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Resistive Random Access Memory (ReRAM)

ORIGINAL ARTICLE

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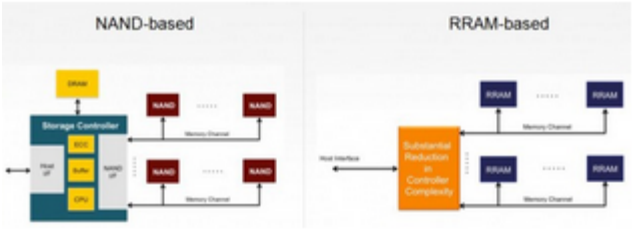
Abstract **- Resistive Random-Access Memory (ReRAM) technology has been viewed as one of the most reliable non-volatile memories that have are emerging in markets. In this research paper, the revolution of ReRAM will be analyzed. Also, the paper will also review the recent progress in the technological development of ReRAM. The performance parameters of these non-volatile memories such as their operating voltage, operation speed, resistance ratio, endurance, retention time, device yield, and multilevel storage will be analyzed. Integration and reliability of Re-RAM in the practical level is compared with other types of memories. Challenges faced by users of ReRAM are addressed in regards to technological fallbacks among other challenges. Finally, the future research on the ReRAM will be analyzed.**

Keywords**:** *resistive random access memory, resistive switching, performance parameters, resistance switching, electrochemical devices.*

I. INTRODUCTION

RRAM, also referred to as ReRAM (resistive random-access memory), is a form of nonvolatile storage that operates by changing the resistance of a specially formulated solid dielectric material [1]. The ReRAM device are known to have a component, memristor, which contracts thus creating some form of resistance which differs with voltages imposed to it. ReRAM is an emerging technology that is being applied by many users and has the special features of combining the advantages of both RAM and Flash. It is likely to replace the flash as it performs highly and has manufacturability benefits as compared to the competing replacement alternatives. Unlike other types of RAM memories, ReRAM involves production of defects in a thin oxide layer, known as oxygen vacancies, that are subsequently charge and drift under an electric field.

ReRAM is comparable to the NAND Flash memory in that ReRAM operates through creating resistance instead of storing charge [2]. The materials of the ReRAM are built to change resistance when current is applied. Figure one below compares the NAND-based memory and a RRAM-based structure of a memory.



The applications of ReRAM popularly known include the memories for computers, consumer electronics, smartphones, tablets, and enterprise storage. With the technological advancements, it is expected that there will be more growth opportunities for the ReRAM application. In the coming years, ReRAM will be used in automotive infotainment and navigation systems, deep learning, wearables, and the Internet of Things (IoT).

II. HISTORICAL PERSPECTIVES OF RE-RAM

For more than four decades, the Flash Memory technology has dominated the electronic memory industry. However, it was until the early 2000s that ReRAM was developed with some pioneer companies such as KB-capacity scale [3]. Different forms of ReRAM have been developed whereby manufacturers use different dielectric materials to gain a more effective storage device. Over the years, RAM memory devices have been drastically been changed to improve speed and performance of GPUs, CPUs, and Computing processes thus have developed exponentially [3].

III. CURRENT TRENDS OF RE-RAM

Currently, the demand for high-driven memory devices has been promised through the revolution of flash cards and RAM devices. The high-standards of next-generation memory demands portray that there are limiting current Flash technology in terms of its crucial scaling limitations [4]. Also, the demand for storage devices that consume less

energy, cheap, and with a high switching speed has retained sustainability of the ReRAM market [5]. The overall market size for Flash memory is estimated to be approximately $40 billion which is growing a steady rate. However, with the emergence of the non-volatile memory market, it is expected that the market will increase from $ 580 million to $ 3,527 million by 2020. According to predictive analytics, the use of ReRAM is expected to grow remarkably from 2019 onwards since it was observed to be growing at CAGR of 53.07% from 2015 to 2020. ReRAM technology is currently considered to be compatible to the CMOS technologies. Being the best resistance switching carrier, the material approved for the manufacture of the ReRAM chips are metal oxides in group VI and III-V semiconductors [6].

IV. PERFORMANCE PARAMETERS OF RE-RAM

The resistive RAM (ReRAM) is popular for its exemplary performance in the memory-class devices. The devices have a fast access time, pertains an ultra-low stand-by power thus making it cost effective. The device is highly reliable as it makes it a viable technology that can perfectly replace the DRAM technologies. The circuit operations parameters of ReRAM are considered essential in promoting its remarkable performance. Some of the circuit operation parameters include the pulse amplitude and pulse widths of the word-line (WL) voltage, bit-line (BL) voltage, and source-line (SL) voltage can be used to lower latency, lower power and thus improve reliability [8]. The appropriate choice of these types of voltages has been used to reduce latency of the 1T1R cell by 29.4% and minimize the write energy by 46.7% over the DRAM cell.

Other performance parameters improving the operations of ReRAM include its operation voltage, high operation speed, high resistance ratio, endurance strengths, high retention time, device yield, and multilevel storage [7]. The numerous resistive-switching mechanisms that portray the high ReRAM capabilities include conductive filament, space-charge-limited conduction, trap charging and discharging features. Schottky Emission, and Pool-Frenkel emission are some of the proposed performance enhancements that will continuously improve the resistive switching features of RRAM devices.

V. INTEGRATION AND RELIABILITY OF RE-RAM

The potential of ReRAM devices has been observed through the practical application level. However, there are more pressing issues presented for how the ReRAM operates. The controlling abilities of the oxidation of the metal during the thin film growth has made the device more reliable than other storage devices [9]. The oxide layer on the ReRAM electrode plates plays a crucial role in ReRAM resistance switching operations. Researchers advocate for more research on how reliability and integration of ReRAM is to be effective. Development of techniques to understand the failures of ReRAM is considered as part of integration. An example provided is on how a transmission electron microscope with an electron energy-loss spectroscopy function will be a powerful tool to investigate how the interface features between metal electrodes and the oxide layer interact. Another integration portrayed is how the capacitance of MOM structure certainly affects the fast operation of the ReRAM device [10].

VI. RESISTANCE SWITCHING CONCEPT

One of the fundamental characteristics of ReRAM is the resistance switching physical effect. The resistance switching phenomenon having been under research for more than 40 years, engineers have for long been working in a memory that would have a strong resistance to the over charged currency. In 2002, when the first ReRAM was developed [11], the engineers responsible demonstrated that ReRAM would perfectly operate below 3V and 2 mA. ReRAM has been considered as the best candidate for the beyond-2Xnm generation of the nonvolatile memories [11]. One reason for this classification is its high compatibility features with the CMOS technologies.

VII. PROS AND CONS OF RE-RAM

There are several advantages and disadvantages that linked to the use and features of ReRAM. To begin with the pros, the ReRAM are attributed to consume less power as compared to other RAM devices installed in computers [12]. The Re-RAM has a simple structure which is small in size. Re-RAMs are also fast both in performance and in the switching speed. The devices are also advantageous since they have a high endurance and a high retention time aspect thus can be scaled down to meet the nanometers measures as well as the 3D stacks that reduce the die area. In past research studies on binary-based-based ReRAM, researchers acknowledge that ReRAM have stable resistance traits existing in the bipolar mode rather than the unipolar mode. The low-power consumption of the ReRAM operation makes the devices strong cost competitiveness to ReRAM.

VIII. CHALLENGES OF USING AND DEVELOPING RE-RAM

The new non-volatile memory technology is faced with several challenges. Firstly, the application of flash technology has long been embraced by most tech-users. As a result, the competition in the memory industry is relatively high for the ReRAM users. Despite some of the ReRAMs, such as the Crossbar's ReRAM, has successfully replaced some of the flash memory devices [12].

More so, in the development of ReRAMs, developers of this particular technology, face several challenges. One of the main challenges is on how to overcome temperature sensitivity during the manufacturing phase without

destroying chips. Secondly, integrating with standard CMOS technology and manufacturing processes have been quite challenging. Thirdly, there are limiting impacts of sneak path currents that alter the stability of data contained in each memory cell [13]. Also, to achieve the ultra-high-density ReRAM of more than 1 Tb has been overcome by the leakage of current in the crossbar arrays of ReRAM.

IX. FUTURE RESEARCH ON RE-RAM

According to research, the endurance of ReRAM devices can be accounted to be currently at 10^9. This level of endurance, is considered not to be sufficient to allow ReRAM replace the DRAM. For DRAM, it also has benefits such as a high switching speed and has similar capacity. Research on how to improve on the current level of endurance to higher levels is necessary in future researches to ensure that ReRAM remains superior in the memory market. Also, the basic studies on ReRAM fail to show a more realistic approach on how resistance switch has promoted realistic applications for more than 30 years [14].

The future of ReRAM technology is that it will not only target the storage-class memory but also targets other segments such as the neural networks. Facebook, Google, and other companied that depend on machine learning are widely using the ReRAM technology by analyzing data to come up with patterns.

X. CONCLUSION

In this research paper, the concept of ReRAM technology has been discussed in detail, the unique features such as resistance switching power, the unique materials such as memristor, and its many benefits in the memory industry have been established. The revolution since the year 2002 to current period has portrayed how advancements in the use of ReRAM are likely to lead to replace the Flash technology. Current trends in the application of ReRAM include application in the machine learning technology. ReRAM technologies have been used in recent developments in IoT, robots, virtual learning among other uses. The integration and reliability of the technology portrays how the oxide layers and the 3D aspects improve the product resistance. The performance advantages include cost effectiveness, low-power usage, and improved storage solutions. However, there have been challenges in the manufacturing and application of the ReRAM devices. The resistance switching capabilities of ReRAM devices have been effective in promoting the performance of the device. Number of studies reviewed show that the future allows the redefinition of the application of ReRAM making it attractable for use in the not only the high-density storage applications but also due to its high performance it has in the memory devices class. The challenges faced by manufacturers of ReRAM are also addressed whereby the min challenge remain overcoming the temperature sensitivity. The integration and reliability of ReRAM is addressed with more opportunities revealed on how the technology can be improved from present failures.

Future research could be considered in neural technology, machine learning by using ReRAM.

XI. DECLARATION

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