Advances in Computer Random Access Memory

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Introduction

Random-access memory (RAM) is a form of computer data storage and is typically associated with the main memory of a computer. RAM in popular context is volatile but as would be seen later on in the discussion, they need not be. Because of increasing complexity of the computer, emergence of portable devices, etc., RAM technology is undergoing tremendous advances. This report looks at some recent advances in RAM technology, including that of the conventional Dynamic Random Access Memory in the form of DDR 3 (Double Data Rate Type 3). We also look at the emerging area of Non-volatile random-access memory (NVRAM). NVRAM is random-access memory that retains its information when power is turned off, which is described technically as being non-volatile. This is in contrast to the most common forms of random access memory today, dynamic random-access memory (DRAM) and static random-access memory (SRAM), which both require continual power in order to maintain their data. NVRAM is a subgroup of the more general class of non-volatile memory types, the difference being that NVRAM devices offer random access, unlike hard disks.

Double Data Rate 3 Synchronous Dynamic Random Access Memory

DDR 3, the third-generation of DDR SDRAM technology, is a modern kind of DRAM with a high bandwidth interface. It is one of several variants of DRAM and associated interface techniques used since the early 1970s. DDR3 SDRAM is neither forward nor backward compatible with any earlier type of RAM due to different signaling voltages, timings, and other factors. It makes further improvements in bandwidth and power consumption in comparison to DDR 2 . DDR3 manufacturers began fabrication using with 90 nm technologies. With increasing production volumes, they are moving toward 70 nm technology. DDR3 operates at clock rates from 400 MHz to 1066 MHz with theoretical peak bandwidths ranging from 6.40 GB/s to 17 GB/s. DDR3 DIMMs (Dual Inline Memory Modules) can reduce power consumption by up to 30% compared to DDR2 DIMMs operating at the same speed. DDR3 DIMMs use the same 240-pin connector as DDR2 DIMMs, but the notch key is in a different position. DDR3 sales account for around 70 percent of the total DRAM units sold in 2011.

DDR3 SDRAM DIMM manufacturers produce two types of DIMMs: Unbuffered DIMMs (UDIMM) and Registered DIMMs (RDIMM). UDIMMs are the most basic type of memory module and offer a lower latency and low power consumption but are limited in capacity. RDIMMs offer larger capacities than UDIMMs and include address parity protection.

Zero-capacitor Random Access Memory

Z-RAM is a memory technology which relies on the "floating body effect" observable in SOI (Silicon on Insulator) substrates. Basically, a type of charge accumulates within the transistor when SOI is used as a substrate, creating an undesirable parasitic effect. While normally unwanted, a technique to utilize the known effect for a type of memory storage in high-speed data systems has been developed, which forms the technological basis for Z-RAM. Since their design does not use capacitors, but rather relies upon the capacitance effect of the floating body, Z-RAM requires significantly less power to operate, for reads, writes and refreshes. Z-RAM is a denser form of memory, when compared to DRAM. It is a capacitor-less design, and therefore consumes significantly less power for data retention, and a commensurate amount of power for data reads and writes.

A non-SOI version of Z-RAM that could be manufactured on lower cost bulk CMOS (Complementary Metal Oxide Semiconductor) technology is supposedly under way.

Thyristor RAM

T-RAM is a new type of DRAM computer memory which departs from the usual designs of memory cells, combining the strengths of the DRAM and SRAM: high speed and high volume. This technology, which exploits the electrical property known as negative differential resistance and is called thin capacitively-coupled thyristor, is used to create memory cells capable of very high packing densities. Due to this, the memory is highly scalable, and already has a storage density that is several times higher than found in conventional six-transistor SRAM memory.

Twin Transistor RAM

TTRAM is a new type of computer memory in development which is similar to conventional one-transistor, one-capacitor DRAM in concept, but eliminates the capacitor by relying on the floating body effect inherent in a Silicon on Insulator (SOI) manufacturing process. This effect causes capacitance to build up between the transistors and the underlying substrate, originally considered a nuisance, but here used to replace a part outright. Since a transistor created using the SOI process is somewhat smaller than a capacitor, TTRAM offers somewhat higher densities than conventional DRAM. Since prices are strongly related to density, TTRAM is theoretically less expensive. However the requirement to be built on SOI fab lines, which are currently the “leading edge”, makes the cost somewhat unpredictable at this point.

In the TTRAM memory cell, two transistors are serially connected on an SOI substrate. One is an access transistor, while the other is used as a storage transistor and fulfils the same function as the capacitor in a conventional DRAM cell. Data reads and writes are performed according to the conduction state of the access transistor and the floating-body potential state of the storage transistor. The fact that TTRAM memory cell operations don't require a step-up voltage or negative voltage, as DRAM cells do, makes the new cell design suitable for use with future finer processes and lower operating voltages.

Magnetoresistive Random Access Memory

Magnetoresistive Random Access Memory (MRAM) is a non-volatile computer memory (NVRAM) technology that has been under development since the 1990s. Unlike conventional RAM chip technologies, in MRAM data is not stored as electric charge or current flows, but by magnetic storage elements. The elements are formed from two ferromagnetic plates, each of which can hold a magnetic field, separated by a thin insulating layer. One of the two plates is a permanent magnet set to a particular polarity, the other's field can be changed to match that of an external field to store memory. This configuration is known as a spin valve and is the simplest structure for a MRAM bit. A memory device is built from a grid of such "cells".

Ferroelectric Random Access Memory

Ferroelectric RAM (FeRAM or FRAM) is a random-access memory similar in construction to DRAM but uses a ferroelectric layer instead of a dielectric layer to achieve non-volatility. FeRAM is one of a growing number of alternative non-volatile memory technologies that offer the same functionality as Flash memory. FeRAM advantages over Flash include: lower power usage, faster write performance and a much greater maximum number (exceeding 1016 for 3.3 V devices) of write-erase cycles. Disadvantages of FeRAM are much lower storage densities than Flash devices, storage capacity limitations, and higher cost.

Ferroelectric RAM was proposed by MIT graduate student Dudley Allen Buck in his master's thesis, Ferroelectrics for Digital Information Storage and Switching, published in 1952. Development of FeRAM began in the late 1980s. Work was done in 1991 at NASA's Jet Propulsion Laboratory on improving methods of read out, including a novel method of non-destructive readout using pulses of UV radiation. Much of the current FeRAM technology was developed by Ramtron, a fabless semiconductor company. One major licensee is Fujitsu, who operate what is probably the largest semiconductor foundry production line with FeRAM capability. Since 1999 they have been using this line to produce standalone FeRAMs, as well as specialized chips (e.g. chips for smart cards) with embedded FeRAMs within. Fujitsu produces devices for Ramtron. FeRAM remains a relatively small part of the overall semiconductor market.

Ferroelectric Transistor Random Access Memory

Researchers are developing a new type of computer memory that could be faster than the existing commercial memory and use far less power than flash memory devices. The technology combines silicon nanowires with a "ferroelectric" polymer, a material that switches polarity when electric fields are applied, making possible a new type of ferroelectric transistor.

The ferroelectric transistor's changing polarity is read as 0 or 1, an operation needed for digital circuits to store information in binary code consisting of sequences of ones and zeroes. The new technology is called FeTRAM, for ferroelectric transistor random access memory.

The FeTRAM technology has non-volatile storage, meaning it stays in memory after the computer is turned off. The devices have the potential to use 99 percent less energy than flash memory, a non-volatile computer storage chip and the predominant form of memory in the commercial market. The FeTRAM technology fulfills the three basic functions of computer memory: to write information, read the information and hold it for a long period of time.

The new technology also is compatible with industry manufacturing processes for complementary metal oxide semiconductors, or CMOS, used to produce computer chips. It has the potential to replace conventional memory systems. The FeTRAMs are similar to state-of-the-art ferroelectric random access memories, FeRAMs, which are in commercial use but represent a relatively small part of the overall semiconductor market. Both use ferroelectric material to store information in a nonvolatile fashion, but unlike FeRAMS, the new technology allows for nondestructive readout, meaning information can be read without losing it. This nondestructive readout is possible by storing information using a ferroelectric transistor instead of a capacitor, which is used in conventional FeRAMs.

Resistive random-access memory

RRAM or ReRAM is a new non-volatile memory type being developed based on different dielectric materials, spanning from perovskites to transition metal oxides to chalcogenides. Even silicon dioxide has been shown to exhibit resistive switching as early as 1967 and has recently been revisited. The basic idea is that a dielectric, which is normally insulating, can be made to conduct through a filament or conduction path formed after application of a sufficiently high voltage. The conduction path formation can arise from different mechanisms, including defects, metal migration, etc. Once the filament is formed, it may be reset (broken, resulting in high resistance) or set (re-formed, resulting in lower resistance) by an appropriately applied voltage giving us a memory cell.

ReRAM has been demonstrated even by a new circuit element called *memristor*. Till now, the resistor, the capacitor, and the inductor; all of which are significant because circuitry is the backbone of memory functionality were the known circuit elements. Hewlett Packard which has pioneered the new circuit element has announced plans to commercialize ReRAM based on the memristor.

Nano-RAM

NRAM is a type of nonvolatile random access memory based on the mechanical position of carbon nanotubes deposited on a chip-like substrate. In theory, the small size of the nanotubes allows for very high density memories. The first generation NRAM technology was based on a three-terminal semiconductor device where a third terminal is used to switch the memory cell between memory states. The second generation NRAM technology is based on a two-terminal memory cell. The two-terminal cell has advantages such as a smaller cell size, better scalability to sub-20 nm nodes), and the ability to passivate the memory cell during fabrication.

Phase-change Random Access Memory

PRAM (also called PCRAM, Ovonic Unified Memory, Chalcogenide RAM and C-RAM) is a type of non-volatile computer memory. PRAMs exploit the unique behaviour of chalcogenide glass. Heat produced by the passage of an electric current switches this material between two states, crystalline and amorphous. Recent versions can achieve two additional distinct states, in effect doubling their storage capacity. PRAM is one of several new memory technologies competing in the non-volatile role.

Conclusion

The constant need to boost memory performance for increasingly powerful system processors drives the development of advanced RAM technologies. The success of the technologies of course depends on a number of factors including that of market forces. Market forces are an important determinant in the success as considerable investment has been made for the commercialization of existing technologies. Many of the technologies discussed are proprietary in nature like Z-RAM, NRAM, ReRAM, etc. which are impediments in their future development and universal acceptability.

The discussion also points out to the fact that there is an increasing trend of developing non-volatile random access memory or NVRAM. This is primarily driven by the fact that such memory can be used also to replace the non-volatile memory technologies that are in use today.

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