

“Future of Electronics - Memristor”

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ABSTRACT

The idea of memristor was proposed by circuit theorist Leon Chua in 1971 as a passive two terminal component. Previously only three basic circuit elements were known that is the resistor, the capacitor and the inductor. Leon Chua observed a mathematical symmetry and believed the existence of a new element linking magnetic flux linkage vs. current named it memristor (memory + resistance).

Memristor set emerging trend in the field of circuit designing, Nano electronic memories, computer logic and neuromemristive computer architectures. Objective of this paper is to discuss the development of memristor and the memristor based applications.

Keywords:

Memristor; Nano electronic memories; neuromemristive.

INTRODUCTION

Memristor was first envisioned in 1971 by Leon Chua. Basically memristor was fourth basic element different from the rest of other fundamental circuit element. Memristor's electrical resistance is variable, the resistance depends on the electric charge and the direction. Some scientists formed a team at HP Labs in 2008 and declared to found the missing of Leon's memristor that was based on thin film of titanium dioxide. So, the memristors are basically a fourth class of electrical circuit, joining the resistor, the capacitor, and the inductor, that exhibit their unique properties primarily at the nanoscale. The symbol of memristor is shown below in fig1.



Fig 1. Symbol of Memristor

THEORY

The memristors are a type of passive circuit elements that maintain relationship between the time integrals of current and voltage across a two terminal element. Thus, a memristors resistance varies according to a devices memristance function, allowing, via tiny read charges, access to a “history” of applied voltage. The material implementation of memristive effects can be determined in part by the presence of hysteresis (an accelerating rate of change as an object moves from one state to another) which, like many other non-linear “anomalies” in contemporary circuit theory, turns out to be less an anomaly than a fundamental property of passive circuitry. The Stanley Williams developed the first stable prototype, memristance as a property of a known material was nearly nonexistent. The memristance effect a non-nanoscale distances is dwarfed by other electronic and field effects, until scales and materials that are nanometers in size are utilized. At the nanoscale, such properties have even been observed in action prior to the HP Lab Prototypes.

DEFINITION

According to the original 1971 definition, the memristor was the fourth fundamental circuit element, forming a

non-linear relationship between electric charge and magnetic flux linkage. In 2011 Chua argued for a broader definition that included all 2-terminal non-volatile memory devices based on resistance switching. Williams argued that MRAM, phase change memory and RRAM were memristor technologies. In 2011, Meuffels and Schroeder noted that one of the early memristor papers included a mistaken assumption regarding ionic conduction. In 2012, Meuffels and Soni discussed some fundamental issues and problems in the realization of memristors. They indicated inadequacies in the electrochemical modelling presented in the Nature paper "The missing memristor found" because the impact of concentration polarization effects on the behavior of metal-TiO_{2-x} -metal structures under voltage or current stress was not considered. This critique was referred to by Valov et al. in 2013.

OPERATION OF MEMRISTOR AS A SWITCH

For some memristors, applied current or voltage causes substantial change in resistance. Such devices may be characterized as switches by investigating the time and energy that must be spent to achieve a desired change in resistance. This assumes that the applied voltage remains constant. The type of memristor described by Williams ceases to be ideal after switching over its entire resistance range, creating hysteresis, also called the "hard-switching regime". Another kind of switch would have event under constant bias. Such device would act as a memristor under all conditions, but would be less practical.

MEMRISTIVE SYSTEMS

The memristor was generalized to memristive systems in Chua's 1976 paper. Whereas a memristor has mathematically scalar state, a system has vector state. The number of state variables is independent of the number of terminals. Chua applied this model to empirically-observed phenomena, including the Hodgkin-Huxley model of the axon and a thermistor at constant ambient temperature. He also described memristive systems in terms of energy storage and easily observed electrical characteristics. These characteristics might match resistive random-access memory relating the theory to active areas of research.

PINCHED HYSTERESIS

One of the resulting properties of memristors and memristive systems is the existence of a pinched hysteresis effect. For a current-controlled memristive system, the input $u(t)$ is the current $i(t)$, the output $y(t)$ is the voltage $v(t)$, and the slope of the curve represents the electrical resistance. The change in slope of the pinched hysteresis curves demonstrates switching between different resistance states which is phenomenon central to ReRAM and other forms of two-terminal resistance memory. At high frequencies, memristive theory predicts the pinched hysteresis effect will degenerate, resulting in a straight line representative of a linear resistor. It has been proven that some types of non-crossing pinched hysteresis curves (denote Type-@) cannot be described by memristors. Fig 2 shows the curve of pinched hysteresis.

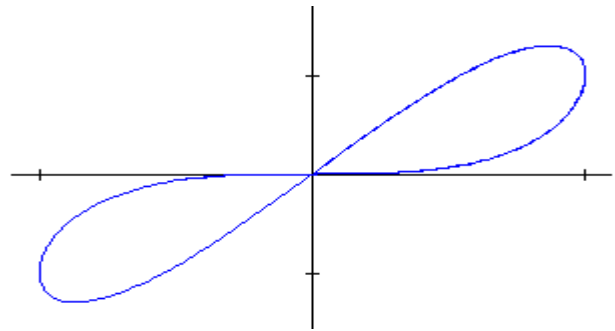


Fig 2. Pinched Hysteresis

TITANIUM OXIDE MEMRISTOR

Interest in the memristor revived when an experimental solid state version was reported by R. Stanley Williams of Hewlett Packard in 2007. The article was the first to demonstrate that a solid-state device could have the characteristics of a memristor based on the behavior of nanoscale thin films. The device neither uses magnetic flux as the theoretical memristor suggested, nor do stores charge as a capacitor does, but instead achieves a resistance dependent on the history of current.

POLYMERIC MEMRISTOR

In 2004, Krieger and Spitzer described dynamic doping of polymer and inorganic dielectric-like materials that improved the switching characteristics and retention required to create functioning nonvolatile memory cells.



They used a passive layer between electrode and active thin films, which enhanced the extraction of ions from the electrode. It is possible to use fast ion conductor as this passive layer, which allows a significant reduction of the ionic extraction field.

LAYERED MEMRISTOR

In 2014, Bessonov et al. reported a flexible memristive device comprising a $\text{MoO}_x/\text{MoS}_2$ heterostructure sandwiched between silver electrodes on a plastic foil. The fabrication method is entirely based on printing and solution-processing technologies using two-dimensional layered transition metal dichalcogenides (TMDs). The memristors are mechanically flexible, optically transparent and produced at low cost.

FERROELECTRIC MEMRISTOR

The ferroelectric memristor is based on a thin ferroelectric barrier sandwiched between two metallic electrodes. Switching the polarization of the ferroelectric material by applying a positive or negative voltage across the junction can lead to a two order of magnitude resistance variation.

APPLICATIONS

1. **NEUROMORPHIC SYSTEM:** - Nanoscale memristor device is used as synapse in neuromorphic system. Neuromorphic circuits with memristor as synapse provide both high connectivity and high density which is required for efficient computing.
2. **NEUROELECTRONICS MEMORIES**
3. **PROGRAMMABLE LOGIC AND SIGNAL PROCESSING:** - Memristor has wide application in programmable logic and signal processing. The memristive applications in these areas will remain relatively the same, because it will only be a change in the underlying physical architecture, allowing their capabilities to expand, however, to the point where their applications will most likely be unrecognizable as related.
4. **BRAIN COMPUTER INTERFACES**

5. Memory for cameras, cell phones, iPods, iPads, etc.
6. Advanced artificial thinking brains

CONCLUSION

If the theory generated by the Williams is right then we should start seeing these memristive memory device in the commercial market soon. With the help of memristors we would take the future of electronics towards the level of brain computing. With memristors every electronic device has the capability of thinking because every single device contains an artificial brain.

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