A

Seminar report

On

Polymer Memory

Submitted in partial fulfillment of the requirement for the award of degree
Of CSE

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Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

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Preface

I have made this report file on the topic **Polymer Memory**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

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INTRODUCTION

Imagine a time when your mobile will be your virtual assistant and will need far more than the 8k and 16k memory that it has today, or a world where laptops require gigabytes of memory because of the impact of convergence on the very nature of computing. How much space would your laptop need to carry all that memory capacity? Not much, if Intel's project with Thin Film Electronics ASA (TFE) of Sweden works according to plan. TFE's idea is to use polymer memory modules rather than silicon-based memory modules, and what's more it's going to use architecture that is quite different from silicon-based modules.

While microchip makers continue to wring more and more from silicon, the most dramatic improvements in the electronics industry could come from an entirely different material plastic. Labs around the world are working on integrated circuits, displays for handheld devices and even solar cells that rely on electrically conducting polymers—not silicon—for cheap and flexible electronic components. Now two of the world's leading chip makers are racing to develop new stock for this plastic microelectronic arsenal: polymer memory. Advanced Micro Devices of Sunnyvale, CA, is working with Coatue, a startup in Woburn, MA, to develop chips that store data in polymers rather than silicon. The technology, according to Coatue CEO Andrew Perlman, could lead to a cheaper and denser alternative to flash memory chips—the type of memory used in digital cameras and MP3 players. Meanwhile, Intel is collaborating with Thin Film Technologies in Linkping, Sweden, on a similar high capacity polymer memory.

PRESENT MEMORY TECHNOLOGY SCENARIO

Digital Memory is and has been a close comrade of each and every technical advancement in Information Technology. The current memory technologies have a lot of limitations. DRAM is volatile and difficult to integrate. RAM is high cost and volatile. Flash has slower writes and lesser number of write/erase cycles compared to others. These memory technologies when needed to expand will allow expansion only two dimensional space. Hence area required will be increased. They will not allow stacking of one memory chip over the other. Also the storage capacities are not enough to fulfill the exponentially increasing need. Hence industry is searching for “Holy Grail” future memory technologies for portable devices such as cell phones, mobile PC’s etc. Next generation memories are trying a tradeoffs between size and cost .This make them good possibilities for development.

NEXT GENERATION MEMORIES

As mentioned earlier microchip makers continue to wring more and more from silicon, large number of memory technologies were emerged. These memory technologies are referred as 'Next Generation Memories'. Next Generation Memories satisfy all of the good attributes of memory. The most important one among them is their ability to support expansion in three dimensional spaces. Intel, the biggest maker of computer processors, is also the largest maker of flash-memory chips is trying to combine the processing features and space requirements feature and several next generation memories are being studied in this perspective. They include MRAM, FeRAM, Polymer Memory and Ovonics Unified Memory.

Polymer memory is the leading technology among them. It is mainly because of their expansion capability in three dimensional spaces. The following graph also emphasis acceptance of Polymer memory.

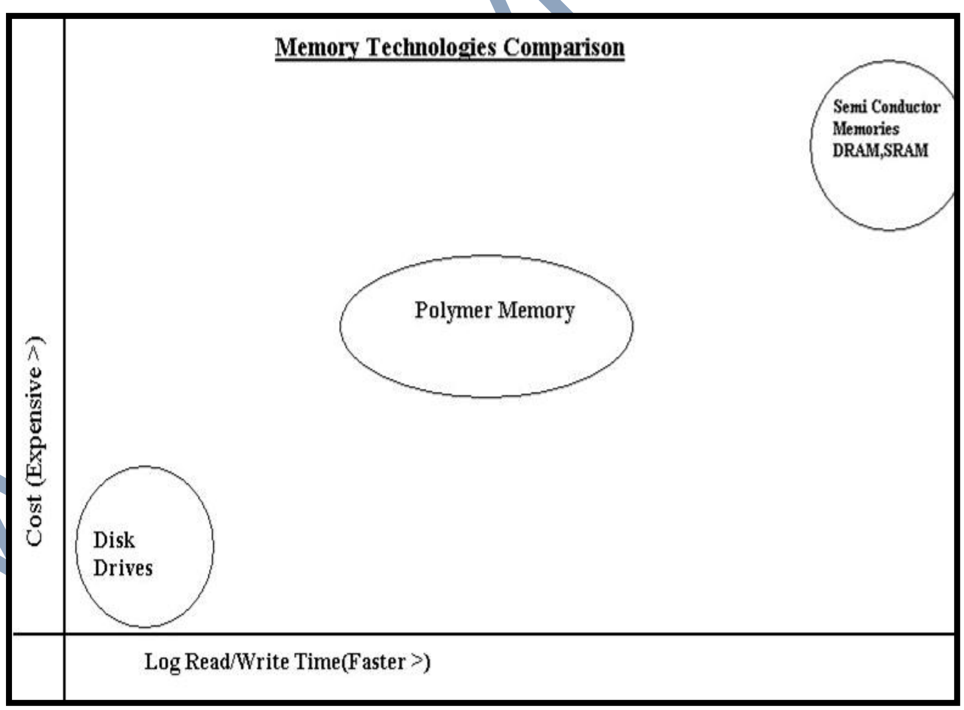
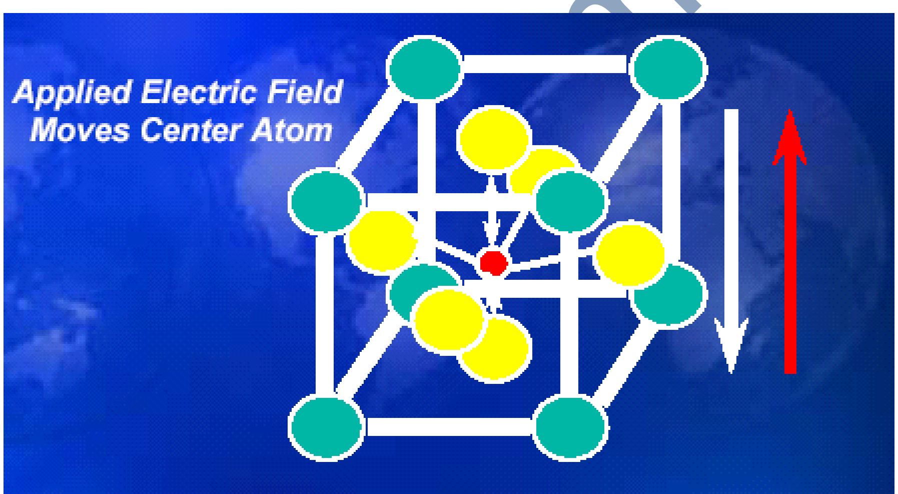


Figure1- Memory Technology Comparison

The graph shows a comparison between cost and speed i.e., the Read/Write time. Disk drives are faster but expensive where as semiconductor memory is slower in read/write. Polymer memory lies in an optimum position.

Polymer-based memory modules, as against silicon-based ones, promise to revolutionize the storage space and memory capabilities of chips. Coatue's polymer memory cells are about one-quarter the size of conventional silicon cells. And unlike silicon devices, the polymer cells can be stacked that architecture could translate into memory chips with several times the storage capacity of flash memory. By 2004, Coatue hopes to have memory chips on the market that can store 32 gigabits, outperforming flash memory, which should hold about two gigabits by then, to produce a three-dimensional structure.

The Fundamental Technology of Next Generation Memories- FeRAM



Central atom responsible for bistable nature.

The fundamental idea of all these technologies is the bistable nature possible for of the selected material which is due to their difference in behavior of internal dipoles when electric field is applied. And they retain those states until an electric field of opposite nature is applied. FeRAM works on the basis of the bistable nature of the centre atom of selected crystalline material. A voltage is applied upon the crystal which in turn polarizes the internal dipoles up or down. I.e. actually the difference between these states is the difference in conductivity. Non –Linear FeRAM read capacitor, i.e., the crystal unit placed in between two electrodes will remain in the direction polarized(state) by the applied electric field until another field capable of polarizing the crystal's central atom to another state is applied.

Attributes of FeRAM

- The FeRAM memory is non volatile: - The state of the central atom or the direction of polarization remains even if power is made off.
- Fast Random Read Access.
- Fast write speed.
- Destructive read, limited read and write cycles.
- Very low power consumption.

Why Polymer memory is called PFRAM?

In Polymer memory the crystalline substance used is polymers. Polymers just as ferroelectric crystals set up local dipoles within them when electric field is applied.

POLYMERS AS ELECTRONIC MATERIALS

Polymers are organic materials consisting of long chains of single molecules. Polymers are highly adaptable materials, suitable for myriad applications. Until the 1970s and the work of Nobel laureates Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa, polymers were only considered to be insulators. Heeger et al showed that polymers could be conductive. Electrons were removed, or introduced, into a polymer consisting of alternately single and double bonds between the carbon atoms. As these holes or extra electrons are able to move along the molecule, the structure becomes electrically conductive.

Thin Film Electronics has developed a specific group of polymers that are bistable and thus can be used as the active material in a non-volatile memory. In other words, the Thin Film polymers can be switched from one state to the other and maintain that state even when the electrical field is turned off. This polymer is "smart", to the extent that functionality is built into the material itself, like switchability, addressability and charge store. This is different from silicon and other electronic materials, where such functions typically are only achieved by complex circuitry. "Smart" materials can be produced from scratch, molecule by molecule, allowing them to be built according to design. This opens up tremendous opportunities in the electronics world, where “tailor-made” memory materials represent unknown territory

Polymers are essentially electronic materials that can be processed as liquids. With Thin Film’s memory technology, polymer solutions can be deposited on flexible substrates with industry standard processes like spin coating in ultra thin layers.

Space charge and Polymers

Making a digital memory device means finding a way to represent the ones and zeros of computer logic, devising a relatively convenient way to retrieve these binary patterns from storage, and making sure the information remain stable.

Digital memory is an essential component of many electronic devices, and memory that takes up little space and electricity is in high demand as electronic devices continue to shrink Researchers from the Indian Association for the Cultivation of Science and the Italian National used positive and negative electric charges, or space charges, contained within plastic to store binary numbers Research Council. A polymer retains space charges near a metal interface when there is a bias, or electrical current, running across the surface. These charges come either from electrons, which are negatively charged, or the positively-charged holes vacated by electrons. We can store space charges in a polymer layer, and conveniently check the presence of the space charges to know the state of the polymer layer. Space charges are essentially differences in electrical charge in a given region. They can be read using an electrical pulse because they change the way the devices conduct electricity.

The researchers made the storage device by spreading a 50-nanometer layer of the polymer regioregularpoly on glass, then topping it with an aluminum electrode. To write a space charge to the device, they applied a positive 20-second, 3-volt pulse. To read the state, they used a 0.2-volt, one minute pulse. Any kind of negative electrical pulse erased this high state, or charge, replacing it with the default low state. The space charges remain stable for about an hour and also can be refreshed by another 3-volt positive pulse. The researchers intend to increase the memory retention ability of their device beyond an hour. Researchers are looking forward to increasing it into days or more. Once this is achieved, polymer devices can be used in data storage devices [and] also as a switch whose state can be changed externally by a voltage pulse.

FEATURES OF POLYMER MEMORY

1. Data stored by changing the polarization of the polymer between metal lines.
2. Zero transistors per bit of storage
3. Memory is Nonvolatile
4. Microsecond initial reads. Write speed faster than NAND and NOR Flash.
5. Simple processing, easy to integrate with other CMOS
6. No cell standby power or refresh required
7. Operational temperature between -40 and 110°C.

How does Polymer Memory work?

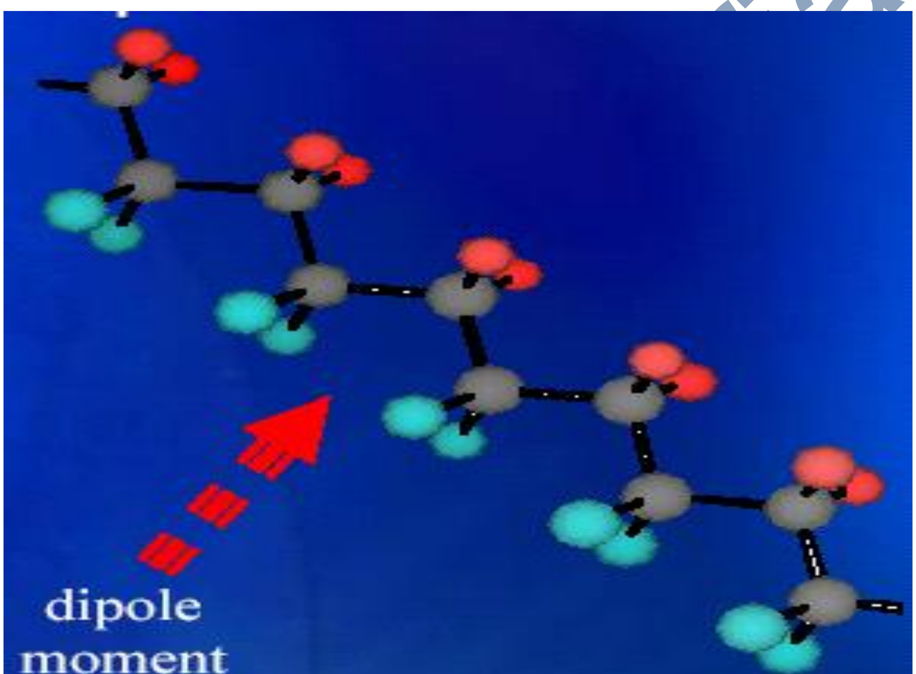
Making a digital memory device means finding a way to represent the ones and zeros of computer logic, devising a relatively convenient way to retrieve these binary patterns from storage, and making sure the information remains stable. Polymer memory stores information in an entirely different manner than silicon devices. Rather than encoding zeroes and ones as the amount of charge stored in a cell, Coatue's chips store data based on the polymer's electrical resistance. Using technology licensed from the University of California, Los Angeles, and the Russian Academy of Sciences in Novosibirsk, Coatue fabricates each memory cell as a polymer sandwiched between two electrodes. To activate this cell structure, a voltage is applied between the top and bottom electrodes, modifying the organic material. Different voltage polarities are used to write and read the cells.

Application of an electric field to a cell lowers the polymer's resistance, thus increasing its ability to conduct current; the polymer maintains its state until a field of opposite polarity is applied to raise its resistance back to its original level. The different conductivity States represent bits of information. A polymer retains space charges near a metal interface when there is a bias, or electrical current, running across the surface. These charges come either from electrons, which are negatively charged, or the positively-charged holes vacated by electrons. We can store space charges in a polymer layer, and conveniently check the presence of the space charges to know the state of the polymer layer. Space charges are essentially differences in electrical charge in a given region. They can be read using an electrical pulse because they change the way the device conducts electricity.

The basic principle of Polymer based memory is the dipole moment possessed by polymer chains. It is the reason by which polymers show difference in electrical conductivity. As explained earlier implementing a digital memory means setting up away to represent logic one and logic zero. Here polarizations of polymers are changed up or down to represent logic one and zero. Now let's see what are a dipole and a dipole moment.

Dipole Moment

When electric field is applied to solids containing positive and negative charges, the positive charges are displaced in the direction of the field towards negative end, while negative charges are displaced in the opposite direction. Two equal and opposite charges separated by a distance form a dipole. Hence this displacement produces local dipoles throughout the solid. The dipole moment per unit volume of the solid is the sum of all the individual dipole moments within that volume and is called Polarization of the solid. The intensity of dipole moment depend on the extend of the displacement which in turn depend on the applied electric field intensity.



The alignment of local dipoles within a polymer chain

Coatue fabricates each memory cell as a polymer sandwiched between two electrodes. When electric field is applied polymers local dipoles will set up. The alignment of local dipoles within a polymer chain is shown in the diagram.

POLYMER MEMORY ARCHITECTURE

The researchers made the storage device by spreading a 50-nanometer layer of the polymer regioregularpoly on glass, then topping it with an aluminum electrode. To write a space charge to the device, they applied a positive 20-second, 3-volt pulse. To read the state, they used a 0.2-volt, one minute pulse. Any kind of negative electrical pulse erased this high state, or charge, replacing it with the default low state. In this process, a continuous sheet of flexible polymer is unrolled from one spool, covered with circuit-board-like patterns of silicon, and collected on another spool.

The Thin Film memory design is solid state, with no mechanical or moving parts involved. It uses a passively addressed, cross point matrix. An ultra thin layer of the TFE polymer is sandwiched between two sets of electrodes. A typical array may consist of several thousand such electrically conducting lines and hence millions of electrode crossings. Memory cells are defined by the physical overlap of the electrode crossings and selected by applying voltage. Each electrode crossing represents one bit of information in a true $4f^2$ (4-Lampda square) cell structure, the smallest possible physical memory cell. The effective cell footprint is further reduced if additional memory layers are applied. In the latter case, each new layer adds the same capacity as the first one. This stacking is a fundamental strength of the Thin Film technology. The polymer memory layers are just 1/10,000 of a millimeter or less in thickness, autonomous and easy to deposit. Layer upon layer may be coated on a substrate. A layer may include a self-contained active memory structure with on-layer TFT circuitry, or share circuitry with all other layers. Both approaches offer true 3D memory architecture. The stacking option will enable manufacturers to give gain previously unattainable storage capacity within a given footprint.

Circuits

Polymer microelectronics is potentially far less expensive to make than silicon devices. Instead of multibillion-dollar fabrication equipment that etches circuitry onto a silicon wafer, manufacturers could eventually use ink-jet printers to spray liquid-polymer circuits onto a surface. Polymer memory comes with an added bonus: unlike the memory in your PC, it retains information even after the power is shut off. Such nonvolatile memory offers potential advantages—not the least of which is the prospect of never having to wait around for a PC to boot up—and a number of researchers are working on various approaches. But polymer memory could potentially store far more data than other nonvolatile alternatives.

In the Thin Film system there is no need for transistors in the memory cells, a substantial simplification compared to state of the art memory designs. The driver circuitry, comprising column and row decoders, sense amplifiers, charge pumps and control logic, is located entirely outside the memory matrix, leaving this area completely clear of circuitry, or be 100% built underneath the memory array. Both of these approaches have certain advantages. With no circuitry in the memory plane, it is possible to build the polymer memory on top of other chip structures, e.g. processors or memory, while the other option, all circuitry located underneath the memory, offers the most area efficient memory design that can be envisaged, with a 100% fill factor. This enables optimal use of the memory cells and marks a radical directional change from state of the art technologies. Translated into hard facts, the Thin Film system requires about 0.5 million transistors per gigabit of memory. A traditional silicon-based system would require between 1.5 to 6.5 billion transistors for that same gigabit.

Figure 5- Polymer memory architecture.

In the Thin Film system, a substrate is coated with extremely thin layers of polymer. The layers in the stack are sandwiched between two sets of crossed electrodes. Each point of intersection represents a memory cell containing one bit of information.

Manufacture

With Thin Film's memory technology, polymer solutions can be deposited on flexible substrates with industry standard processes like spin coating in ultra thin layers. Using an all-organic architecture, the Thin Film memory system is suitable for roll-to-roll manufacture. This is a continuous production method where a substrate is wound from one reel to another while being processed. The basic premise is to exploit the fact that polymers can be handled as liquids and, at a later stage, printed directly with the cross matrices of electrodes, thus allowing square meters of memory and processing devices to be produced by the second. This can be taken even further by the use of simple ink-jet printers. Such printers, with modified printer heads, will have the capability to print complete memory chips at the desktop in the future. With the Thin Film technology, there are no individual components that must be assembled in a purpose-built factory, nor is the technology limited to a particular substrate.

EXPANDING MEMORY CAPABILITY- STACKED MEMORY

Expanding memory capability is simply a matter of coating a new layer on top of an existing one. The footprint remains the same even after expansion because each new layer adds the same capacity as the first one. This stacking is a fundamental strength of the Thin Film technology. A layer may include a self-contained active memory structure with on-layer TFT circuitry, or share circuitry with all other layers. Both approaches offer true 3D memory architecture. This means that the new technology is not just for saving space, but also the option of using different, and optimized software architectures.

The driver circuitry, comprising column and row decoders, sense amplifiers, charge pumps and control logic, is located entirely outside the memory matrix, leaving this area completely clear of circuitry, or be 100% built underneath the memory array. This is the fundamental factor which enabled the stacking option. With no circuitry in the memory plane, it is possible to build the polymer memory on top of other chip structures, e.g. processors or memory.

If you want to add more memory with silicon-based technology, you move in a two-dimensional space. Put simply, the area taken, 128 MB RAM, is more than the area occupied by 64 MB RAM. With the new polymer-based technology, you will move in a three-dimensional space.

That is, you move from talking about area to talking about volume. Put simply, a 128 MB RAM module will have the same footprint as a 64 MB module, but slightly thicker (or higher). This difference in thickness or height will be so small, that we may not even be able to tell the difference by just looking at it. If a 64 MB silicon-based module takes up 20mmx10mmx6mm (1200 cubic mm of space), then 124 MB occupies approximately double that volume. However, with polymer-based memory, the footprint (length x breadth) will remain the same (200 sq mm) but the height would increase only by about 1/10000th of a millimeter, which adds practically nothing to the volume. Polymer memory layers are just 1/10,000 of a millimeter or less in thickness, autonomous and easy to deposit. Layer upon layer may be coated on a substrate. A layer may include a self-contained active memory structure with on-layer circuitry and TFT, or share circuitry (as in hybrid polymer-over-silicon chips). In the latter case, stacked layers may be individually addressed from the bottom circuitry, giving three dimensional storage capacities. The Thin Film memory system is expandable by the addition of new layers manufacturers will be able to gain previously unattainable storage capacity within a given footprint.

Examples: The equivalent of 400,000 CDs, or 60,000 DVDs, or 126 years of MPG music may be stored on a polymer memory chip the size of a credit card.

Holographic storage using Polymer

Holographic storage relies mainly on laser light and a photosensitive material—usually a crystal or a polymer—to save data. It works by splitting a laser beam in two. One beam contains the data and is referred to as the "object beam"; the other holds the location of the data and is known as the "reference beam." The two beams intersect to create an intricate pattern of light and dark bands. A replica of this so-called interference pattern gets engraved three-dimensionally into the photosensitive material and becomes the hologram. To retrieve the stored data, the reference beam is shone into the hologram, which refracts the light to replicate the data beam.

The holographic technique packs data so tightly that one 12-centimeter disk could eventually hold a terabyte of data—about as much information as 200 DVDs. What's more, holographic storage opens the possibility of reading and writing data a million bits at a time, instead of one by one as with magnetic storage. That means you could duplicate an entire DVD movie in mere seconds.

The idea of storing tons of data three-dimensionally was first proposed by Polaroid scientist Pieter J. van Heerden in the 1960s. But developing the technology was difficult, because the required optical equipment was large and expensive. A typical laser back then, for example, was two meters long. Today, lasers are measured in mere centimeters and are much cheaper.

NUMBER OF TRANSISTORS, SPEED, COST ETC.

Number of transistors

The stacking also means that a lesser number of transistors can be used for the circuitry in the chip. The Thin Film system requires about 0.5 million transistors per gigabit of memory compared to 1.5 to 6.5 billion transistors required by traditional silicon-based systems for one gigabit. While the illustrations on advantages regarding the size were based on RAM for matters of convenience, the fact is that the new polymer-based technology can offer total storage solutions.

Speed

The absence of moving parts offers a substantial speed advantage compared to mechanical storage systems such as magnetic hard disks and optical storage. Thin Film memory technology is all solid state based. The absence of moving parts in itself offers a substantial speed advantage compared to all mechanical systems, like magnetic hard disks and optical systems. The polymer film can be read in two modes either destructive or non-destructive. In the first case, reading speed is symmetric with write. Depending on how the polymer is processed and initialized this speed can range from nanoseconds to microseconds. This speed symmetry puts the Thin Film memory in a favorable position versus e.g. another non-volatile memory, NAND flash, where the erase before write may be orders of magnitude slower than the read. In the non-destructive read mode the Thin Film memory speed will be comparable to or better than DRAM read speeds. More important than single bit speed capacity is the potentials embedded in the 3D architecture per sec, allowing massive parallelism in multiple dimensions and the use of mega words rather than the prevailing 64 and 128 bit words.

Cost

Cost-wise, because the polymer is solution-based and can easily be applied to large surfaces with regular coating processes (even something as simple as printing a photograph on an ink-jet printer), there is a huge advantage in terms of price for capacity. The use of a solution based memory material opens up for better price/capacity performance than hitherto experienced by the electronic industry. For the hybrid silicon-polymer chips, the substrate circuitry with one memory layer will typically cost the same to process per area unit as competing silicon devices, however, since more bits can be packaged in that area, the cost per MB will be substantially lower. The ability to expand capacity by stacking also means that the cost per MB will reduce substantially. TFE believes that the cost per MB will become so low that truly disposable memory chips will become possible. One report says that this technology could take flash card prices to 10 per cent of what they are today.

One can imagine what this would mean to laptops (same footprint, but gigabytes of space and RAM), mobile phones (more and more phone numbers and SMS messages), PDAs (more e-mail, more addresses, and more notes), digital cameras (more and better pictures per card, and the cards are cheap!). The news is explosive: Evidently, for the cost of a few cents, a Norwegian company can produce a memory module with a capacity of up to 170,000 gigabytes, which could fit on a bank card. This price advantage scales with the number of memory layers. Typically 8 layers involve about the same number of mask steps as making a conventional memory chip, or twice the cost of a single layer chip, while the storage capacity increases 8x. Even greater cost advantages will come with TFT based chips, using inkjet printers or roll-to-roll production. Cost per MB will here become so low that true disposable memory chips can be envisaged.

Operational temperature

Polymers are robust by nature. The polymer memory developed by Thin Film has undergone stringent reliability tests at temperatures between -40 and 110°C. The results underline the exceptional stability of the polymer memory and compliance with military and commercial standard tests.

Different companies working in Polymer memory field

The revolution has already begun. Here are some companies and their products in Polymer memory. But turning polymer memory into a commercial product won't be easy. These all are made of just some prototypes are ready. However, the path from lab prototype to mass production is long and rock.

Intel, the biggest maker of computer processors, is also the largest maker of flash-memory chips (that store data when devices are switched off) is collaborating with Thin Film Technologies in Linköping, Sweden, on a similar high capacity polymer memory. Advanced Micro Devices of Sunnyvale, CA, is working with Coatue, is a research and development company on the forefront of a new generation of memory chips based on electronic polymers, a startup in Woburn, MA, to develop chips that store data in polymers rather than silicon Opticom polymer memory.

Coatue –A company on the forefront of new generation memories using Electronic Polymers

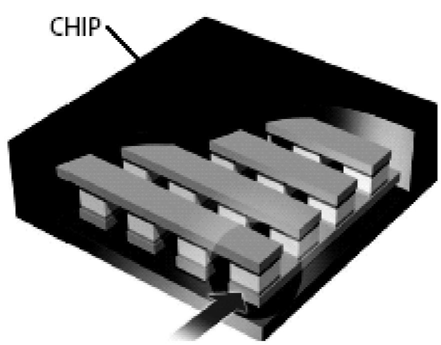


Figure 8-a Coatue's chip.

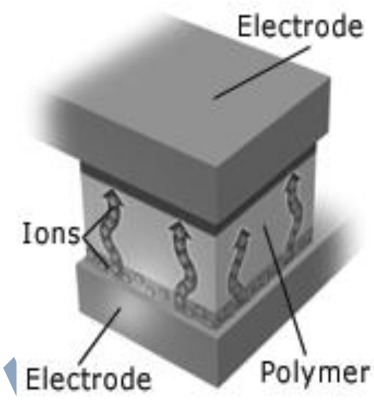


Figure 8-b Coatue's memory cell.

In Coatue's chip an electric field draws ions up through the polymer increasing the conductivity. Difference in conductivity represents bits of data. Coatue is a research and development company on the forefront of a new generation of memory chips based on electronic polymers. This disruptive technology promises to deliver cheaper, higher performance, higher density memory for use in many products ranging from portable devices to desktop computers. Coatue's memories utilize molecular storage, eliminating the need for transistors to store information and drastically simplifying both the architecture and manufacturing process of today's chips.

Coatue's multi-state polymer materials emulate the function of traditional memory cells by switching between on and off states, representing 1's and 0's. Polymer memory devices have significant advantages over existing memory storage techniques, however. Polymer memory does not require transistors which drastically reduces the cell footprint and simplifies the cell architecture. Large on/off ratios in Coatue's chips provide hundreds of distinct conductivity states which yield up to eight bits per memory cell (versus 2 in Flash and 1 in DRAM). In addition, polymers can be stacked vertically on a single piece of silicon paving the way for true three dimensional architectures, further enhancing the density. In terms of performance, polymer cells have fast switching speeds (ultimately in the terahertz domain) and can retain information for long periods of time. Because polymer memory utilizes a molecular switching mechanism, Coatue's chips can be scaled down to molecular dimensions (1-10 nm). Finally, polymer materials can be deposited on traditional silicon for near term commercialization and are solution soluble for extremely low cost reel-to-reel manufacture in the future.

ADVANTAGES OF POLYMER MEMORY

1. Polymer memory layers can be stacked → This enable to achieve very high storage capacity.
2. Memory is Nonvolatile
3. Fast read and write speeds
4. Very low cost/bit, high capacity per dollar
5. Low power consumption
6. Easy manufacture → use ink-jet printers to spray liquid-polymer circuits onto a surface
7. Thin Film system requires about 0.5 million transistors per gigabit of memory. Traditional silicon-based system would require between 1.5 to 6.5 billion transistors for that same gigabit.

LIMITATIONS OF POLYMER MEMORY

But turning polymer memory into a commercial product won't be easy. Memory technologies compete not only on storage capacity but on speed, energy consumption and reliability. The difficulty is in meeting all the requirements of current silicon memory chips.

Until new memory materials are able to compete with the high performance of silicon, their notes, they are likely to be limited to niche applications. One likely use is in disposable electronics, where cost, rather than performance, is the deciding factor. Researchers at Lucent Technologies' Bell Laboratories are working on polymer memory devices for use in identification tags.

The polymer memory made at Bell Labs is still relatively slow by silicon standards, and anticipated capacity is only on the order of a kilobit. But, says Bell Labs chemist Howard Katz, the flexible and low-cost polymer memory devices could be "very attractive" for, say, identification tags meant to be thrown away after a few uses.

CONCLUSION

The fundamental strength, i.e. the stacking of memory layers which yields maximum storage capacity in a given footprint is the main reason why Polymer memory is highly preferred.

The nonvolatileness and other features are in built in molecular level and offers very high advantages in terms of cost. Polymers ,which are once considered to be the main reason for pollution and refered to be removed from the earth, has found a new area of utilization.

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