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Research of Memory Cells and Their Applications

Pok Chung Ryan Cheng

Yew Chung International School of Shanghai, Shanghai, China

*Corresponding author: pokchung.cheng2026@ycis.com

Abstract:

In our rapidly evolving world saturated with technology, the demand for superior and more efficient memory cells is increasingly crucial to fuel further technological advancements. As artificial intelligence and cutting-edge technologies become a reality, enhancing the quality of memory cells embedded in our machines and devices is paramount. This report will explore the future of memory cells and provide an overview of their current state. The primary focus of this paper will be on the present state of memory cells, including the various types that exist, explaining the fundamental principles behind them, and delving into the new technologies our society will possess and utilize in the future. During my research, this paper discovered several promising developments for the future of memory cells, such as NAND technology and Solid-State Drives (SSDs). The progression of storage technology is critical in supporting emerging technologies like big data, cloud computing, and the Internet of Things. As data volumes grow exponentially, this paper requires faster, more reliable, and energy-efficient storage solutions. Innovative concepts like quantum storage and DNA storage are also being researched, potentially revolutionizing how this paper store and access information. Moreover, advancements in storage technology will impact fields such as mobile devices, wearable technology, and autonomous vehicles. More efficient memory cells will enable these devices to handle more complex tasks and provide richer user experiences. Overall, the future of storage technology is promising and will continue to drive technological innovation and societal progress.

Keywords: Technology; Efficiency; Innovation.

1. Introduction

The quantity of data generated worldwide is growing at an unprecedented rate, by the next year there will be 175 zettabytes of data worldwide [1]. In this situation of extreme data growth, this paper needs to

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combat this with new and improved storage and memory cells to help combat this data explosion. To understand the ubiquity of memory cells in our daily lives, let's start with a simple exercise. Look around the room. Memory cells can be found everywhere one looks. They are extremely crucial for electronic devices and are a fundamental component of electronic devices. Ranging from the laptops used for work or school; to phones used for relaxation or even digital cameras for taking pictures. Memory cells are responsible for storing data and essential instructions to allow our devices to execute and process different things. Memory cells are the fundamental units of memory storage in electronics, designed to store binary data - either a '0' or a '1'. Memory can either be volatile or nonvolatile, which utilize different architectures. If it is volatile, this means that the content stored is lost whenever there is no constant power supply, this means that RAM is a volatile memory, where memory cells are usually found. Things such as flash memory or SSDs are nonvolatile memory, and so their contents are stored permanently even if there is no power supply, suitable for long-term use.

However, as our technology is advancing as this paper approach the late middle 21st century, the need for more efficient, faster, and high-capacity memory cells is crucial. Things that were once seen as impossible such as playing games in 4k are now common worldwide. If this paper still use the same memory cells this paper use today for future development, development may be nonexistent. Seeing as how our computers today that this paper use for pleasure and work were once the most efficient and fast computers in the world in the past century. This report will take a look into the current architecture of memory cells, how it works, its structure, and also what the future of memory cells could look like.

2. Current State of Memory Cells

2.1 Current types of volatile memory cells

In today's technology, SRAM and DRAM are the most common types of memory cells used in devices. The SRAM is a memory cell that uses flip-flop circuits, which have two stable states that can store information that represent either 1 or 0, SRAM are usually made up of 6 transistors that form a latch. While DRAM does not use flip-flop circuits and instead uses one MOS capacitor and one MOSFET transistor; however, DRAM needs to be periodically refreshed as data is delayed [2]. In SRAM or DRAM, both utilize MOS architecture such as MOS capacitors, in addition to MOSFET.

The two different types of structures implemented into SRAM and DRAM can have differences. SRAM is way faster at processing than DRAM. Also, SRAM has more power consumption than DRAM leading it to be more expensive. In addition to that, SRAM is usually designed as an integrated chip whilst DRAM is usually designed as a chip. SRAM is also smaller than DRAM, with SRAM being less dense than DRAM. Overall, SRAM is fast and efficient but expensive and power-intensive, making it ideal for cache memory. In contrast, DRAM is slower but cheaper and more power-efficient, making it suitable for main memory (RAM) [3].

2.1.1 Current Memory cells

Volatile memory in RAM, including SRAM and DRAM, is built upon MOSFET technology, which is derived from the field effect transistor (FET). A field effect transistor utilizes an electric field to control the current that flows through a semiconductor channel.

The FET consists of three terminals: source, drain, and gate. The source is where either electrons or holes enter the FET, and the drain is where either electrons or holes leave the FET; where the gate is the terminal that controls the conductivity of the channel between the source and the drain. When voltage is applied to the gate, an electric field is created. This field either attracts or repels charge carriers, depending on the polarity of the applied voltage.

The MOSFET architecture is based on the FET structure, however it has more features to make it more reliable and faster. As MOS stands for metal oxide semiconductor, the gate is made from metal and, there is an insulating layer of metal oxide between the gate and the channel; this allows only the electric field to change and alter conductivity, (Saurabh, 2019). This ability to change conductivity with the amount of applied voltage can be used for amplifying and or switching electronic signals.

2.1.2 Current Types of Non-Volatile Memory Cells

As previously mentioned, memory cells are also a key component of nonvolatile memory systems. Most non-volatile memory structure is based on the floating gate memory cell architecture, which is based on floating gate MOSFET transistors. SSD, Hard drives, etc... Use this type of memory structure, as there is all nonvolatile memory.

While similar to the FET architecture in having a source and a drain, the floating gate memory cell differs by incorporating both a control gate and a floating gate. The voltage applied to the control gate will charge up the floating gate, which then will change the resistance between the drain and the source. A high voltage is needed to write, a high voltage with opposite polarity is needed to erase and a low voltage to control gate is needed to read.

2.1.3 Current Types of Non-Volatile Memory Cells

The size of a memory cell is typically 64 nanometers long, 32 nanometers wide, and 360 nanometers tall. The DRAM is organized into 8 bank groups composed of 4 banks each which come out to 32 total banks. With the banks multiplied with columns and rows, it typically results in 17 billion memory cells in one 2GB DRAM. When storing a “1”, the capacitor is charged and maintains a high voltage state, while storing a “0” the capacitor is discharged and maintains a low voltage state. For a basic DRAM, to read or write, the transistor is activated, this then allows the charge in the capacitor to be detected and or altered. A basic DRAM cell consists of just two components: a capacitor to store the electrical charge, and a transistor to control access to this capacitor. As mentioned before, the DRAM has to be periodically refreshed as data will slowly discharge naturally. The regular refresh operation is usually performed every 64 milliseconds to ensure the data stored is accurate and can be used [4]. DRAM is also denser to increase storage density and store more data.

2.2 The Future of Memory Cells

Looking to the future of memory cells, it’s worth considering a technology that’s already becoming ubiquitous. Solid-state drives (SSDs) are now commonly found in laptops and personal computers. SSDs are a prime candidate for the role model of memory cells that could be used in the next decades or centuries. SSDs are nonvolatile memory storage devices that store data permanently, replacing traditional hard disk drives while offering improved performance for the same functions. SSDs are also sometimes incorporated inside graphics cards [5].

SSDs use NAND flash memory, a type of storage that does not need power to retain its data. There are also different types of NAND flash memory, with there being single-level cells, double-level cells, triple-level cells, and quadruple-level cells with each storing 1,2,3,4 bits per cell respectively. The results of this are that single-level cells are fast, durable, and efficient, with the quad-level cell being more cost-effective and having worse performance. The multi and triple-level cells are balanced in the middle [6].

2D NAND was once hailed as the “future of memory cells” due to its potential for increased storage density. 2D NAND is a type of flash memory, where flash memory cells are placed side by side on a transistor planar disc. For years, the limiting factor of 2D NAND has been the number of cells that can fit within a single plane on a chip. People have tried making the cells smaller, but the chance of electron leakage is higher which then reduces the reliability of the whole flash memory. However, we’re now reaching the physical limits of what can be achieved on a 2D plane.

Now, 3D NAND technology is making a name for itself. 3D NAND is the latest generation of NAND technology. Unlike 2D NAND where memory cells are stuffed into a limited space on a chip, 3D NAND stacks the memory cells vertically as shown in Fig. 1. 3D NAND chips use state-of-the-art process technology to vertically connect the cell layers with channel holes, which are passageways for data [1]. This is analogous to a city running out of land for expansion, and thus building upwards to accommodate a growing population. Significantly greater storage capacity is provided by this new architecture, and the cost per gigabyte is also cheaper, but storage capacity isn’t the only factor. In addition to processing data twice as quickly as previous NAND chips, 3D NAND reduces power usage by half [7].

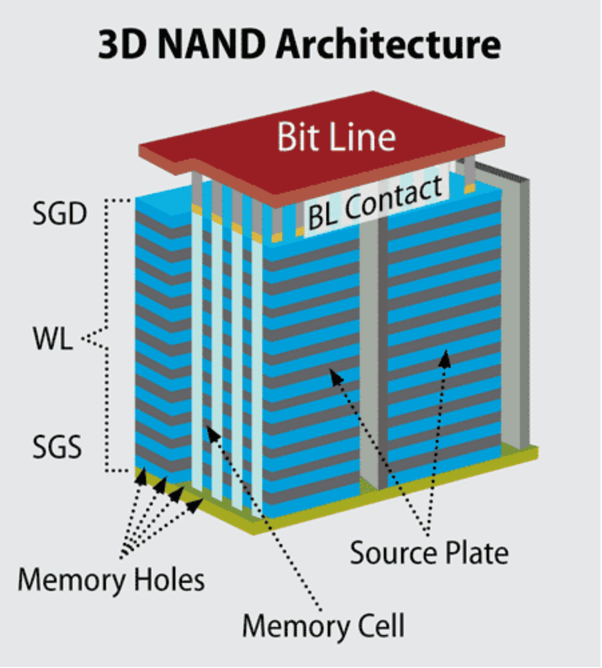

Fig. 1 3D NAND [1].

3. Conclusion

In conclusion, current memory cell technologies have proven to be highly effective for their intended purposes. SRAM, DRAM, and nonvolatile memory such as hard disk drives have had a great impact on our world of electronics and our storage capabilities. However, the need for more innovative and new concepts of memory storage has never been in greater demand. As our world has almost reached a combined total of zettabytes of worldwide storage, new memory cell architecture will be needed. This new era of 2D and 3D NAND technology will not only bring us more storage capacity but will also enable us to

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do greater feats in the future that this paper never could have even deemed to be possible. This means that for the everyday user of electronic devices, there will be more data capacity, more reliability, faster speeds, and better power durability in our devices.

However, there are numerous challenges that come with 3D NAND. The leap from 2D to 3D NAND necessitated a complete overhaul of manufacturing processes for memory devices. A focus on process efficiency, materials innovations, and contamination controls will be crucial to achieving high volume manufacturing that meets performance, yield, and cost requirements. With this in mind, this paper hopes our electronics become more and more innovative in the future.

References

[1] Merck Group. 3D NAND: The Future of Flash Memory. 2018. Available: www.merckgroup.com/en/research/science-space/envisioning-tomorrow/smarter-connected-world/3d.html.

[2] Gillis Alexander S. Flash memory and storage. TechTarget. Available: techtarget.com. Accessed 9 Aug. 2024.

[3] Unacademy. DRAM and SRAM. 16 May 2022. Available: unacademy.com/content/difference-between/dram-and-sram/#:~:text=Definition%3A%20Both%20SRAM%20(Static%20Random. Accessed 9 Aug. 2024.

[4] Built In. What Is an FET (Field-Effect Transistor)? Available: builtin.com/hardware/fet#:~:text=A%20field%2Deffect%20transistor%20(FET. Accessed 9 Aug. 2024.

[5] H. Q. Pon, et al. Reliability issues studied in Solid-State Drives. 2014 IEEE 6th International Memory Workshop, Taipei, Taiwan, 2014, 1-4.

[6] Central Valley Computer Parts. Memory Cells Explained! Available: centralvalleycomputerparts.com/articles/memory-cells-explained/. Accessed 9 Aug. 2024.

[7] Content Studio. What Is 2D NAND and How Does It Work? Pure Storage. 24 Jan. 2022. Available: www.purestorage.com/knowledge/what-is-2d-nand.html. Accessed 16 Aug. 2024.