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Analysis of PRAM Memory

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***Abstract*—Memory is an essential storage space in computer. The instructions as well as data required for processing are stored in the memory. In computing, memory refers to the computer hardware integrated circuits that store information for immediate use in a computer. Without memory there will be no computer in the present day. Computer memory operates at a high speed.**

Memories are broadly classified as volatile and non-volatile memory. Random Access Memory a volatile memory has a distinction from storage that provides slow to access information but offers higher capacities. Phase change memory or Phase change Random access Memory is a non-volatile memory exploits the unique behavior of chalcogenide glass. The unique features of PRAM are a promising next generation memory. Newer Phase Change Memory technologies have been trending in the present-day technology. Various memories that has been developed on Memory Devices is presented.

Keywords*—*Memory; Phase change; Random access; Hardware;

I. INTRODUCTION

Computer memory is broadly classified into random access and read only memory. Further random-access memory (RAM) is classified into volatile and non-volatile. Few examples in the volatile category are static and dynamic, while in non-volatile category are NVRAM, BRAM, FRAM and PRAM. RAM is popularly called as a read or write memory. It forms an integral part of the internal memory of the central processing unit (CPU) for storing data, program and program result.

A RAM memory chip is an integrated circuit (IC) which consists of millions of transistors and capacitors. It is a type of memory which serves as a main memory of a computer. It temporarily stores a copy of information and files loaded from a computer hard disk drive (HDD) that are required by a processor. It is volatile in nature such the data will be erased once the power supply is turned off. It stores data randomly and the processor accesses these data randomly from the RAM storage.

When the computer first starts a program, it sends an address to the RAM to begin retrieving that program. The RAM address just consists a series of the binaries ie 1's and 0's representing 'ON' and 'OFF' state of the wire. RAM does not do anything with that address until the CPU turns on the "SET" or "ENABLE" wire. If the enable wire is turned ON the RAM automatically senses the data corresponding to that address back to the CPU, that data is then processed by the CPU accordingly.

PRAM (chalcogenide RAM) is a type of non-volatile random-access memory. It is a form of computer random-access memory (RAM) that stores data by altering the state of the matter from which the device was fabricated.

II. METHODOLOGY

Phase-change Random Access Memory (PRAM) as shown in Figure 1 is the next generation non-volatile memory [1]. This is because PRAM has a great potential not only to provide sufficient solutions for solving the scaling issues that other conventional non-volatile memories might face in the future generations, but PRAM has been the fastest evolutionary memory.

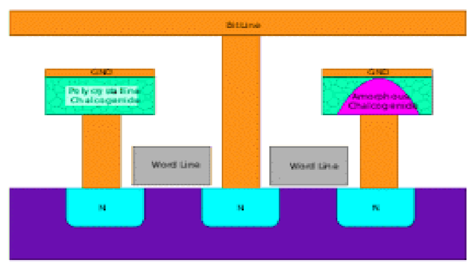

Figure 1: Fabrication structure of PRAM

The crystalline and amorphous states of chalcogenide glass have very different electrical resistivity values. The amorphous, high resistance state represents a binary 0, while the crystalline, low resistance state represents a binary 1. The internal details of PRM are shown in Figure 2.

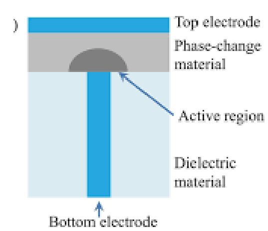

Figure 2: Internal details of PRAM

Chalcogenide is the same material used in re-writable optical media (such as CD-RW and DVD-RW). In that situation, the material's optical properties are manipulated, rather than its electrical resistivity. PCM is sometimes called "perfect RAM" (PRAM) because data can be overwritten without having to erase it first. The electrical behavior of PRAM for the variations in voltage resulting in corresponding current is as shown in Figure 3.

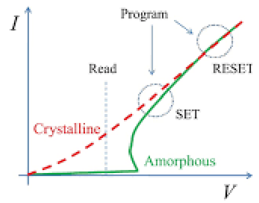

Figure 3: V-I characteristic of PRAM

Though it is a promising candidate for next generation memory due to many advantages, the reset current is high to drive a small CMOS transistor [2].

III. Analysis

A. Speed and Potential

PRAM enables the rewriting of data without a separate erase step, making the memory to be 30 times faster than the flash, but its access speed does not match that of flash memory. A person using a computer with PRAM could turn it off- on and pick up right where he left off. He could do so immediately or even after 10 years. Such computers do not lose critical data in a system when it crashes or when the power goes off unexpectedly.

'Instant-on' would become a reality and users would no longer have to wait for a system to boot up and load DRAM. PRAM memory could help significantly to increase the battery life for portable devices. The properties of PRAM are listed as in Table 1.

Table 1: PRAM property

State	Properties
Amorphous	Short range atomic order High reflectivity High resistance
Polycrystalline	Long range atomic order Low resistance

B. Scalability

For the future technology or generations, the scalability of PRAM is another area where it could provide advantages, although which is yet to be realised. The reasoning is that both NOR and NAND flash variants rely on floating gate memory structures which are very tough to shrink.

It is found that as the memory cell size is decreased, the number of electrons stored on the floating gate is reduced. This makes the detection of smaller charges more challenging to reliably detect with accuracy.

PRAM does not store charge, but instead it relies on a resistance change. As a result, it is not susceptible to the same scaling phenomena.

C. Advantages

PRAM has various advantages as it exploits the unique behavior of chalcogenide glass. This memory technology is being trending in present days. They are

1) Non-volatile: Phase change RAM is a non-volatile form of memory. It does not require power to retain its contents. This enables it to compete with the flash memory.

2) Bit alterable: Similar to RAM or EEPROM, P-RAM or PCM is termed as bit-alterable. The information can be written directly to it without the need for an erase process. Whereas Flash memory requires an erase cycle before new data can be written to it.

3) Fast read performance: Phase change RAM has fast random access time. It enables the execution of code directly from the memory, without the need to copy the data to RAM and execute the program.

The read latency of P-RAM is comparable to single bit per cell NOR flash, while the read bandwidth is similar to that of DRAM cell.

4)Write/erase performance: The write erase performance of P-RAM is appreciable by having faster speed and lower latency than NAND flash. Since erase cycle is not required there will be an overall significant improvement over Flash memory.

D. Disadvantages

There are a number of obstructions to the successful commercialization of PRAM due to its high cost.

1) Multiple bit storage per cell of Flash: The ability of Flash to store and detect multiple bits per cell still gives flash memory an advantage over PRAM. PRAM has advantages in scalability phenomena for the future memory technology.

2) Commercial viability: Despite of having many advantages in PRAM, few companies have been able to manufacture chips that have been successfully commercialized and marketed in the real-world applications.

IV. Comparison of Different RAM

A. Static RAM (SRAM)

It is able to retaining its information even as long as power remains applied. SRAM chips use a matrix of 6-transistors and capacitors are not used. Static RAM is used as cache memory.

SRAM as shown in Figure 4 uses more chips than DRAM for the same amount of storage space, which indirectly increases the manufacturing costs. It is a type of memory in which the memory refreshing is not required. It uses flip-flops to store the binary bit message.

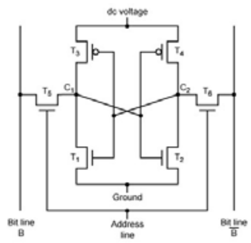

Figure 4: Static RAM

B. Dynamic RAM (DRAM)

It requires periodic refresh in order to retain the data. DRAM is made up of memory cell consists of one capacitor and one transistor as shown in Figure 5. It is used for majority of the system memory because it is less expensive and small in size. It is a type of RAM that stores each bit of data in a separate capacitor within an integrated circuit.

It uses the capacitor to store data, 1 means charging and 0 means discharging. Capacitor will lose its charge with time need to be refreshed periodically. Its advantage is its structural simplicity as compared to four transistors in SRAM. This allows DRAM to have very high density. DRAM chips are available in different varieties of design.

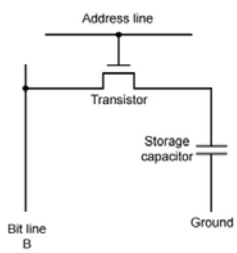

Figure 5: Dynamic RAM

C. Extended Data Out DRAM (EDODRAM)

The cells of the EDODRAM hold the data valid until it receives an additional signal. It has a dual-pipeline architecture which allows the memory controller to simultaneously read the new data while discarding the old data. Figure 6 shows an EDODRAM which is available the present-day market.

Figure 6: Extended Data Out DRAM

D. Synchronous DRAM (SDRAM)

It has a synchronous interface and pipeline architecture which means that it waits for a signal before responding to the control inputs. Pipelining means that the chip can accept a new instruction before it has completed processing the previous instruction.

It is synchronized with the computer's system bus. SDRAM as shown in Figure 7 allows the chip to have a more complex pattern of operation than asynchronous. SDRAM has synchronous interface whereas DRAM does not have.

Figure 7: Synchronous DRAM

E. Rambus DRAM(RDRAM)

It is a type of synchronous DRAM which was designed by the Rambus Corporation as shown in Figure 8. It is fairly fast and has tried to deal with some of the complex electrical and physical problems involved with the memory.

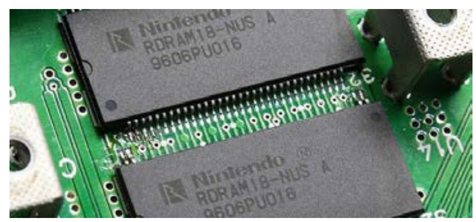

Figure 8: Rambus DRAM

F. Double Data Rate DRAM (DDRDRAM)

Unlike SDRAM, it can do two operations per cycle thereby doubling the memory bandwidth over the corresponding single-data-rate SDRAM. Short form for Double Data Rate is DDR shown in Figure 9 is a type of memory that was first introduced in 1996 and has been replaced by DDR2.

DDR utilizes both the rising and falling edge of the system clock, potentially of doubling the speed of the memory. Today, DDR technology is found on high-end video cards and computer memory such as DDR-SDRAM.

Figure 9: Double Data Rate DRAM

G. NAND and NOR Flash Memory

NAND is a type of solid-state memory which persists data electronically without any mechanical assistance (i.e. moving parts) like standard platter based hard drives do. NAND memory shown in Figure 10 is a non-volatile type of memory.

It does not require power to retain the data stored on it. Due to lack of random-access capabilities, it is most commonly used in secondary memory applications.

Figure 10: NAND Flash Memory

Due to its non-volatility, higher density, lower cost, and faster write times relative to NOR flash memory, it is ideal for the use as storage in mobile devices such as digital cameras, MP3 players, and USB pen drives. It

is a type of solid-state memory, unlike NAND flash memory which persists data electronically without the use of mechanical parts. It can be used as an ordinary non-volatile secondary storage.

Comparison of memories is done by considering the parameters like non-volatility, latency, energy and power. The respective values are tabulated as in Table 2.

Table 2: Comparison of Memories

	DRAM	PCM	NAND Flash	HDD
Non-volatility	No	Yes	Yes	Yes
Read Latency	50ns	50 - 100ns	10-25us	~10ms
Read Energy	~0.1nJ/b	<<1nJ/b	<<1nJ/b	>10nJ/b
Write Latency	~20 - 50ns	~1us	~100us	~10ms
Write Energy	~0.1nJ/b	<1nJ/b	0.1 - 1nJ/b	>10nJ/b
Power	10mW/GB	500mW/die	~100mW/die	~10W
Idle Power	10mW/GB	<<0.1W	<<0.1W	<10W

V. CONCLUSION

The amount of RAM is more important than the type of RAM being used. This is because more the RAM available in a system, more the number of tasks can be performed simultaneously without any performance drop. Computers used nowadays comes with DDR2, DDR3 RAM.

While RDRAM did not become popular due to high licensing fees, high cost, being a proprietary standard, and low performance advantages for the increased cost. It is being used in some graphics accelerator boards in place of VRAM and is also being employed in Intel's Pentium III Xeon processors.

VI. FUTURE OF PRAM

Future computers and electronic gadgets will need memory chips that are smaller, faster and cheaper than those of present day RAMs. RRRAM (Resistive RAM) and Z-RAM (Zero-capacitor RAM) are the future runners in the global technology race as the next generation RAM. Innovative Silicon, developer of Z-RAM claims that the technology offers memory access speeds similar to a standard SDRAM used in cache memory but it uses only a single transistor, therefore affording much higher packing densities.

On the other hand, crossbar, a U.S based tech firm claims to have achieved a "simple and scalable" memory cell structure of RRAM consisting of three layers. The structure is that the cells can be stacked in 3D, squeezing terabytes of storage capacity onto a single chip of the size of a postage stamp.

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