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Review on Nanoelectronic Devices

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ABSTRACT: A review on research developments toward nanometer scale is being provided by this paper for use in making ultra densely integrated electronic computers. Here special attention to two classes of alternative to field effect transistors will be given. Two different classes which are considered in this review are :quantum effect single electron solid state devices. and molecular electronic devices. Literature about different types of nanoelectronic devices is surveyed in this review. This information is presented in non-mathematical form

KEYWORDS: Nanomaterials, Quantum dots, electronic components.

I. INTRODUCTION

Nano electronics refers to the usage of nanotechnology in electronic components. The term covers a distinct set of devices and materials with common characteristics. These devices are so small that inter atomic interactions and quantum mechanical properties need to be studied completely. Some of these candidates constitutes hybrid molecular/ semiconductor electronics, 1-D annotates/ nanowires .or advanced molecular electronics. Recent silicon CMOS technology generations are already with this system. Nanoelectronics are sometimes treated as disruptive technology because present candidates are somewhat different from traditional transistors.As the basic subunit of electronic computers i.e. transistors has shrunk for the past forty years ,they become more powerful. But further reduction in size of today's conventional field effect transistors may soon be prevented because of limitations of fabrication techniques, laws of quantum mechanics. In the field of next generation electronics many investigators project that during the next 10-15 years as the size of transistors reduced from 250 nm to 100 nm and below ,the devices will become difficult and costly to fabricate. In addition in ultra densely integrated electronic circuits they may no longer function effectively. For miniaturization of circuit elements down to nanometer scale many alternatives to transistors are investigated by researchers for ultra dense circuitary. Just like transistors these new nanometer scale electronic (nanoelectronic) devices perform as both switches and amplifiers. These new devices take the advantage of quantum mechanical phenomenon that emerge on nanometer scale. Especially we will analyze two broad classes of alternative nanoelectronic switches & amplifiers.

- Solid state quantum effect and single electron devices.
- Molecular Electron Devices

In order to explore new technology nanoelectronic devices fabricating quantum effect and single electron devices in solids is the approach taken by most of the research groups.It makes novel devices out of same semiconductors used for transistors. Molecular electronics is relatively new approach that would change operating principles and materials used in electronic devices. In 1965 Gorden Moore observed that silicon transistors were experience an unbroken process of scaling downward, a cognition which was later codified as Moore's law. Since his examination transistor minimum feature sizes have decreased from 10 micrometers to 28-22 nm range in 2011. The field of nano electronics target to enable continued recognition of this law by using new methods and materials to form electronic devices with feature sizes of nanoscale.

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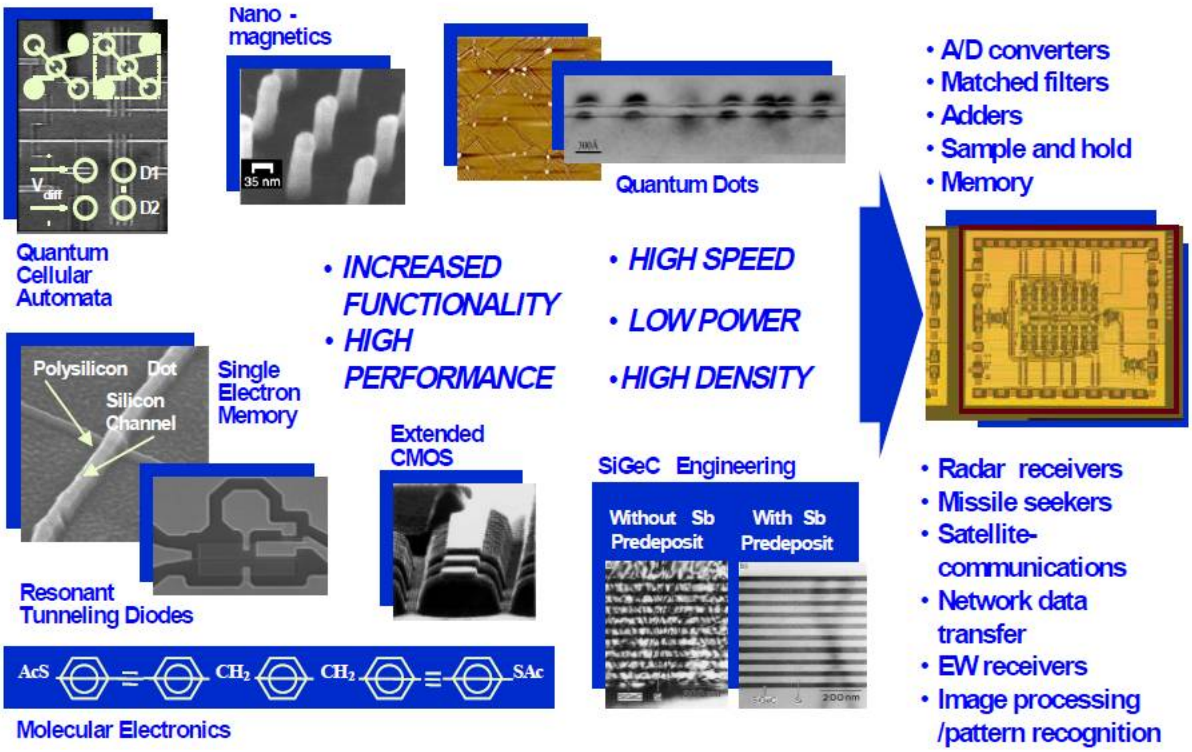

Nanoelectronics: device and architecture options for high-performance electronics.

II. SOLID STATE QUANTUM EFFECT AND SINGLE ELECTRON NANOELECTRONIC DEVICE

In order to overcome difficulties such as heat dissipation in transistors, shrinkage of depletion regions a no. of nanometer scale solid state replacements for bulk effect semiconductor transistor have been suggested.All these devices have essential structural feature in common is a small "island" composed of semiconductor or metal in which electrons may be confined. Role of Island In Nanoelectronic devices is analogous to that of the channel in Fets. The extent to which these electrons are confined in island defines three basic categories of nano electronic devices.

- Quantum dots: Also known as artificial atoms. In quantum dots electrons are confined in island with zero classical degrees of freedom remaining.
- Resonant tunneling Devices: Island confines electrons with one or two classical degrees of freedom.
- Single Electron Transistor: electrons are confined in island with 3 classical degrees of freedom.

III. QUANTUM DOTS

Quantum dots are constructed with island which are confined in all three dimensions and in quantum well electrons are confined in island with zero classical degrees of freedom. This dot like island will be made up of either metal or semiconductor. It comprises of either small deposited or lithographically defined regions. Quantum dots are basically nanoscale semiconductor devices that confines either electrons or electron holes in all 3 dimensions. They can be made

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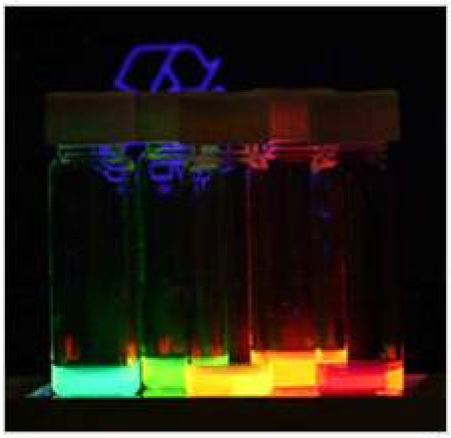
either via colloidal synthesis, plasma synthesis, mechanical fabrication. The electronic properties of the quantum dots fall between those of bulk semiconductors and those of discrete molecules of comparable size whereas optoelectronic properties such as band gap will be proportional to particle size and shape of given composition. For example by controlling diameter photoluminescence of quantum dots can be manipulated to specific wavelengths. Larger QDs (radius of 5-6 nm, for example) emit longer wavelengths resulting in emission colors such as orange or red. Smaller QDs (radius of 2-3 nm, for example) emit shorter wavelengths. resulting in colors like blue and green, although the specific colors and sizes vary depending on the exact composition of the QD. QDs are of interest in many research applications such as transistors, solar cells, LEDs,diode lasers. They have ability to precisely convert and tune a spectrum makes them useful for LCD displays. Previous LCD displays can waste energy converting red-green poor, blue-yellow rich white light into a more balanced lighting. By using QDs, only the necessary colors for ideal images are contained in the screen. The result is a screen that is brighter, clearer, and more energy-efficient



Colloidal quantum dots irradiated with a UV light. Different sized quantum dots emit different color light due to quantum confinement.

IV. RESONANT TUNNELING DIODE

Tunneling diodes (TDs) have been widely considered for their importance in achieving very high speed in wide-band devices and circuits that are beyond conventional transistor technology. Conventional transistor technology is not capable of supporting future ultra high speed applications.RTD is an important advancement to this problem. RTDs have been shown to gain a maximum frequency of up to 2.2 THz as opposite to 215 GHz in conventional Complementary Metal Oxide Semiconductor (CMOS) transistors. [1] The very high switching speeds provided by RTDs have allowed for a variety of applications in wide-band secure communications systems and high-resolution radar and imaging systems for low visibility environments. RTDs utilize a quantum well with identically doped contacts to provide similar I-V characteristics. It consists of two heavily doped, narrow energy-gap materials surrounding an emitter region, a quantum well in between two barriers of large band gap material, and a collector region, as shown in Figure . A current method of growth for this device is Metal Organic Chemical Vapor Deposition using GaAs-AlGaAs. The quantum-well thickness is typically around 5n m and the barrier layers are around 1.5 to 5 nm thick

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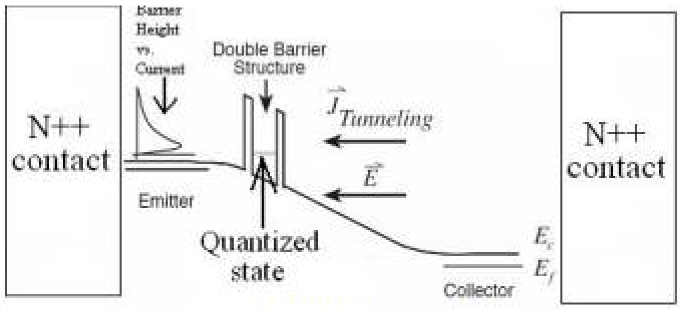

Figure 3. Structural diagram of RTD. [1] According to the graph on the emitter side, the current is at a maximum at the quasi-bound energy state indicated by the gray area in the quantum well.

The current-voltage (I-V) curve shows the negative differential resistance (NDR) characteristic of RTDs. For a specific voltage range, the current is a decreasing function of voltage. This property is very important in the circuit mplementation because it can provide for the different voltage-controlled logic states corresponding to the peak and valley currents

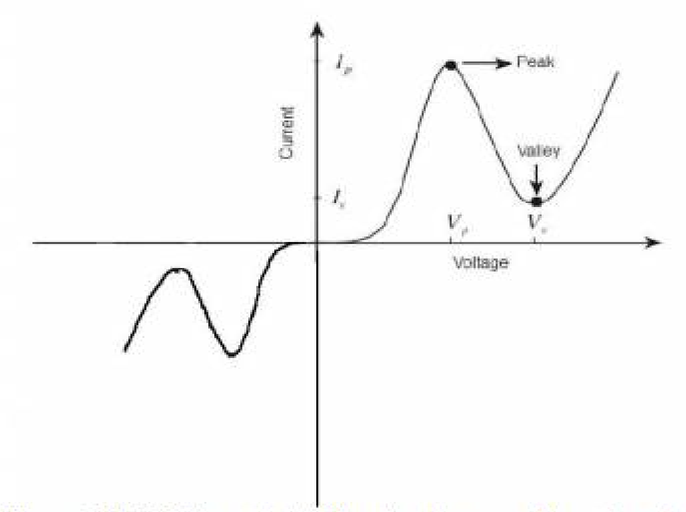

Figure 4. RTD I-V characteristic. When there is a reverse bias voltage, the current is not very large, unlike the TD.

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V. SINGLE ELECTRON TRANSISTOR

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Single-electron transistors (SET's) are often reviewed as elements of nanometer scale electronic circuits because they can be made very small and they can identify the motion of individual electrons. However, SET's have low voltage gain, high output impedances, and are sensitive to random background charges. This makes it unlikely that single-electron transistors would take over field-effect transistors (FET's) in applications where large voltage gain or low output impedance is necessary. 'Single electron transistor [SET]' which is capable of controlling the transport of only one electron is a key element of current research area of nanotechnology which can offer low power consumption

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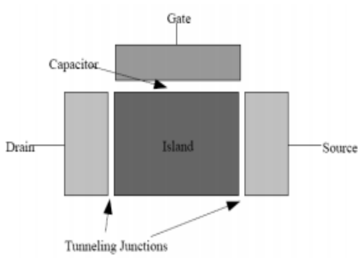
and high operating speed. The single electron transistor is made of an island connected through two tunneling junctions to a drain and a source electrode, and through a capacitor to a gate electrode . When there is no bias on any electrode, electrons in the system do not have enough energy to tunnel through the junctions



A conventional field-effect transistor, the kind that makes all modern electronics work, is a switch that turns on when electrons are added to a semiconductor and turns off when they are removed. These on and off states give the ones and zeros that digital computers need for calculation. Interestingly, these transistors are almost completely classical in their physics. Only a few numbers that characterize their behavior are affected by quantum mechanics. However, if one makes a new kind of transistor, in which the electrons are confined within a small volume and communicate with the electrical leads by tunneling, all this changes. One then has a transistor that turns on and off again every time one electron is added to it, we call it a single electron transistor (SET).

VI. CONCLUSION AND FUTURE WORK

For many electronic devices, various nanoelectronic devices are being used because of their unique properties. In this paper a review to the basics of nanotechnology and nanoelectronic devices like Quantum dots, Resonant tunneling devices& single electron transistors are studied. These nanoelectronic devices are the foundation of future electroni

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