SMART MOLECULES: A FUTURE MEDIUM OF MEMORY WITH SPECIAL REFERENCE TO POLYOXOMETALATES (POMs)

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ABSTRACT

Memory Devices, similar to human brain, are the places where information and instruction are stored. These devices consists of memory media i.e. semi-conductor, magnetic, optical, holographic or optical memory media acts. Semi conductor uses semi conductor based integrated circuits to store information, magnetic storage media uses magnetically coated surface to store information similarly holographic and optical media acts. In addition to above, molecular memory stores information in Polymers in terms of electric charges. These are meant for primary storage. The theoretical storage capacity of molecular memory is 10 terabits / inch². Many inorganic/ organic chemical compounds such as single molecule magnets (SMMs) Aniline compounds, or Organometallic compounds act as memory devices. The novel Polyoxometalates are well known for their multi electron redox properties which enables these molecules to act as molecular memory storage medium.

Key words: Molecular Memory, Semi conductor media, magnetic media, Polyoxometalates (POMs) memory media

[1] INTRODUCTION

The storage of computer information is generally performed by computer memory devices. Computer memory [1] is a space in computer where processing of data takes place as well as it contains instructions required for processing.

Memory devices act as human brain to information and instruction stored and process for further action. These devices are mainly consists of storage media. In other words, these are the materials where actually data is stored or retrieved. These may be semi conductor, magnetic, optical or holographic data storage media.

Holographic media stores information inside crystals or photo molecules and optical media stores information in the deformities on the circular disc like the action of semiconductor and magnetic
storage media. Recently, a novel storage medium has been introduced in the form of nano-particles. It is also known as Molecular Memory Storage Media. It encompasses the data storage system that uses molecular substances as data storage element [2].

These molecular entities are employed in flash memory device. Thus is nothing but a non-volatile computer storage media that can be electrically erased and reprogrammed. They perform the functions of charge storage, photo chromism or changes in capacitance.

This is the start of portable or microelectronics where it is required to scale down the size of metal-oxide-semiconductor (MOS) below ten to twelve nano- metres per data cell. The huge growth of microelectronics is mainly due to miniaturization of metal –oxide-semiconductor field effect transistor (MOSFET)-a fact known as Moore’s law [3].

Therefore, a top- down approach has been considered where small chemical molecules have been introduced instead of MOS to be used as memory media in the computer or electronic devices [Fig1]. However, Aviram and Ratner [4] are first to propose the chemical molecules to be employed as functional electronic device. Since then, it has made its way in the world of electronics and computer industries [5,6].

Molecular species are synthesized and designed in such a way that each individual molecule contains a bit, leading to voluminous data storage capacity. Therefore research is going on to develop molecules and small chemical groups which could be replaced instead of chip in use. The development of nanotechnology leads to an idea of electrical measurement over single molecule [7].e.g One semiconducting [8,9] single wall carbon nanotube [10-11] have been used to prepare field effect transistor. Nano wires and nano tubes also participates in building blocks for nano scale electronics and hotonic structures.

In the present piece of review work, an attempt has been made to study the molecules and materials which can be proved for its ability to perform logical calculation and to provide the memory effect [12].

![Figure 1-Miniaturization of amplification devices used in electronic circuits over the last century. From left to the right starting with the vacuum tube over the transistor to current integrated circuits [13]](image-url)

[2]. MEMORY MEDIA
[2.1]. SEMI CONDUCTOR MEMORY MEDIA

It is a data storage material which is based upon semiconductor integrated circuits also known as IC or chips. Its existence may be volatile or non volatile. Semi conductor memory chip consists of small transistor or capacitor. Its existence may be volatile and non volatile. These are counted under random
access memory [14]. They are very fast i.e a byte of data can be written or read within a few nanoseconds. Due to their fast accessibility, it is used in main memory.

[2.2] MAGNETIC MEMORY MEDIA.

Storage device such as diskette drives, hard drives and tape drives is meant to hold the computer memory. The surface of these storage devices are coated with magnetically sensitive material such as iron oxide or cobalt based alloys [15,16]. All the ions in the magnetic material align or orient themselves in one direction, known as polarization. The magnetic field orientation is the basis of the storage of data. There are two magnetic polarities, each of which represents either 0 or 1. Magnetic grains are aligned by an external magnetic field, the information remains stored longer periods of time.

Magnetic recording in the form of magnetized dots is done on magnetic tape. This is narrow strip of plastic film which is coated with magnetic substances. The dots are arranged along the long plastic strip in magnetic tapes and in the form of circles over the surface of plastic, metal or glass in floppy drives or hard disc.

[2.3] OPTICAL MEMORY MEDIA

Optical storage device is an alternative to magnetic storage system. The most widely used optical storage medium is the compact disk (CD) and photo CD system [Fig2]. It is named so because stored data, in the form of dots, can be studied by beam of laser light from a reflected surface. The beam is reflected back after hitting the dots and it is compared with reflected light which hits the surface without dots. This difference is utilized to retrieve the stored data.

Figure 2-Magnified image of the dots on the surface of the CD. These dots depict the stored information over the compact disk. [Taken from IGCSE IGT]

[2.4] HOLOGRAPHIC MEMORY MEDIA

Holographic memory is nothing but a 3D data storage system. It stores data in the form of holographic image or hologram. Hologram is a photographic recording of a light field. It records information throughout the volume of medium and is capable of recording multiple in the same area utilizing light at different angles.
[3] MOLECULAR MEMORY MEDIA

Molecular memory is defined as the storage of data in memory devices by utilizing molecular species rather than magnetic or optical materials. Molecular memory consists of individual molecules as a storage element which can store a bit of data leading to massive data capacity i.e it promises to increase another 1000 fold increase in storage density. According to a study molecular memory can store a data of 10 terabits/Sq inch [17].

The chemists at the IISER Kolkata believed that molecules could be useful for the type experimental devices studied by Moodera’s which uses spin property of tiny particles of matter to represent data. A supra molecule has been synthesized which can be used to store and retrieve information. This smart molecule can be used in non-volatile memory devices which can work at room temperature [18]. Flash memory has become significant when non volatile and solid state storage is needed. The fast access time and shock resistance added in the popularity of flash memory in portable devices [19].

Miniaturization, a top-down approach, is the prime requirement of the portable devices. This top-down approach needs smart nano molecules which are able to donate or accept electrons or having redox properties.

[3.1] HYBRID MOLECULES AS MEMORY MATERIAL

Flash memory is widely used as storage device which are very much in vogue in smart phones, in camera and in other electronic gadgets. These devices require mini materials which compelled the researchers to develop memory devices and materials which are very-very small in size i.e may in some nanometers. The devices must have increased storage capacity and can fit into conventional silicon chip [20]. Organic molecules may replace memory material of the storage devices in future. These may be amorphous and crystalline and can be able to store or retrieve the digital information i.e in the form of one and zero.

Researchers from the University of Washington in Seattle and south east university synthesized an organic crystal which is made from bromine mixed with carbon, hydrogen and nitrogen. Its full name is diisopropylammoniumbromide [21]. It is organic ferroelectric molecule which may be employed as a storage material in memory chips or sensors. They are cheap, flexible, non hazardous molecules which shows promising alternative to today’s silicon based semiconductor.

Metal organic framework such as Cu3(BTC)2 in filtered with 7,7,8,8 tetra cyanoquinado dimethan, is another potential molecule that came into light after the researchers in 2014 proved that it could be used in semiconductor [22-23].

Robert R Birge, Professor in chemistry Carnegie-Mellon University, Pittsburge said that it has to go long for the replacement of silicon based electronics with carbon based electronics [24]. Under this preview, Organometallic compounds can also act as molecular switch which can exist in two stable states 0 and 1. This property makes it a data storage material [24]. Similarly, there are many other organic molecules which are interchangeable in their property.
Ex-Bacteriorhodospin. Brige and Coworkers employed this bacterial pigment which exist in two optical states i.e one absorbs green light and another state absorb orange light, to develop high density memory drives [24].

Single molecule magnet (SMM) is named so because single molecule can act as a magnet. This is a class of molecules which can store data or act as storage media. These are the molecular magnetic material but similar to conventional magnets [25]. SMM behave like a tiny magnet due to the large differences between energy barrier between spin states. The basic single molecule magnet is Mn₁₂. It is a polymetallic manganese (Mn) having formula [Mn₁₂O₁₂(0Ac)₁₁(H₂O)₈] [26]. SMM is bottom up approach for nano magnetism [27]. Single molecular magnet are also based upon Iron cluster [28] such as Fe₈Br where as Fe₈O₂(OH)₁₂(tacn)₈⁺ tacn is 1,4,7-triazacyclononane

[3.2]. POMS AS MOLECULAR MEMORY MEDIA

Polyoxometalates (POMs) supported the miniaturization of electronic devices. Polyoxometalates (POMs) are nothing but nano sized metal-oxygen cluster. They are composed of anions having metal oxygen octahedral as basic structural units [29]. In the present scenario, it is found to be mature field but still many stones still left unturned.

Berzelius reported the first compound Phosphomolybdate [PMo₁₂O₄₀]³⁻ in 1826 [30]. Since then more than 100 hundred years have passed, a large number of publication and patents continue to evolve. POMs found their uses as industrial catalysts [31], in electrochemistry [32], as oxidizing agents [33], as photo catalysts [34], medicine [35], magnetism [36a], POMs based QBITS [36b]. Recent advances show the inclusion of POMs in various sophisticated material and devices which are used in instrumentation and nano scale sciences. Glasgow group headed by Leroy Cronin has found Polyoxometalates doped with Selenium derivatives [Se(IV)O₄]²⁻ as potential agent in building flash memory devices [37].

Dr Chris Ritchie et.al [38] shows POMs-mediated self assembly of single molecule magnet [XW₁₀O₄₀]²⁻[Mn₄Mn₂O₄(H₂O)]¹²⁻ A.M.Douvas et.al. showed that the Keggin type Polyoxometalates i.e H₃PW₁₂O₄₀ combined with 1,12-diaminododecane (DD) on 3 amino propyltriethoxy silane (APTES)-modified silicon surface has been found to be molecular material for electronic devices [39].

Angelika et.al profound low dimensional Polyoxometalate molecule/Tantalum oxide hybrids for non volatile capacitive memories. Dodecatungstophosphate [PW₁₂O₄₀]³⁻ with Ta₂O₅ matrices are introduced charge storage material. POMs are hybridized with Tantalum oxide and made functional by doping it with primary amines as the anchoring moiety [40]. Polyoxometalates are highly versatile molecule which is widely employed in molecular material. Therefore Laia Vila –Nadal et al has proposed the utilization of Well Dawson as a nanoscale molecule memory element due to their nanoscale size and unique electronic properties. POMs are better in forming electronic complementary with SiO₂ in comparison to organic molecule due to their oxide in nature [41].

[4].CONCLUSION

Computer memory media may be in the form of semi conductor, optical, magnetic or holographic. Nowadays there is an existence of miniaturized form of memory devices. This can only be possible when small sized memory media will be incorporated in the memory devices. Therefore, in
addition to conventional memory media, smart molecules, hybrid substances as well as Polyoxometalates (POMs) can taken as future memory media for the purpose of storage of memory in computer world.

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