Review Paper on MEMRISTOR

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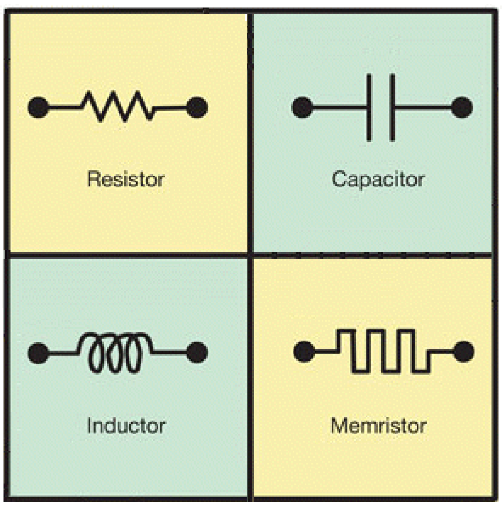
Abstract- *During the time of Chua's 1971 seminal paper on memristors, only three passive circuit elements were known: the resistor, the capacitor, and the inductor. Chua's interest involved the mathematical theory of electronics rather than circuit design and after examining the mathematical relationships between the three known circuit elements, he saw something missing. He observed a mathematical symmetry and predicted that there should exist a fourth element to complete the symmetry. He coined the missing element, the memristor.*



I. INTRODUCTION

What is memristor ?

"A memristor is an electrical component that limits or regulates the flow of electrical current in a circuit and remembers the amount of charge that has previously flowed through it. Memristors are important because they are non-volatile, meaning that they retain memory without power."

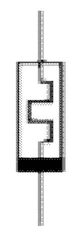
The original concept for memristors, as conceived in 1971 by Professor Leon Chua at the University of California, Berkeley, and he believed for reasons of symmetry -- that an extra component could one day be constructed to join the resistor, the capacitor and the inductor.

He called it "memristor", a portmanteau of the words memory and resistor.

A memristor is a hypothetical non-linear passive two-terminal component relating electric charge and magnetic flux linkage.

According to the characterizing mathematical relations, the memristor would hypothetically operate in the following way: The memristor's electrical resistance is not constant but depends on the history of current that had previously flowed through the device,i.e., its present resistance depends on how much electric charge has flowed in what direction through it in the past; the device remembers its history — the so-called non-volatility property. When the electric power supply is turned off, the memristor remembers its most recent resistance until it is turned on again.

Electronic symbol Fig. Memristor symbol



The memristor is formally defined as a two-terminal element in which the magnetic flux Φm between the terminals is a function of the amount of electric charge q that has passed through the device. Each memristor is characterized by its memristance function describing the charge-dependent rate of change of flux with charge.

$$M(q) = d\emptyset m/dq$$

As we know from, Faraday's law of induction that magnetic flux is simply the time integral of voltage, and charge is the time integral of current, we may write the more convenient

$$M(q) = \frac{d\emptyset m/dt}{dq/dt} = \frac{V}{I}$$

It can be inferred from this that memristance is simply charge-dependent resistance. . i.e. ,

V(t)=M(q(t))*I(t)

This equation reveals that memristance defines a linear relationship between current and voltage, as long as charge does not vary. Alternating current, however, may reveal the linear dependence in circuit operation by inducing a measurable voltage without net charge movement—as long as the maximum change in q does not cause much change in M.

II. WORKING OF MEMRISTOR

Semiconductors are doped to make them either p-type or n-type. For example, if silicon is doped with arsenic, it become n-type. However, when we apply an electric field to piece of n-type silicon, the ionized arsenics atoms sitting inside the silicon lattice

(V0+) can be in the direction of current will not move. We do not want them to move, in any case. Pure titanium dioxide (TiO2), which is also a semiconductor has high resistance, just as in the case of intrinsic silicon, and it can also be doped to make it conducting. If an oxygen atom, which is negatively charged, is removed from its substantial site in TiO2, a positively charged oxygen vacancy is created (V0+) which act as a donor of electrons. These positively charged oxygen vacancies applying electric field. Taking advantage of this ionic transport, a sandwich of thin conducting and non-conducting layers of TiO2was used to release memristor.

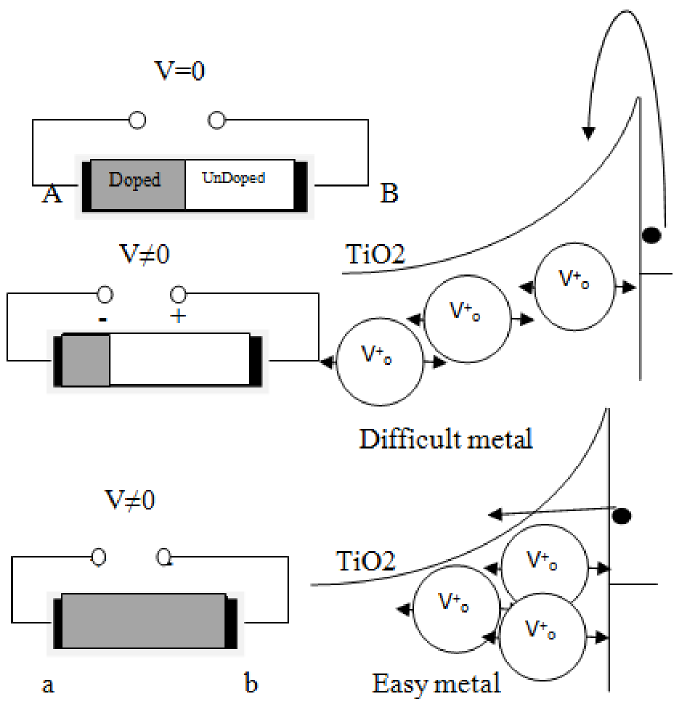


fig .Conduction Mechanism in a memristor

The speciality of Memristor is not just that it can be turned OFF or ON, but that it can actually remember the previous state. This is because when the applied bias is removed, the positively charged Ti ions do not move anymore, making the boundary between the doped and undoped layers TiO2 immobile. When we next apply a bias (positive or negative) to the device, it starts from where it was left.

Applications:

Williams' solid-state memristors can be combined into devices called crossbar latches, which could replace transistors in future computers given their much higher circuit density.

The three main areas of application currently under development for memristor electronics are non-volatile memory, logic/computation, and Neuromorphics.

They can potentially be fashioned into non-volatile solid-state memory, which would allow greater data density than hard drives with access times similar to DRAM, replacing both components. HP prototyped a crossbar latch memory that can fit 100 gigabits in a square centimeter, and proposed a scalable 3D design (consisting of up to 1000 layers or 1 petabit per cm3). In May 2008 HP reported that its device reaches currently about one-tenth the speed of DRAM.

The devices' resistance would be read with alternating current so that the stored value would not be affected.[74] In May 2012 it was reported that access time had been improved to 90 nanoseconds if not faster, approximately one hundred times faster than contemporaneous flash memory, while using one percent as much energy. Memristor patents include applications in programmable logic, signal processing , neural networks, control systems, reconfigurable computing, brain-computer interfaces and RFID. Memristive devices are potentially used for stateful logic implication, allowing a replacement for CMOS-based logic computation. Several early works in this direction are reported Neuromorphics Lab, has been developing neuromorphic architectures which may be based on memristive systems .

NON-VOLATILE MEMORY- Non-volatile memory is the dominant area being pursued for memristor technology.

LOGIC/COMPUTATION- The uses of memristor technology for logic and computational electronics is less well developed than for memory architectures but the seeds of innovation in this area are currently being sown. Memristors appear particularly important to the areas of reconfigurable computing architectures such as FPGAs in which the arrangement between arrays of basic logic gates can be altered by reprogramming the wiring interconnections.

NEUROMORPHIC ELECTRONICS Neuromorphics has been defined in terms of electronic analog circuits that mimic neuro- biological architectures.

Types of Memristor

Memristor are classified into different types, depending on how they are built. Memristors are divided into two types

I. Logic thin film and Molecular memristors
II. Magnetic and spin based memristors

I. Logic thin film and Molecular memristors: It is mostly rely on different material properties of thin film atomic lattices that display hysteresis below the application of charge. These memristors are classified into different types:

- Titanium Dioxide Memristors: These types of memristors are broadly explored for designing and modeling.
- Ionic or Polymeric Memristors: Ionic and Polymeric memristors utilize dynamic doping of inorganic die-electric type or polymer materials. In this type of memristors, the charge carriers' solid state ionic's move all over the structure.
- Resonant Tunneling Diode Memristors: These types of memristors use specially doped quantum well diodes of the space layers between the sources and drain regions.
- Manganite Memristors: These types of memristors use a substrate of bilayer oxide films based on manganite as opposite to titanium dioxide memristors.

II. Magnetic and Spin Based Memristors

Spin based memristors are opposite to ionic nanostructure and molecule based systems, and rely on the property of degree in electronic spin. In this type of system, the polarization of electronic spin is aware. These types of memristors are classified into two types:

- Spintronic Memristors: In these types of memristors, the route of spin of electrons changes the magnetization state of the device which consequently changes its resistance.
- Spin Torque Transfer Memristors: In these types of memristors, the comparative magnetization position of the two electrodes affect the magnetic state of a tunnel junction which in turn changes its resistance.

Memristor Spice Model

In recent times the research on memristors has increased rapidly due to their potential applications as well as the demonstration of memristor manufacturing. As of now the Research is in full swing to use memristors in analog circuits, digital or programmable logic controllers, computers and sensors. The new models of memristors need to be available for the design engineers to use them as a circuit element throughout design exploration. There are three types of models available for the design engineers: Verilog-A, MATLAB and Spice model. Verilog-A and MATLAB models can be used for a high-level abstracted simulation only. But, the recent memristor spice model can be used f r a circuit level simulation.

This spice model makes it possible to design and simulate memristor circuits. In this model, we simulate two circuits – a low-pass filter in which a memristor is in series with an inductor, and a resistor with an Operational Amplifier. The results are contrasted with the inductor circuits, in which the memristor is replaced by an inductor. The contrast shows that a memristor acts like an inductor under some conditions. Memristor has immense performance in terms of size and power dissipation.

Key Terms;

- **Resistor -** a two-terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current.
- **Inductor-** a passive electrical component with significant inductance
- **Capacitor-** an electronic device that can store energy in the electric field between a pair of conductors.

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