Single Electron Transistor & its Applications

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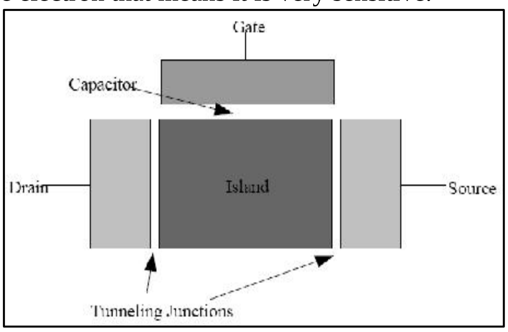
Abstract— Single electronic transistor is an application of the nanotechnology. The aim of this paper is to discuss on this nano electronic device, also known as SET. The Single electron transistor is considered as one of the main candidate for the basic element of future ULSI chips. The fundamental physical principle of single electron transistor are the tunnelling effect and the Coulomb blockade. ASET is a very small and sensitive device and is similar to Field Effect Transistor (F.E.T).Due to its small size its future is very bright. It will be very useful in making Quantum computer. It can be used as sensors, detector. Due to its small size we could make strong and more powerful chip. Recent research in SET gives new thoughts which are going to change the random access memory and digital data storage technologies. SET is capable of controlling the transport of only one electron at a time.

Key words: CNT, Tunneling Effect, Coulomb Blockade

I. INTRODUCTION

SET is a simple three terminal device namely source, drain & two tunnel junctions which offers the low power consumption & high speed. The size of SET is very small. SET has low voltage gain, high input impedance. It is a highly sensitive device. The single electron transistor is another kind of switching device that uses controlled electron tunneling to amplify current. In a single electron transistor, a drain and source cathode are associated through a tunneling junction to an island, which is additionally capacitive associated with a gate. When all the biases are zero, electrons don't have much energy to tunnel through the junction. Notwithstanding, if you increase the bias, but keep it not exactly the coulomb hole voltage, expanding the gate bias inclination over the purpose of most extreme slant on the coulomb staircase causes the state with one or zero abundance electrons on the island to have the same energy, resulting in the coulomb barrier being expelled and permitting electrons to tunnel through the junctions and between the source and the drain. The single electron transistor is a new type of switching device that uses control electron tunneling to amplify current. An ultra-small device that transfer one electron at a time based on coulomb's interaction. This occur in a tiny conducting layer known as island. Its electrostatic potential increase with increase even a single electron that means it is very sensitive.



But usually the concentration of the CNTs in the Tunneling effect: It is a quantum phenomenon based on orthodox theory. A tunnel junction like as a sandwiched structure of a layer with a very thin insulating material and two layers like a conductor. Tunneling the occasion in which transportation of charge happens. The tunnel junction characteristics depends upon the junction capacitor (Cj), junction resistance (Rj) and voltage across the junction (Vj). For tunneling Vj must satisfy the condition

II. QUANTIZATION OF CHARGES

1) Single electron tunnelling oscillation will be appeared with frequency f=I/e.
2) This single electron tunnelling technology introduces the capacity to control the exchange of individual electrons.
3) Single electron transistor (SET) can be operated as sensitive, linear charge amplifier, through the exploitation of this single electron quantum tunnelling effect. More accurate measurement of the strength of this tunnelling impact is charge in energy or electrostatic energy, which is given by:

$$Ec = e2/2c.$$

If capacitor is very small, the charging energy may be dominating. The current flows through a conductor in a continuous manner because the number of free electrons is available in it. This current might be controlled by figuring the charge exchanged however the conductor per time interim. Since, the charge transferred through the conductor may have any value, therefore it is not quantized.

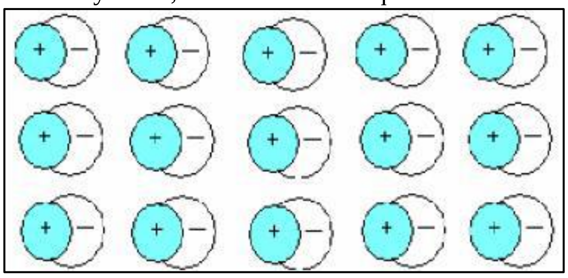


Fig. 1(a):

4) Now, if a tunnel junction is placed in an ordinary conductor, the stream of electrons penetrating this thin insulating barrier will be restricted by it. This is shown in fig. 1(a).

$$j < V$$

Where VC is the critical voltage. The junction is said to be in the stable state ifj cV<=V Here e is electronic charge ($e=1.602x10^{-19}$ C) and CC is the equivalent capacitor of the remainder circuit apart from the tunnel junction. Thus, the current through a conductor may be quantized in this situation.

A. *Limitation of SET*

The major problem with the SET is background charge. When a single charge trapped in insulating environment, the island of the SET become polarized. Result is an image charge Qo created on its surface, so the external charge cancelled by the image charge.

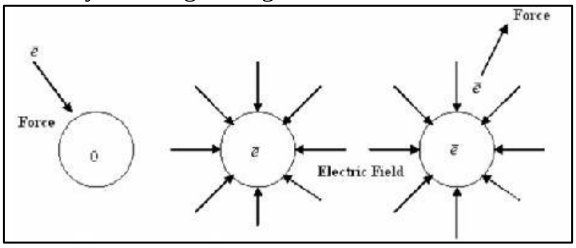


Fig. 1 b): an Electron Feeling a Small Attractive Force as it approaches a sphere. b) Once sphere gets charge by a single electron; different electrons will feel a strong repelling force.

The most difficult issue is the island size of SET. All SET requirement of Ec~100KBT for their satisfactory operation where EC is the coulomb energy and *T* is the temperature of the system. It is necessary that the Single Electron Transistor island has to be smaller than100nm for operate at room temperature. If there is any variation in the temperature, leads to the change in its energy level which may result variation in its size, hence UN stability. In VLSI circuits, this fabrication technology level is very complicated. In addition, regardless of the possibility that these islands are created by any kind of nanolithography, their shape will scarcely be completely general. Since in such small conductors the quantum kinetic energy gives a dominant contribution to the electron extra energy (Ek>>Ec,), even little variations in island shape will lead to capricious and rather considerable varieties in the range of energy levels and hence in the device switching thresholds. In order to fabricate SET, e-beam lithography consolidated with a picture reversal process using inductive coupled plasma (ICP) etcher will be used. E-beam lithography has the ability to make designs having nanometer highlight sizes because of its short wavelength and sensible energy density characteristics. The fundamental points of interest of e-beam lithography over the customary lithography techniques include very high resolution and versatile pattern formation.

III. Coulomb Blockade

The impact in which electron can't pass through the island unless the energy in the system is equal to the coulomb energy e^2/cg coulomb blockade tries to reduce any leak by current during the off state of the SET. The coulomb blockade additionally like as a barrier. When we rise voltage from zero, no current can flow between the electrodes because electron has not enough energy. This suppression of electron flow is called the coulomb blockade. This section discusses the electro static energy that is required to add or remove an electron from a small conductor and this leads to a phenomena called the coulomb blockade.

IV. Advantage of SET

- Scalability
- High operating speed
- Charge sensitivity
- Low power consumption
- Less thermal fluctuation.

V. SET Operation

Single Electron Transistor have been consist with critical dimensions of just a few nano meter used metal, semiconductor, single well carbon nanotubes or individual molecules. The SET made of two tunnel junctions sharing one common electrode with a low self-capacitor, known as the island. The electrical potential of the island can be tuned by electrode (the gate), capacitive coupled to the island.

- Unlike Field Effect transistor, Single electron device based on an intrinsically quantum phenomenon, the tunnel impact.
- Electrical behaviour of the tunnel junction relies on upon how successfully hindrance transmit the electron wave, which diminish exponentially with the thickness, which is given by the area of tunnel junction divided by the square of wave length.
- In the blocking state no available energy levels are within tunneling range of the electron on the source contact. All energy levels on the island electrode with lower energies are occupied.
- At the point when a positive voltage is connected to the gate terminal the energy levels of the island electrode are brought down. The electron can tunnel onto the island, occupying a formerly empty energy level. From there it can tunnel onto the drain electrode where it in elastically scatters and reaches the drain electrode Fermi level.
- The energy levels of the island electrode are evenly spaced with a separation of ΔE. ΔE is the energy needed to each subsequent electron to the island, which acts as a self-capacitor C. The lower C the bigger ΔE gets.

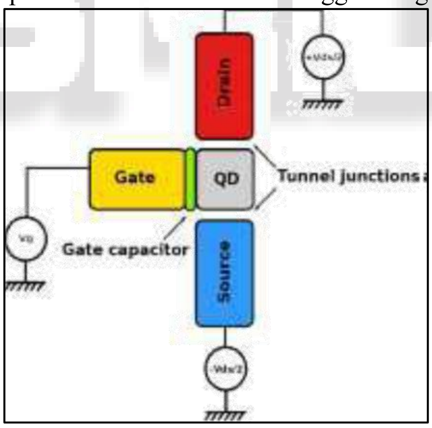


Fig. 2: Schematic Diagram of the Single Electron Transistor

Sr. No.	SET	MOSFET
1.	Extremely small.	Very large than SET
2.	Two tunneling barrier	Inversion channel
3.	Based on the principle of coulomb'sblockade	based on the principle of electron diffusion
4.	10000 time more Sensitive than MOSFET	Less sensitive than SET.
5.	It is Low power consumption	It is High power consumption than SET.

Table 1: Difference between SET & MOSFET

VI. Application

A. *Single-Electron Spectroscopy*

A standout amongst the most critical utilization of single electron electrometry is the likelihood of measuring the electron expansion energies (what's more, subsequently the energy level dispersion) in quantum dabs and other nanoscale objects.

B. *Charge State Logics*

The issue of spillage current is fathomed by the utilization of another rationale device name charge state logic in which single bits of data are exhibited by the presence/absence of single electrons at certain conducting islands throughout the entire circuit. In these circuits the static currents and power vanish, subsequent to there is no dc current in any static state.

C. *Ultrasensitive Microwave Detector*

Another application of Single Electron Transistor can be as an Ultrasensitive Microwave Locator; island is weakly coupled to a bias circuit through two capacitor tunnel junctions and a capacitor gate. SET at low bias voltages and temperatures, a single quasiparticle may only be introduced to the island through photon-helped tunneling. When this happens, the quasiparticle is caught on the island since it requires a moderately long time for this specific quasiparticle to tunnel off. While it is caught, charge is transported through the framework two electrons at once. Since the photon-helped transmitted simply switches the detector current on, this device is not constrained to one electron tunneled through the framework per ingested photon. This makes the device an amazingly delicate and possibly helpful locator of microwave radiation.

VII. Conclusion

With all exciting properties of single electron device the pace of large scale integration can continue. Only one thing is certain, if pace of miniaturization continue abated, the quantum properties of electron will become crucial in determining the design of electronic device before the end of next decade. Researchers may someday assemble these transistor into molecular version of silicon chips, yet there are still imposing obstacles to cross. SET could be utilized for the memory gadget, yet even the most recent SET experience the ill effects of "counterbalance charges which implies that the gate voltage needed to achieve maximum current shifts arbitrarily from device to device. Such fluctuations make it possible to design complex circuit. Resistance of SET is dictated by the electron tunneling and the capacitor depends on the size of the nano particle. The present begins to flow through the junction when applied voltage is only adequate to raise the energy of electron over the coulomb obstructed, this is called threshold voltage Vth and the level zero current endure for 2Vth.

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