

Introduction

Modern day electronic semiconductor devices depend heavily on silicon-based technology owing to many reasons such as the abundance of the silicon in nature, the robustness and scalability of devices made from silicon. Since the advent of the field of semiconductor technology the number of semiconductor devices, which are primarily transistors, per unit area has been growing exponentially by following Moore's law [Moore, 2006]. However, there has been a saturation in the number of transistors per unit area in recent years.

The reason behind this saturation is the bottleneck of the channel length of metal oxide semiconductor (MOS) transistors. As the channel length decreases, the number of silicon atoms which are encountered in the path of a charge carrier (electron or hole), also decreases. After a threshold, when these atoms are reduced to a very few in number, the channel doesn't act as a bulk anymore. Effects such as hot carrier injection [Takeda, 1984] and the degradation associated with it starts showing up. Quantum effects, such as tunneling currents which are averaged out in bulk devices, become prominent as the devices become smaller. The tunneling currents increase exponentially with the decreasing oxide thickness [Maserjian, 1974], and the design rules of CMOS technology dictate that the gate oxide has to vary almost proportional to the channel-length [Dennard *et al.*, 1974]. Hence, the tunneling leakage current puts an upper limit on the channel length (and in turn, device size). To overcome this barrier, a whole new approach toward fabrication was inevitable. Another subsidiary problem is when we decrease the thickness of the oxide layer the capacitance for the device also increases which will lead to charge accumulation [Sodini *et al.*, 1982].

Conventional fabrication methods fall under the *top-down approach* where the bulk semiconductor is patterned to form small-sized electronic devices. This rather traditional approach towards fabrication relies on the efficiency of the technology of lithography available at the maker's dispense. Almost all silicon and GaAs based semiconductor devices are fabricated using the top-down approach. On the other hand, there is a relatively new approach towards fabrication where atoms and/or molecules are arranged to form nanostructures which act as electronic devices [Mijatovic *et al.*, 2005]. This approach, popularly known as the *bottom-up approach*, uses molecules (mostly organic) as the building blocks for the electronic devices. The most apparent advantage of using such an approach is having a higher device density due to the use of molecules as building blocks. With the advent of new methods of self-assembly of monolayers, the bottom-up approach started to gain popularity. Fully bottom-up and partly bottom-up/top-down strategies have also been used for nanoelectronic fabrication [Lu and Lieber, 2007]. This gave rise to a new branch of electronics - *Molecular Electronics*.

1.1 MOLECULAR ELECTRONICS

Molecular electronics is a branch of electronics which incorporates molecules as building blocks of the electronic devices. Some organic molecules have a unique property of having a conjugated core, i.e. the presence of alternate double bonds (e.g. benzene). These molecules can function as semiconductors [Brütting, 2005]. Due to the use of organic molecules, sometimes it is also referred to as *Organic Molecular Electronics*.

1.1.1 History

The term 'Molecular Electronics' was first coined by the US Air Force in 1958 for their new path-breaking research program [Choi and Mody, 2009]. Needless to say, the program failed and the term 'Molecular Electronics' slowly disappeared from the discussion. However, it came back to the fore in the 1970s when the first mono-molecular diode was conceptualized by Ratner and Aviram [Aviram and Ratner, 1974]. However, the real movement in the field of molecular electronics was seen after the electrical conduction mechanisms in *self-assembled monolayers* (SAM) deposited by *Langmuir Blodgett* (LB) method were discovered [Sugi *et al.*, 1975]. Although the electrical and structural studies on these SAM films have been found as early as 1966 [Handy and Scala, 1966], the studies of these films from an electronics point of view were not carried out until mid-1970s or early 1980s [Roberts *et al.*, 1980; Roberts *et al.*, 1978; Sugi *et al.*, 1975; Sugi and Iizima, 1980].

1.1.2 Fabrication Methods

For such an unconventional branch of electronics, there are rather simple fabrication techniques available for molecular electronics. Thin films of organic materials can be deposited with two major methods: *Vacuum Deposition and Solution Processing* [Brütting, 2005]. Vacuum deposition of these films contains techniques such as Molecular beam deposition [Kowarik *et al.*, 2008] and physical vapor deposition [Laudise *et al.*, 1998]. Other techniques such as sputtering and laser-based deposition are very rarely used because of the high energy of beams involved in the process which can damage the organic semiconductor. It is because of the possibility of the use of solution processing organic molecules have become a new trend in the field of electronics. The low cost and ease of operation of solution processed fabrication techniques make organic molecular electronics the futuristic technology in the field of electronics.

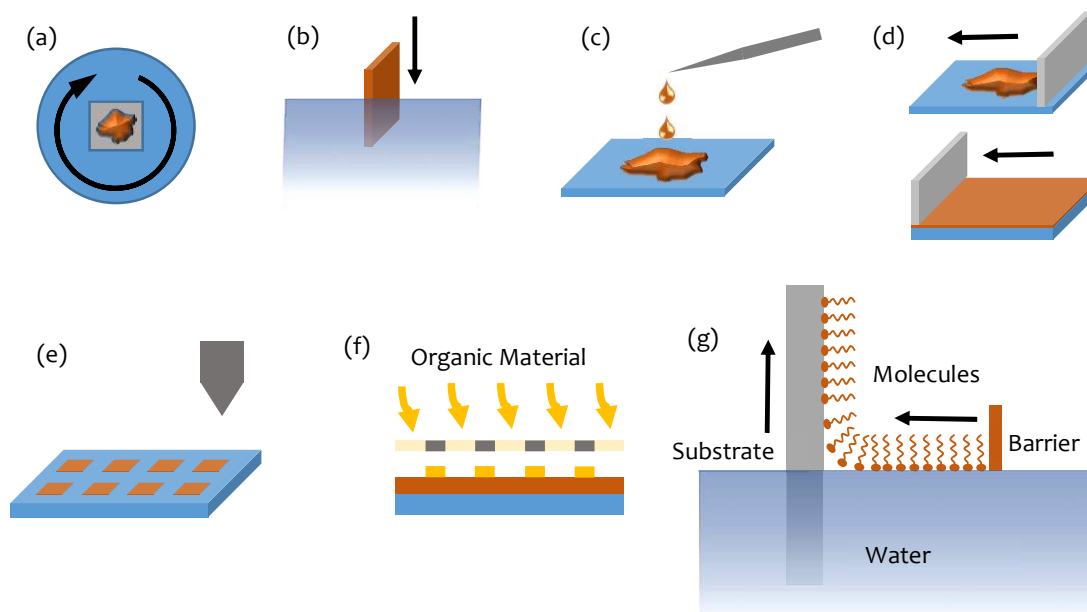


Figure 1.1: Methods of deposition of organic molecules by solution processing: (a) Spin coating, (b) Dip coating, (c) Drop cast, (d) Blade coating, (e) Ink-jet printing, (f) Screen printing, and (g) Langmuir Blodgett deposition

Spin coating is one such technique in which solution of the targeted material is dropped over a substrate and then the substrate is spun at a high rotational speed to spread the solution evenly on the substrate [Ossila, 2018]. After the solvent dries up, a thin layer of evenly spread material is left on the substrate. Quality of film depends on various parameters like the viscosity

of the solution, concentration, rotational speed, adhesion of the solvent to the substrate. Dip coating is another such technique to deposit organic thin films [Diao *et al.*, 2013]. If the molecules and substrate are chosen appropriately, SAM can also be fabricated with it. This technique involves uniform linear dipping of the substrate into the solution. After which, a uniform thin layer of the targeted molecule is formed on the substrate. Quality of film mainly depends on the adhesion of the molecule on the substrate, and also on the dipping speed. Another crude method of depositing organic semiconductors is drop cast [Park *et al.*, 2006]. In this method, a drop of the solution of the desired material is dropped on to the substrate. As the solvent evaporates, it leaves behind a layer of the material. There is very less control over surface roughness and film thickness in this method. Blade coating is a method where the material is drop casted over a substrate and then scraped off with a blade [Chen *et al.*, 2011]. For transferring the device design pattern onto the substrate at a large scale, there are two methods available, namely ink-jet printing, and screen printing [Sturm *et al.*, 2000; Thaidigsmann *et al.*, 2013]. In ink-jet printing, much like printing text onto a paper, solution of the organic material is filled instead of ink into the cartridge. Then the desired pattern is printed on the substrate by the printer. In screen printing, the material is poured through a thin screen patterned with the desired device design. Langmuir Blodgett (LB) deposition technique is another method of fabrication of monolayers [Handy and Scala, 1966]. In LB, single (or a few) layers of individual molecules having a hydrophobic and a hydrophilic part (called surfactants), are spread over water. A substrate is then dipped into and/or taken out from the water. The surfactants stick to the surface of the substrate in a very orderly manner. It is a very low cost and easy method of deposition. All the methods are illustrated in figure 1.1. Each of the solution processing methods mentioned above has its own distinct advantages and disadvantages. The most apparent advantages are room-temperature processing and low cost. However, one concern for all these methods is that there is no universal method for all the materials. Depending on various properties of material the suitable process of deposition has to be chosen.

1.1.3 Applications

Ever since the theoretical study of molecular rectifier reported by Aviram and Ratner [Aviram and Ratner, 1974], a lot of progress has been made in the field of molecular electronics. Though the single molecular device has not yet been realized experimentally, there still has been a lot of work done on chemically fabricated organic molecular devices. These devices include electronic switch [Gittins *et al.*, 2000], organic light emitting diodes (OLED) [Tang and VanSlyke, 1987], organic field effect transistors (OFET) [Horowitz, 1998], organic photovoltaic cells [Tang, 1986], and computer memories [Green *et al.*, 2007]

Due to the many advantages of organic molecular devices over the conventional silicon-based technology, like use of low cost substrates, ease of fabrication [Forrest, 2004], flexibility [Hamedi *et al.*, 2007; O'Connor *et al.*, 2016], low static, off-state power [Klauk *et al.*, 2007], and large active area [Sekitani and Someya, 2010], these devices have found their applications in many areas such as sensors and actuators, photovoltaic cells, flexible memories, large - curved display screens etc. as shown in figure 1.2. The applications listed above indicate that the research on organic molecular devices is not limited to the scientific and academic disciplines, but has been explored in the commercial domain as well.

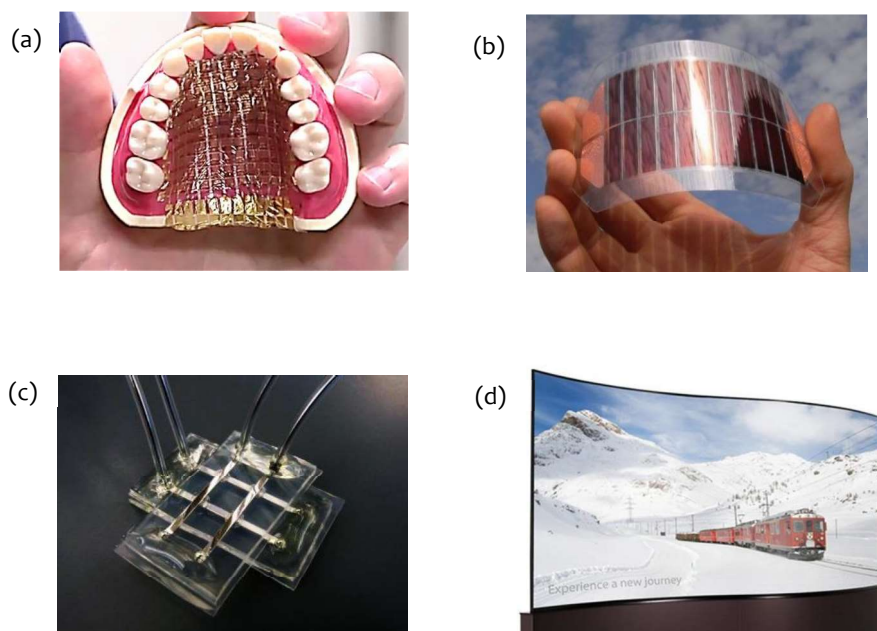


Figure 1.2: Applications of organic molecular devices: (a) A flexible bio sensor (Image courtesy: www.osadirect.com), (b) Flexible solar cell (Image courtesy: ise.fraunhofer.de), (c) A flexible memory chip (Image courtesy: Dickey M., phys.org), (d) A 65 inch flexible OLED display (image courtesy: lg.com)

1.2 PHYSICS OF ORGANIC SEMICONDUCTORS

There are two major categories of organic molecules – small molecules and polymers. One characteristic which is common to both of the materials is the presence of a conjugated π -electron system with one non-hybrid p_z orbital. The difference between the categories of organic molecules mentioned above is the way they can be deposited. Small molecules can be deposited by vacuum evaporation as well as solution processing, whereas polymers can only be deposited by solution processing techniques [Brütting, 2005]. The intra-molecular π -conjugation is a distinguishing feature of organic semiconductors making it different from other organic molecules. For π -conjugation, each carbon atom in the molecular core has to have sp^2 hybridization which is possible only when there are double bonds in the alternative positions at the backbone of the molecule. Now each carbon atom is left with a lone un-hybridized p_z orbital as shown in figure 1.3. Every pair of adjacent p_z orbitals forms a π -bond. Additionally, there is some amount of interaction between two p_z orbitals of adjacent π -bonds. This additional interaction is a unique feature of organic semiconductors which allows π -electrons to travel within (and in some cases, also outside) the molecule beyond their own π -bond. This interaction stretches to a length up to which the $\pi - \sigma$ conjugation is present. If the conjugation is present throughout the length of the molecule, the molecule is a suitable conducting medium for the charge carriers.

Molecular orbital theory suggests that the wave functions of orbitals in molecules are formed by the superposition of the wave functions of orbitals of individual atoms. When a molecular orbital is formed by the addition of the wave functions of participating atoms, it is called a bonding molecular orbital. Whereas, the wave function of molecular orbital found by subtracting the individual wave functions of participating atoms is called an antibonding molecular orbital [Atkins and Paula, 2006].

When two individual carbon atoms having sp^2 hybridization come closer, their individual atomic orbitals combine linearly and form σ bonding and σ^* antibonding orbitals to form a sigma bond. Similarly, un-hybridized p_z orbitals form π bonding and π^* antibonding orbitals forming a π -bond. The σ bond is stronger than π bond because of much stronger overlapping. Due to this

difference of energies between σ and σ^* is higher than the energy difference between π and π^* . Hence the energy of σ bonding is lower than that of π bonding and the energy of π^* antibonding is lower than that of σ^* antibonding [Klausk, 2006].

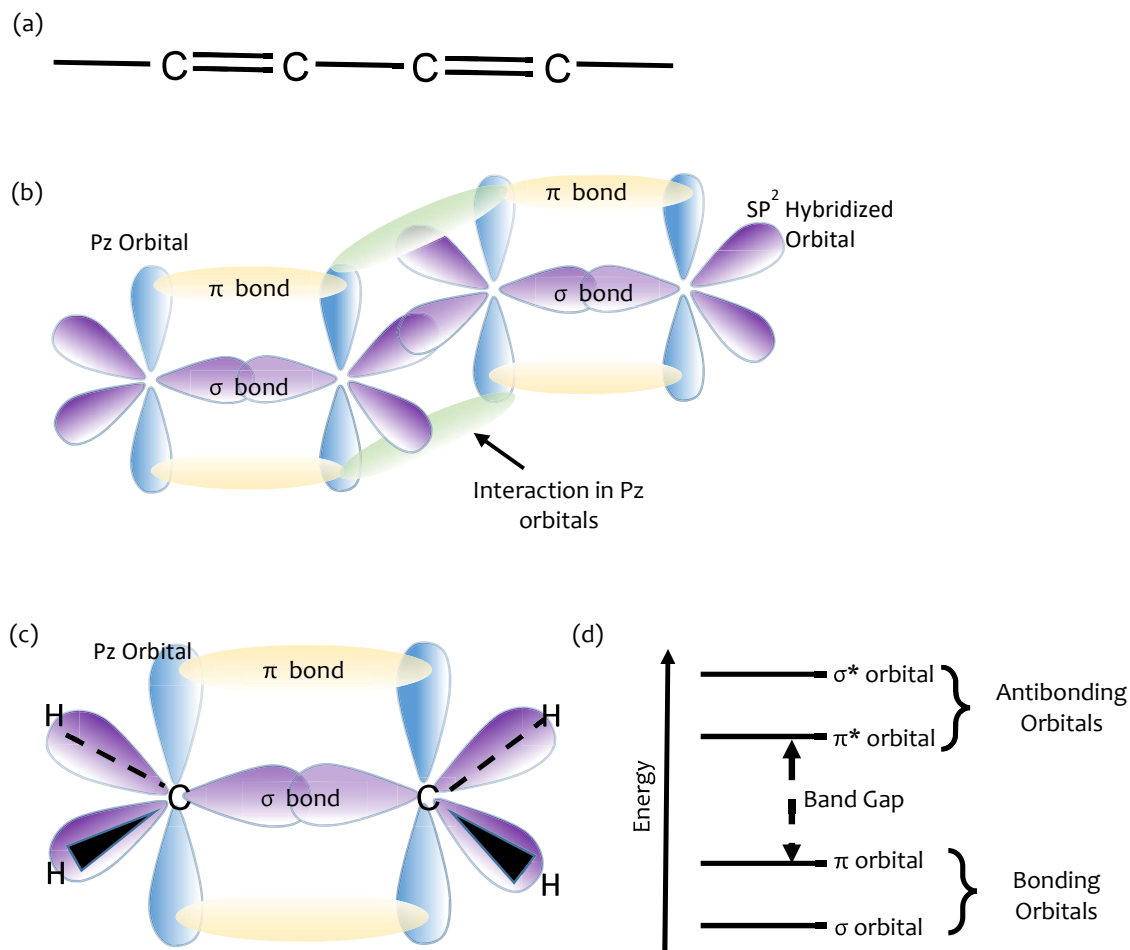


Figure 1.3: Illustration of organic molecules: (a) An organic molecule with double bonds at alternate positions, (b) Electronic cloud in conjugated organic molecule, (c) Electronic cloud in simplest conjugated structure – Ethylene, (d) Formation of bonding and antibonding orbitals' energy levels in ethylene.

Organic molecules are bound with the weak Van der Waal forces within the bulk solid. In bulk organic semiconductor, the delocalization of wave function is far lesser compared to an inorganic solid. Due to this, the interaction between two neighboring molecules is minimal. This unique feature of organic semiconductors causes the fundamental difference between the band structures of organic and inorganic semiconductors. This also makes it possible to study the molecular properties of the organic semiconductor by studying the bulk solid. Because molecules in an organic solid are very loosely bound with each other, each molecule acts as if it is almost isolated. Organic semiconductors have distinct energy levels corresponding to the HOMO (Highest Occupied Molecular Orbital), and LUMO (Lowest Unoccupied Molecular Orbitals). On the other hand in inorganic semiconductors, as we know, there are continuous valance and conduction bands. HOMO and LUMO are analogical to their inorganic counter-parts valance and conduction bands respectively. Analogous to the inorganic electronic devices, the difference in the energies of HOMO and LUMO is called the band-gap of the organic semiconductors. Bandgap in organic semiconductors typically ranges from 1.5eV to 3eV. Whereas conventional electronic materials like silicon and germanium have the band gaps of 1.1eV and 0.72eV respectively. This

implies that in a conventional sense, organic semiconductors are actually, insulators. They become semiconducting only when charge carriers are injected by metal contacts, optical excitation or generated by intended or accidental dopants [Kallmann and Pope, 1960].

1.3 ELECTRONIC MEMORIES

Memories are an essential part of any digital computer as they are used for storing programs and data. The memory unit that communicates directly with the processor is called the *main memory*. There are generally two types of main memories in a computer namely Random Access Memory (RAM) and Read Only Memory (ROM). RAMs can be of two types based on the technology used. *Static RAMs* or *SRAMs* are made up of the flip-flops. Data lasts in an SRAM till the power is applied to the device. *Dynamic RAMs* or *DRAMs* are made up of the MOS capacitors. DRAMs need to be charged in each refresh cycle in order to preserve the data stored in them. Refreshing is required in every few milliseconds for maintaining the decaying charge in the capacitors. RAMs are used for the storage of data being used in the currently running program.

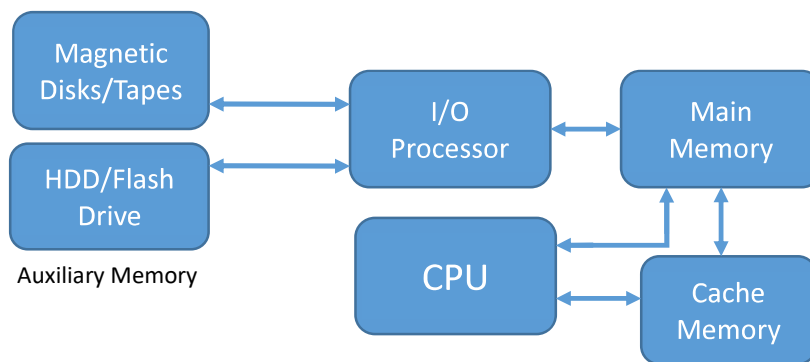


Figure 1.4: Hierarchy of memories in a computer system. Auxiliary memories are at the far end of the system storing large files or backup data for a long time whereas main memories interact with the CPU directly. Cache memory is an ultra-high-speed memory which provides the frequently used data to the CPU.

ROMs on the other hand, are used for storing the information that is essential to the functioning of the computer and that is not to be changed, such as bootstrap loader or BIOS (basic input output system). On the basis of programmability, there are several types of ROMs. A Programmable Read Only Memory (PROM) can be programmed initially. The data remains unchanged thereafter. Erasable Programmable Read Only Memory (EPROM) gives us the flexibility to erase data from the ROM. In Electrically Erasable Programmable Read Only Memories, the data can be erased with the help of an electric (voltage/current) pulse. PROMs are useful for customized applications, whereas EPROMs and EEPROMs are useful in applications where frequent upgrades are required.

Though a very small computer with minimal instruction set and having merely essential features (such as non-programmable, basic calculators or basic digital watches), might be able to function accordingly with only the main memory, but most general purpose computers would run more efficiently if they had additional storage which is more than the main memory. Also, for the permanent storage of custom software, data, and programs, some sort of permanent storage is required because the enormous amount of data and software accumulated over a long time is not needed all the time by the processor. The memory which stores such a backup or auxiliary information for a long time is called an *auxiliary memory*. Magnetic tapes and disks of yesteryears technology, hard disk drives (HDDs), and flash drives fall into this category. In most high-end computers used today, a special, very high-speed memory, called a *cache memory* is also used. A cache is used to store the programs and data that are currently/recently used by the processor [Mano, 1992]. Figure 1.4 shows the hierarchy of memories in a typical computer.

Conventional RAMs and ROMs are made up of silicon-based transistors and/or MOS capacitors whereas magnetic disks and tapes of past years used magnetic media. DRAMs are fast, but there is a need for a circuit which enables the repetitive refreshing of the charge in the MOS capacitor every few milliseconds. This repetitive refreshing costs power. Modern hard disk drives work on the principle of giant magneto resistance (GMR) effect [Nagasaka *et al.*, 2006]. They have a stack of magnetic disks and a reading head situated a few nanometers above the disk surface. Per-bit cost of such memories is very low. Also, their data density and repeatability are very high. However, the access time in such a large memory is a bit high. To reduce this time, disks need to spin faster, and that consumes power. Also, there is a high chance of crashing the head which is very close to the disk surface [Scott and Bozano, 2007]. Flash memories are compact and handy in terms of usage. But the erase and rewrite process is a bit slow and also they have limited endurance. Per-bit cost of flash memories is also a concern for the market.

1.4 ORGANIC MOLECULAR MEMORIES

There has been a great deal of research in the field of organic molecular memories in recent times. As discussed earlier, the traditional semiconductor-based technology is reaching a bottleneck in terms of packing density and performance. A paradigm shift in the approach of fabricating new devices is the need of the hour. An organic switching device, also known as organic molecular memory is one such device which gives an opportunity for such a paradigm shift. In contrast to the conventional solid-state memories which are essentially based on transistors, the organic molecular devices are mainly dependent on the conductance switching. The device shows different conductance at the same voltage at the same point [Bandhopadhyay and Pal, 2003; Mukherjee and Pal, 2004]. An appropriate electrical pulse is required to achieve the switching between the high and low conductance levels. Setting a device to the high conductance level (the so-called ON-state) can be considered as 'writing' a '1' on that particular memory cell, whereas resetting the device back to the low conductance level (OFF state) can be considered as writing a '0'. A low enough voltage, which doesn't set/resets the device can be applied to 'read' the device to know in which state the device is - ON or OFF. Some devices are shown to have multiple levels of conductance upon multiple levels of write pulses [Mukherjee and Pal, 2004]. Such devices can have multiple bits stored in one cell - e.g. for 4 levels of conductance, the device may store 2 bits of information. Such multilevel switching can increase the density of packing for the memory devices.

Figure 1.5 is a depiction of how a resistive switching organic memory's current-voltage characteristics looks like. As shown in figure 1.5, at read voltage V_r , there are two values of current. The device shows very low conductance at the start, as the voltage increases, the device switches into high conduction mode at a voltage V_w , which is called the 'write voltage' or the 'set voltage'. After going to the high conduction state, the device stays in it even after decreasing the voltage, until a sufficiently large negative voltage called as 'erase voltage' is applied to it. However, it is not always necessary that a device shows switching in the positive half region only. Some organic memory devices show a switching behavior in both directions of electric voltage, such devices are said to be showing a 'bipolar switching' behavior [Wang *et al.*, 2015].

There are several types of resistive memories available in the literature. Memory elements using ferroelectricity have been popular lately [Naber *et al.*, 2010]. The ferroelectric memories make use of hysteresis in the I-V characteristics of these materials. Another mechanism of the resistive memories is making use of conformational change in the molecules of the active layer [Taylor *et al.*, 2003]. Formation of a metallic filament in an insulating material is another mechanism found in the literature for the switching [Cho *et al.*, 2011]. Formation of a charge transfer complexes has been recently explored in the literature [Zhang *et al.*, 2016].

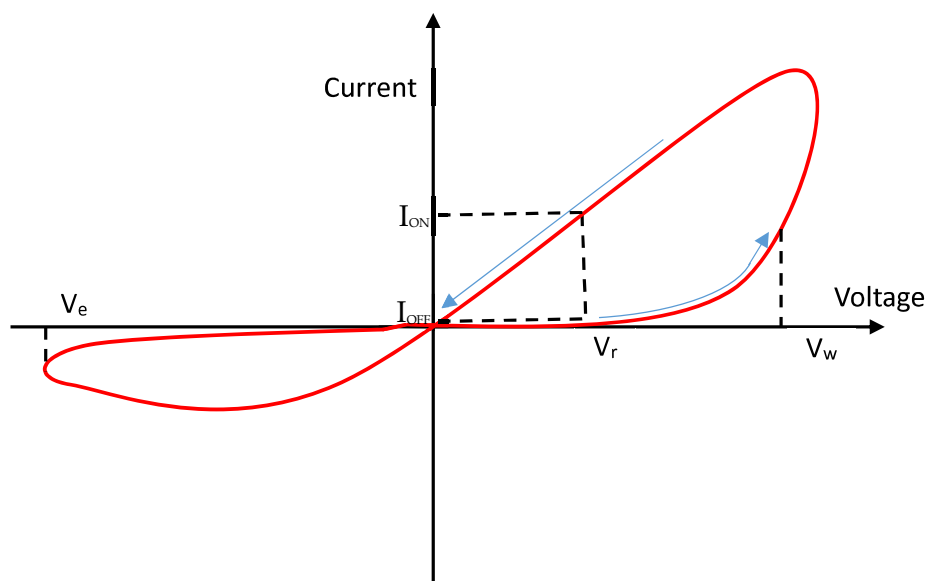


Figure 1.5: Current voltage characteristics of a conductance switching memory. V_r , V_w and V_e respectively are the read, write and erase voltage levels. Observe that at a same voltage V_r , there are two values of current namely I_{ON} and I_{OFF} . Arrows show the direction in which voltage is increased/decreased.

1.4.1 Parameters for Measuring the Performance of Organic Molecular Memories

Performance of organic molecular memory devices (or any memory device for that matter), is assessed on the basis of various parameters such as ON/OFF ratio, retention time, and repeatability.

As shown in figure 1.5, at read voltage V_r , there are two levels of the current- the higher value of current is observed after the device has gone through the so-called 'write voltage' V_w , and the lower value of current is observed after the device has gone through the 'erase voltage' V_e . These currents are called as ON and OFF currents (I_{ON} and I_{OFF}) respectively. For a device to function properly, ON current must be high and OFF current should be very low. To quantize it, we have a metric called as *ON/OFF ratio* or *switching ratio* which is the ratio of ON current, or high conductance state current to the OFF current or the low conductance state current. For a device to allow a high noise margin, this ON/OFF ratio must be as high as possible. An ON/OFF ratio of '1' signifies that there is no switching. A memory with a low ON/OFF ratio might succumb to erroneous reading/writing because of the presence of noise.

For a memory device, the retention time is another crucial feature to quantify the ability of the memory to preserve a particular state. Retention time can be defined as the time till the application of read voltage results in the same state of current (ON or OFF). The phrase 'same state of current' can have different meanings for different tolerance limits and noise margins, but largely it means that the order of ON or OFF state current does not change. For the applications like non-volatile memory, it is essential that the memory preserves a state even without the application of bias voltage.

Repeatability or *endurance* is the measure of how many read-write-erase cycles a memory can survive before its ON/OFF ratio perishes below the permissible levels. Endurance is an essential feature for any memory device, be it non-volatile or RAM. A memory on which data can't be stored and deleted repeatedly is a lousy memory, unless it is a read only memory on which one only needs to write the data once.

1.4.2 Switching Mechanisms in Organic Molecular Memories

Switching in organic molecular memories can be due to various reasons. Redox is one reason where electrochemical oxidation and reduction of two materials respectively occurs [Li *et al.*, 2004]. This sort of switching occurs due to molecules only. Ferroelectric materials have also been found to have switching properties [Furukawa, 1989]. Resistive switching devices are those devices which switch from high resistance to low resistance state upon application of a voltage [Bandhopadhyay and Pal, 2003; Bandyopadhyay and Pal, 2004]. These devices are made up of an insulator sandwiched between two metals, such a structure is called as metal-insulator-metal (MIM) device [Kiguchi and Fujii, 2017]. Formation of a charge transfer complex (CTC) between molecules leads to switching behavior in resistive memories too [Zhengchun *et al.*, 2006]. Using thin metallic layers as floating islands in an organic molecular matrix is another way of obtaining switching in the organic molecules [Ma *et al.*, 2002; Ma *et al.*, 2002].

A special mention of resistive switching is due here, because of its simplest structure, which is metal insulator metal or MIM. First MIM structures showing switching in conductance were reported by Gregor [Gregor, 1968]. In resistive memories, the switching can be achieved by filamentary conduction [Dearnaley *et al.*, 1970]. A filament is a thin, wire-like conducting structure with a very small cross-sectional area compared to the device, formed between the two electrodes. The simplest of all filaments consists of the metal diffused into the active layer [Pagnia and Sotnik, 1988], but it can also be formed by the local alignment of the storage medium [Scott and Bozano, 2007]. In essence, the current density can be written as a product of the number of charge carriers (N), charge of an electron (e), mobility of the charge carriers (μ), and the electric field (E). Affecting any of the above factors changes the current. For example, the filament formation changes the number of charge carriers (N) and mobility (μ) (both increase), hence the conduction increases [Scott and Bozano, 2007]. The number of charge carriers also changes with the exchange of electric charge between the acceptor and donor molecules present in the insulating layer which leads to the formation of charge transfer complexes (CTC) [Kamitsos *et al.*, 1982]. Blocking the flow of charge carriers with the help of trapped, immobile charges is another method of achieving the conductance switching with the help of altering electric field (E). The presence of the trapped charges make a space-charge region (much like that of the depletion region of a diode), which blocks the current flow in a certain direction, and thus highlighting the low conductance state of the memory [Nakashima and Uozumi, 1997; Shin *et al.*, 1998]. The metallic nanoparticles' (NPs) inclusion into the active layer also have known to provide the device with the switching behavior. The reason for increasing mobility (μ), after the inclusion of NPs is the hopping of charge carriers that results between the molecules and NPs or among the NPs [Bozano *et al.*, 2005].

1.4.3 Recent Trends in the Field of Organic Molecular Memories

There have been many recent advancements in the field of organic molecular memory devices. Considering the case of resistive memories, filamentary action has been a reasonably well sought after method of switching. For example, in a study, it was found that silver (Ag) filamentary paths were responsible for switching in the Ag/polymer/poly-silicon memory device [Cho *et al.*, 2011]. These devices showed a high ON/OFF current ratio of more than 10^4 , the retention time of the order of 10^4 s without any signal degradation, and the repetitions could be achieved about 1000 times. Memories based on Redox action have also been researched in recent times. In one particular study, multilevel switching of four different ON/OFF ratios (ones, tens, thousands and hundred thousands) is contributed to charge transfer under the external electric field [Zhang *et al.*, 2016]. A lot of emphasis has been given to the suspended and interfacial nanoparticles (NPs) in the past few years. These nanoparticle-based memories include inorganic NP in the polymer matrix [Kaur *et al.*, 2017], inorganic NP interfacial layer between two small molecule organic semiconductors [Abhijith *et al.*, 2017], and organic quantum dots-polymer composites [Bok *et al.*, 2017]. In particular, the last one of these studies has shown a remarkably

low OFF state current between 10^{-12} and 10^{-9} A with a retention time of the order of 10^4 s and a high ON-OFF ratio of 10^6 in graphene quantum dot - polymer based devices fabricated by spin coating. It shows that the high performance parameters have been achieved lately using the easiest of the fabrication processes. A rather unique resistive memory design with an inorganic and organic molecules hybrid has also been explored lately [Jae-Won and Won-Ju, 2017]. The hybrid devices in the study mentioned above, showed a significant improvement over pure polymer-based devices in terms of retention time, voltage window and endurance, and they showed improvement over inorganic resistive memories in terms of flexibility.

1.5 RESEARCH FOCUS AND THESIS ORGANIZATION

There has been a great amount of research and advancements in the field of organic molecular memory devices in recent years. Many aspects and combinations of new materials have been discovered lately. The outcome of these studies mentioned in the previous section has given a boost to the new research in the area. There are still numerous areas open about organic molecular memories for researchers to discover such as physics, chemistry, and processability of new materials and designs.

One of the focuses of the research was to study the switching capabilities of devices with a blend of small molecules and polymer. The search for the blend stems from the different advantages that both small molecules and polymers have. The ease of fabrication and low processing cost with the incorporation of solution processing has been stressed. The variation of the concentration ratio of small molecule 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) and polymer poly(4 vinyl phenol) (PVP) was studied in terms of switching mechanisms, their endurance and retention properties. The possibility of more than one switching mechanisms is discovered and experimentally verified with various physical characterization techniques.

Another focus of the research was on the study of effects of variation of surface morphology of the aforementioned blend of small molecule (DDQ) and polymer (PVP), on its switching capability and the physics behind it. The stress in this study was to find out optimum process parameter i.e. the rotational speed at the time of spin coating. The goal of optimization was to achieve a high ON-OFF ratio. Ease of fabrication also remained a point throughout the research.

A brief description of what each chapter in the thesis encapsulates is given below:

Chapter 2 provides a short account of basic principles of all the experimental techniques that have been used during the research work.

Chapter 3 presents the design and fabrication of a new polymer-small molecule based memory device with PVP and DDQ, with its switching capabilities and discusses the possible switching mechanisms of these memories.

Chapter 4 explores the effect of changes in the surface morphology of DDQ-PVP blend thin films on the device characteristics in terms of ON-OFF ratio by varying the rotational speed of the spin coating procedure.

Chapter 5 sums up and provides a conclusion of the research work. It also discusses future research possibilities in the field of organic molecular memories.