducting wires now known as Tour wires. The low temperature properties of some of the RTD designs demonstrate PVCRs of over 1000 at low temperatures while the room temperature properties require improvement before they can be used in circuits.

Work at the Mitre Corporation has investigated possible architectures using organic molecules. A number of designs have been proposed based on diode logic using the Tour wires and diodes. AND, OR, and XOR gate designs are given along with an adder. The major problem with such organic systems is that the conductivity is relatively poor through the interconnecting Tour wires.

The major limitation is the conductivity, and unless better conductors or architectures for which the performance does

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not depend on resistance can be found, the organic systems will always be much slower than silicon.Carbon nanotubes have also been used to conduct electrons and demonstrate reasonable conductivities for their size. A large number of groups have published results in the field. Both single and multiple walled tubes can be created that may potentially reduce resistance. Conductivities as high as 2000 Sm−1 that corresponds to a resistance per millimeter of 200 Ω have been measured, substantially better than organic polyphenylene molecules. To date, no switch or three-terminal device has been produced that is a basic requirement for most logical architectures. If the resistance of the molecule is about 200 Ω and there is 1010 molecules, then the circuit will consume $108 W! Molecular nanoelectronics is at a very early stage and potentially offers very cheap self-assembly fabrication routes, but a substantial break through is required if the technology is ever to come to fruition.

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