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Recent Developments in Electronics-Nanotechnology

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***Abstract:* -- This paper presents an insight into some of the recent breakthroughs in nanotechnology which includes various traditional devices like transistors, light emitting diode, capacitors, integrated circuits to achieve efficiency resulting in lesser time and low power consumption. Nanotechnology can be applied to the field of electronics using carbon nanotubes, which when used on a polyamide substrate of a semiconductor wafer provides high mobility, flexibility, shock resistance, on off ratios and switching speeds, impossible to be achieved with glass plates as substrates. Its usage in Active Matrix Organic Light Emitting Diode displays results in high current driving capability unlike polycrystalline silicon in traditional Liquid Crystal Displays. Lately semiconductor nanowires have been developed, exhibiting transparency and highly uniform electrical performance. CNT FETs have come of age where single walled CNTs replace the silicon channel resulting in strong coupling thus shrinking the FET size. The latest area of development of CNTs have been in Super capacitors where CNT heterogeneous films are used to store high amount of energy catering to the needs of high power, energy density and long operation cycles. Thus this farsighted technology has helped in achieving unprecedented densities and speeds which is the need of the hour.**

I. INTRODUCTION

Nanotechnology is the general purpose exponential technology which utilizes technology less than 100 nm in size. Thus in a simpler sense it means 'engineering of tiny machines'. Carbon nano tubes and nanowires are used as basic building blocks of nanoelectronics. Nanowires are ultra fine linear array of dots made up of silicon, gallium nitride and indium phosphide semiconductors, having remarkable optical, electronic and magnetic characteristics. CNTs are allotropes of carbon with a cylindrical nanostructure. They are carbon molecules, having unusual properties like extraordinary thermal conductivity and mechanical and electrical properties. CNTs are used in a transistor and integrated circuits, whereas nanowires are used in liquid crystal displays and super capacitors make use of CNT heterogeneous films.

II. NANOELECTRONICS

Nanoelectronics refer to the use of nanotechnology on electronic components, especially transistors, that are so small that it explores all possibilities of integrating nano fabrication, semiconductor growth and organic chemistry. It is 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. IT holds some answers for how we might increase the capabilities of electronics devices while we reduce their weight and power consumption.

III. IMPLEMENTATION OF NANO-TECH IN CONVENTIONAL DEVICES:

a) Transistor Channeling Using Single Walled CNTs

Various ideas have been explored in response to the limitations that scaling process offer. Amongst the alternative technologies, carbon based technology has been particularly significant, based on 1991 discovery of carbon nanotubes1 and recent study of individual graphite layers called 'Graphenes'2. A very reason to use CNTs in electronics is their excellent transport properties. In CNTs there is very weak elastic scattering of charge carriers and long carrier mean free path, which is basically in the order of a micrometer. Elastic phonon scattering therefore tends to dominate.

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The scattering strength depends on the energy of the carrier. In a CNT FET, the silicon channel is replaced by an individual single walled CNT3.

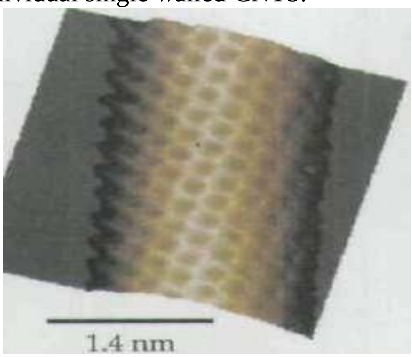

Fig.1: A single-walled nanotube3, shown in this scanning tunnelling microscope image

Owing to the uniqueness of the atomic and electronic structure of CNT, there are advantages of CNT as an FET channel. Its small 1 to 2 nm diameter enhances the gate's ability to control the potential of channel particularly when gate is configured to wrap around the CNT.

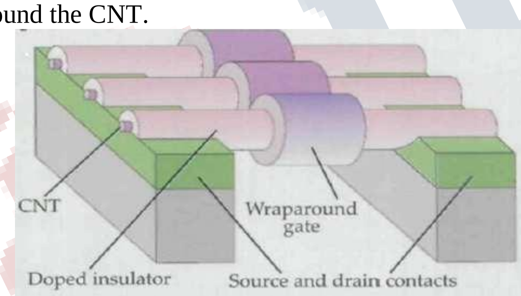

Fig.2: In an alternate configuration, an insulating layer and metal gate are wrapped around each nanotube to optimize the gate-channel coupling. The nanotube segments away from the gate are doped3.

The strong coupling makes the CNT the ultimate thin body semiconductor system and allows the FET to shrink in size and still avoid the drawbacks of short channel effects, in which the gate field basically looses control of the device. Thus all the bonds in the CNT are satisfied and surface is atomically smooth whereas scattering of electrons by surface states and roughness especially at high gate voltages, hampering the growth of conventional FETs. The electrical band gap of a semiconducting CNT is inversely proportional to the tube diameter, high charge mobility 'μ' and low capacitance are of key importance to CNT's efficiency. Thus CNT's quasi one dimension character, strong electron confinement, nanometer width, strong covalent bonding drastically affects the thermal and electrical transport properties of the channel. Thus simple substitution of a silicon channel with a CNT dramatically alters the detailed physics of the device.

b.) SWNT Fabricated ICs

Nanotechnology offers various attributes like conformal and flexible formats, light weight and shock resistant construction of electronic devices which are difficult or next to impossible to be achieved with technology that uses semiconductor wafers or glass plates as substrates4. Carbon based semiconductors offer comparatively high performance consisting of sub monolayer, random networks of single walled CNTs to yield small to medium scale integrated digital circuits composed of nearly 100 transistors on plastic substrates. Transistors here have excellent properties; mobilities as high as 80cm2 v-1s-1,subthreshold slopes as low as 140 mv/dec operating voltages, high on off ratios(105), switching speeds in KHz range even for coarse (~100 μ m) device geometries and good mechanism flexibility are with levels of uniformity and reproducibility that enable high yield fabrication of integrated circuits. Thus, sub monolayers are considered as the attractive material for flexible integrated circuits with a lot of potential in various fields of electronics.

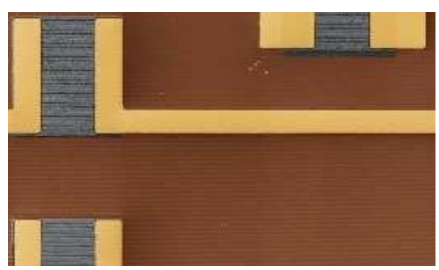

Fig.3: (a) Image of SWNT circuit before deposition of gate level interconnects

Recently developed carbon based semi-conducting nano materials especially a linear aligned arrays of SWNT's which showcase exceptionally high intrinsic mobilities, current carrying capacities, cut-off freq above 1 GHz for devices on plastic, mechanical and optical characteristics in a bendable format5. The system layout of silicon integrated circuit consists of a thin sheet of polyamide, which serves as substrates. Random networks of SWNTs6-9 are grown by chemical vapors deposition and transferred on polyimide form of semiconductor layer10. Source and drain of gold serve as low resistance contacts to these networks.

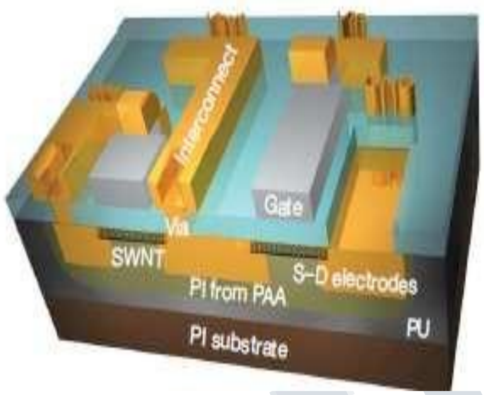

Fig.3: (b)Cross section of SWNT PMOS inverter on a PI substrate (PI polyimide)

Roughly one third of the SWNTs are metallic and for present purposes we use soft lithography and reactive ion etching to cut fine lines into the networks. In this we use low cost patterning technique called screen printing which is responsible for influencing the geometry of etched lines described above on the device surface with coarse dimensions(channel length Lc =100μm). With such high density of SWNTs we achieve uniformity as thin film conductor. Thus the development of optimized metals and solution printing techniques for fabricating SWNT based integrated circuits that achieve better performance levels coupled with further exploration of circuit and system level implementation represents some directions for future work.

c) AMOLED Displays Based On Implication of Nano-wires Active matrix organic light emitting diode (AMOLED) display holds great potential for next generation visual technologies due to high light efficiency, flexibility, light weight and low temperature processing

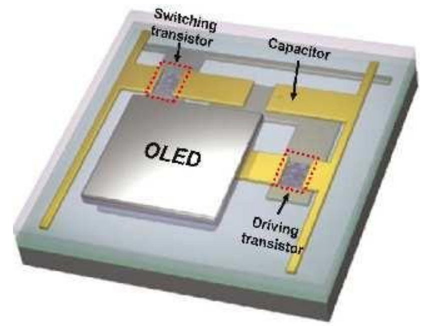

Fig.4: Top view for the layout of a single pixel AMOLED

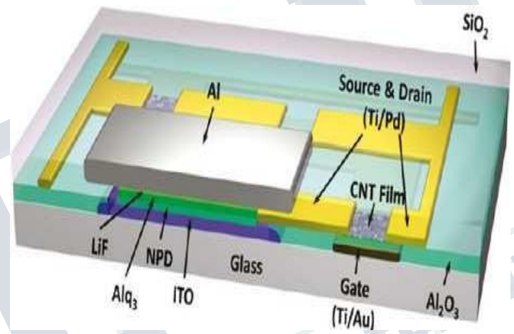

Fig.5: Cross-sectional view for the structure of the AMOLED pixel11-15.

Thin film transistors are required to realize the advantages of AMOLED. However fabrication of thin film transistors in the active matrix back pane is still challenging. Unlike the requirement of driving transistors for traditional liquid crystal displays (LCDs) where amorphous silicon with mobility16-17 (~1cm2v-1s-1) is applied as transistor channel material, higher current driving capability is needed. Similarly polycrystalline silicon18, 19 is also used but due to high temperature processing, short lifetime and poor uniformity, implementation of AMOLED displays are limited. In the figure 5 the red box shows the structure within a given pixel. Each pixel contains one switching transistor (Ts), driving transistor (TD), one charge storage capacitor (Cs) and one OLED15. Thus we use one dimensional nanoscale materials such as semiconductor nanowires20-22. Single walled carbon nano tubes23-25 have the advantages in terms of mobility, transparency, flexibility and low temperature processing. Thus AMOLED displays using nanowires are active channel materials. By using TFTs with semiconducting nano tubes they (TFTs) exhibit highly uniform electrical performance. Besides, due to the use of high purity semi-conducting nanotubes, ON/OFF ratio (>105), excellent on- current density (~1μ A/μ m at VD =1V) and superior mobility (70 cm2 V-1 s-1) are achieved, which makes such separated carbon nanotube TFT's very attractive for AMOLED display applications.

d) Supercapacitors Built On CNT's

Electrochemical capacitor (supercapacitor) with properties of high energy storage, small size and light weight has become one of the best candidates of energy storage devices26-29. Supercapacitors built on carbon nanotubes may be not as good as redox capacitors (e.g.RuO2, MnO2 and IrO2)30, 31, but these are transparent and flexible in nature. The typical supercapacitor structure is made of polynomial electrolyte layer sandwiched between two transparent and flexible nanowire/ nanotube film electrodes. The device structure includes the following features. First of all, metal oxide nano wires dispersed on CNT films are chosen. Owing to their unique properties of high aspect ratio and short diffusion path length to ions, metal oxide nano wires can provide high surface area, fast charge/ discharge and facial redox reaction, are suitable for supercapacitors. Secondly, transparent flexible polymer membrane is used with aqueous electrolyte to work as a separator and an electrolyte. Thirdly, the thickness of nanowire/ nanotube film is optimized for mechanical flexibility and optical transparency, which allows in achieving flexible and transparent supercapacitors, based on In2O3 nanowire/ CNT heterogeneous films. To make a CNT film, a CNT suspension is filtered through a porous alumina filtration membrane, the CNT's are trapped on the membrane surface, thus forming a homogenous entangled network. An adhesive and flat poly (dimethylsiloxane) stamp is adopted to peel the CNT film off the filtration membrane which is then released onto a polyethylene terephtalate (PET) substrate on hot plate at 100ºC.

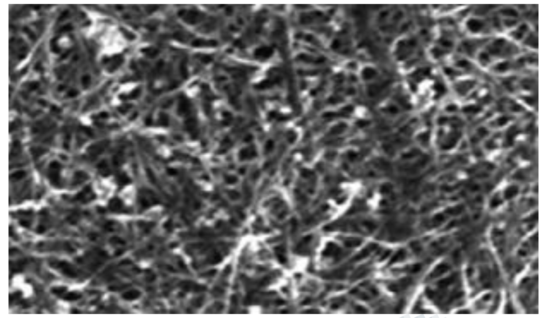

Fig.6: The scanning electron microscopy (SEM) image of a transferred CNT film on PET substrate.

Studies found that performance of CNT heterogeneous films can be improved by the dispersion of In2O3 nanowire on CNT films due to the redox transition of In2O3 nanowires without degradation in transparency. Enhanced specific capacitance, power density, energy density, and long operation cycles have been realized with the incorporation of In2O3 nanowire. Extensive studies are underway to further improve the device performance and fill the gap of practical applications.

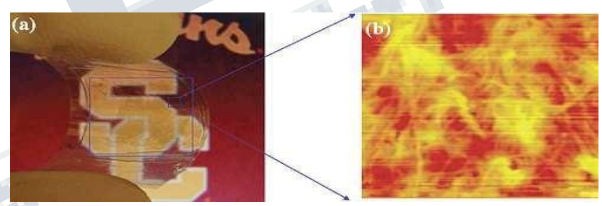

Fig.7: (a) Supercapacitor made of transferred CNT films.

(b) A typical atomic force microscopy (AFM) image of a transferred CNT film on a PET substrate.

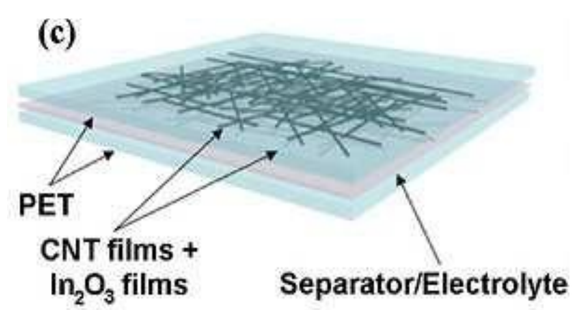

Fig.7: (c) The schematic diagram of the supercapacitor in this work is depicted.

IV. CONCLUSIONS AND FUTURE SCOPE:

Considering miniaturization as the key, various exciting nanofabrication techniques have unfolded different methods to fabricate nanowires and nanotubes which help in achieving high current driving capacity, mobility, transparency, flexibility and low temperature processing thus attaining high electrical performance. The CNT transistors can be built with quantum dots, forming the channel through which the current flows. The new world of nano devices would be comparatively faster, will produce less energy, will utilize less material and will consume very less space. Nanotechnology based devices will enable the creation of a new world of innovative products, such as biosensors, molecular memory, spin based electronic products, and flexible and light-weight photovoltaic cells. In a nutshell, nanoelectronics in near future will explore the possibilities of integrating nanofabrication, semi conductor growth and organic chemistry to lay the cornerstone of this farsighted technology.

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