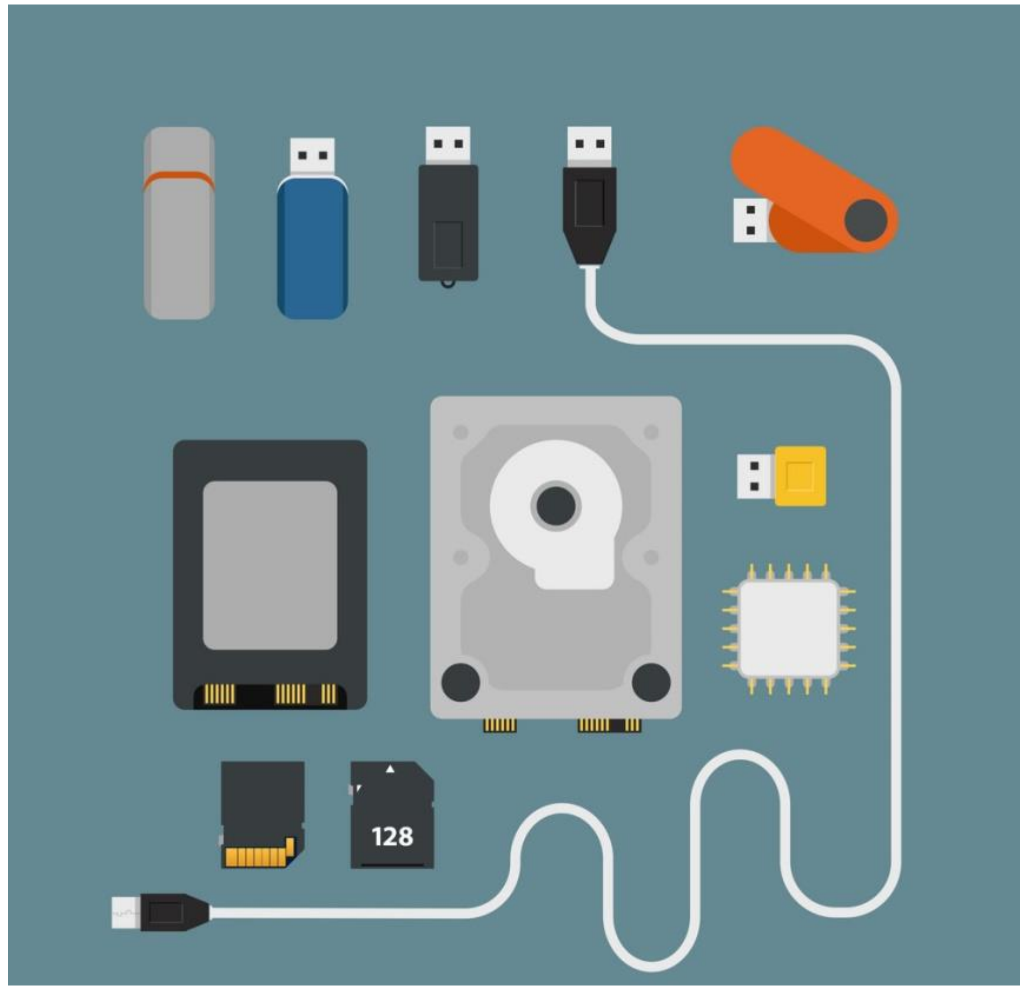
UNIT-III

Materials for memory and display technology
Materials for memory storage: Introduction to materials for electronic memory, classification (organic, polymeric and hybrid materials), manufacturing of semiconductor chips. Green computing: Bio-composite based memory devices. **Fabrication of smart materials and devices**: Photo and electro active materials for memory devices, materials for display technology (Liquid crystals display, organic light emitting diode and light emitting electrochemical cells).

Memory storage

Computer storage devices:
The storage device is a hardware device that is used to store data and information. They Provide one of the core functions of the modern computer. Every desktop computer, laptop, smartphone, and tablet will have some kind of storage device within it. It can be inside or outside of the computer or the main device. They come in different sizes and shapes depending on the needs and functionalities.

Computer storage or memory devices



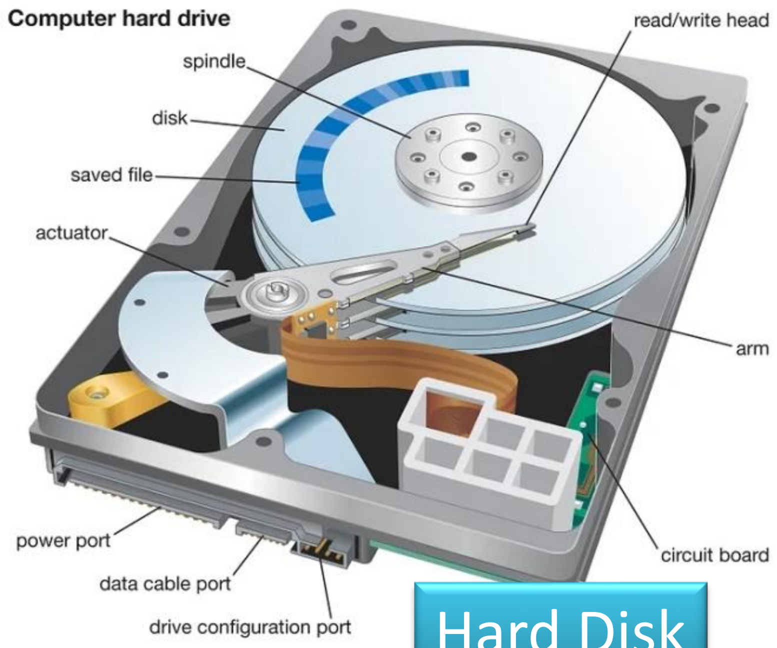
Memory storage devices

Internal Hard disk

External Hard disk

Magnetic tape

Floppy Disk



Hard Disk

Memory Card

Online Cloud storage devices

Pen drive

Characteristics of memory devices

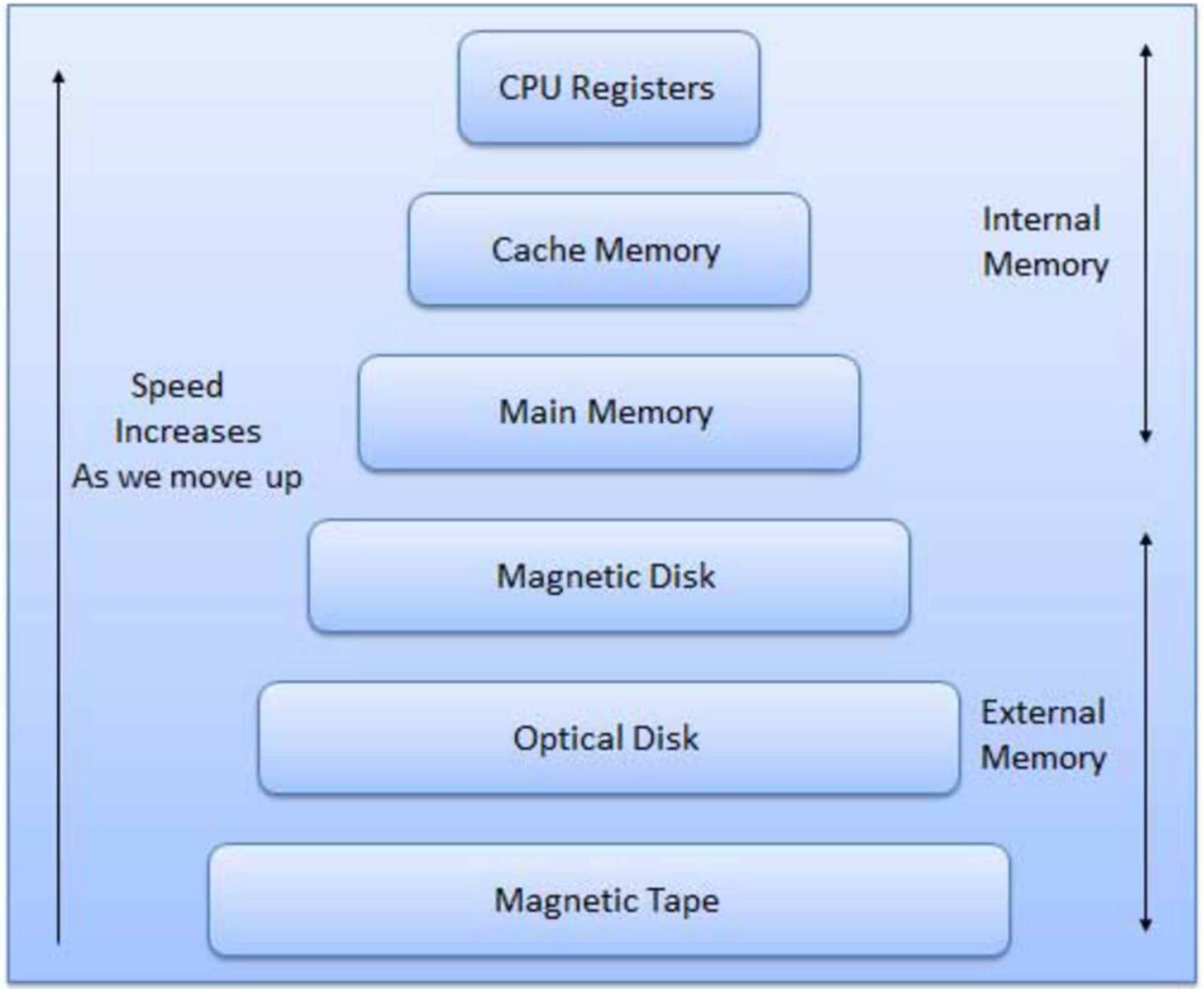
Location: The memory can either be stored externally with the help of some devices or internally.

Capacity: The amount of data a device can store is called capacity. It is measured as a byte (1 byte = 8 bits, 1 bit is either 0 or 1).

Performance: The performance of any memory device depends upon the rate at which data is transferred, the time taken by the device to carry out the process and the access time.

Classification of memory devices

1. Primary memory or Internal memory (RAM, ROM, Cache)
2. Secondary memory or external memory (SSD, CD, Floppy disk, magnetic tape)
3. Cache memory (It is part of primary or internal memory)



Primary memory

It is used to store data and programs or instructions during computer operations. It uses semiconductor technology and hence is commonly called semiconductor memory.

Types of primary memory

1. RAM (Random Access Memory)

(i) S RAM (Static RAM)
(ii) D RAM (Dynamic RAM)

2. ROM (Read Only Memory)

It is a non-volatile memory. Non-volatile memory stores information even when there is a power supply failed/ interrupted/stopped

(i) MROM(Masked ROM)
(ii) PROM (Programmable Read Only Memory)
(iii) EPROM (Erasable Programmable Read Only Memory)
(iV)EEPROM (Electrically Erasable Programmable Read Only Memory)

Secondary Memory

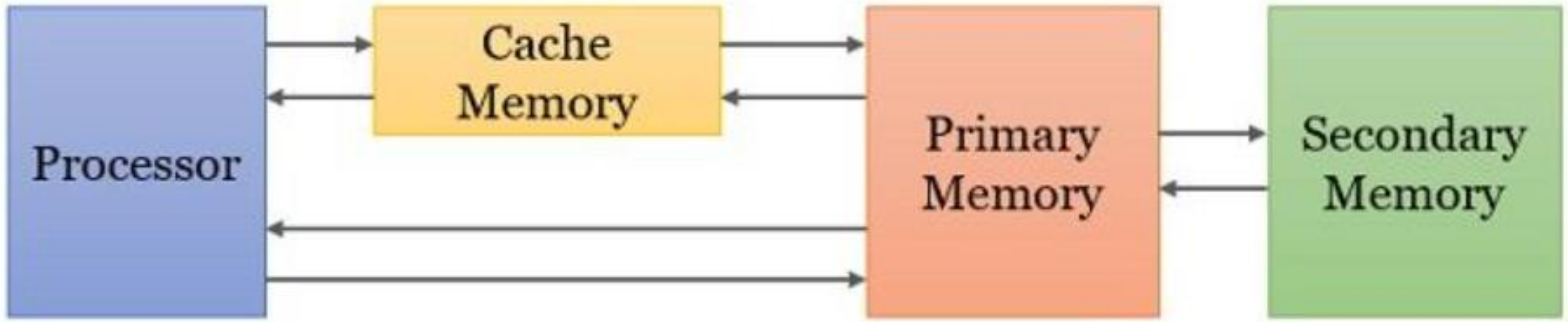
It is also known as auxiliary memory and backup memory. It is a non-volatile memory and used to store a large amount of data or information. The data or information stored in secondary memory is permanent, and it is slower than primary memory. A CPU cannot access secondary memory directly. The data/information from the auxiliary memory is first transferred to the main memory, and then the CPU can access it.

Characteristics of Secondary Memory

- It is a slow memory but reusable.
- It is a reliable and non-volatile memory.
- It is cheaper than primary memory.
- The storage capacity of secondary memory is large.
- A computer system can run without secondary memory.
- In secondary memory, data is stored permanently even when the power is off.

Cache Memory

It is a type of high-speed semiconductor memory that can help the CPU run faster. Between the CPU and the main memory, it serves as a buffer. It is used to store the data and programs that the CPU uses the most frequently



Cache Memory Diagram

- The capacity of the cache ranges from 2 KB to a few MB.

Cache memory

Advantages of Cache memory

- It is faster than the main memory.
- When compared to the main memory, it takes less time to access it.
- It keeps the programs that can be run in a short amount of time.
- It stores data in temporary use.

Disadvantages of cache memory

- Because of the semiconductors used, it is very expensive.
- The size of the cache (amount of data it can store) is usually small.

Classification of Electronic Memory

According to the device structure, electronic memory devices can be divided into three primary categories: transistors, capacitors and resistors.
Memory Devices: Classification of memory devices;

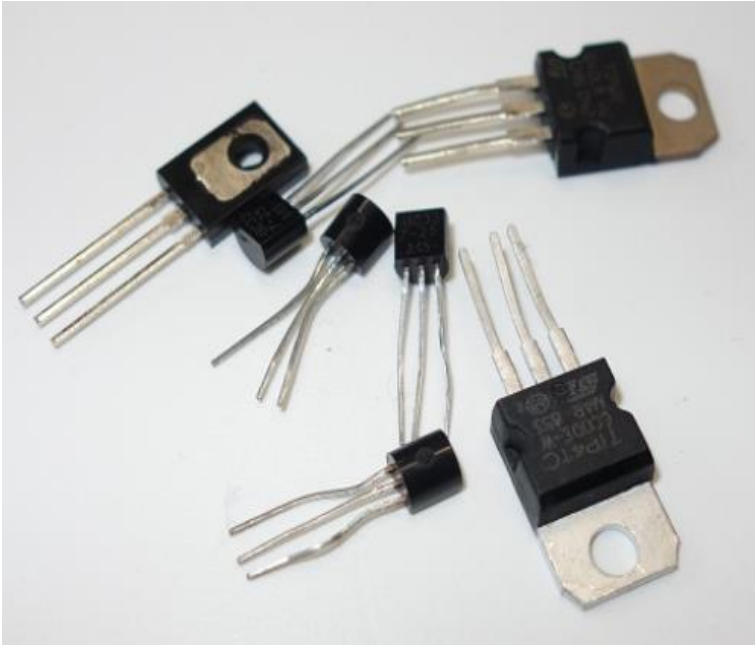
1. Transistor-type Electronic Memory
2. Capacitor-type Electronic Memory
3. Resistor-type Electronic Memory
4. Charge transfer type electronic Memory

1. Transistor-type Electronic Memory

A transistor is a miniature electronic component that can work either as an amplifier or a switch.

- It is converted to p-type and n- type semiconductor by doping trivalent and pentavalent impurities.
- A computer memory chip consists of billions of transistors, each transistor is working as a switch, which can be switched ON or OFF. Each transistor can be in two different states and store two different numbers, ZERO and ONE.
- Since chip is made of billions of such transistors and can store billions of Zeros and Ones, and almost every number and letter can be stored..

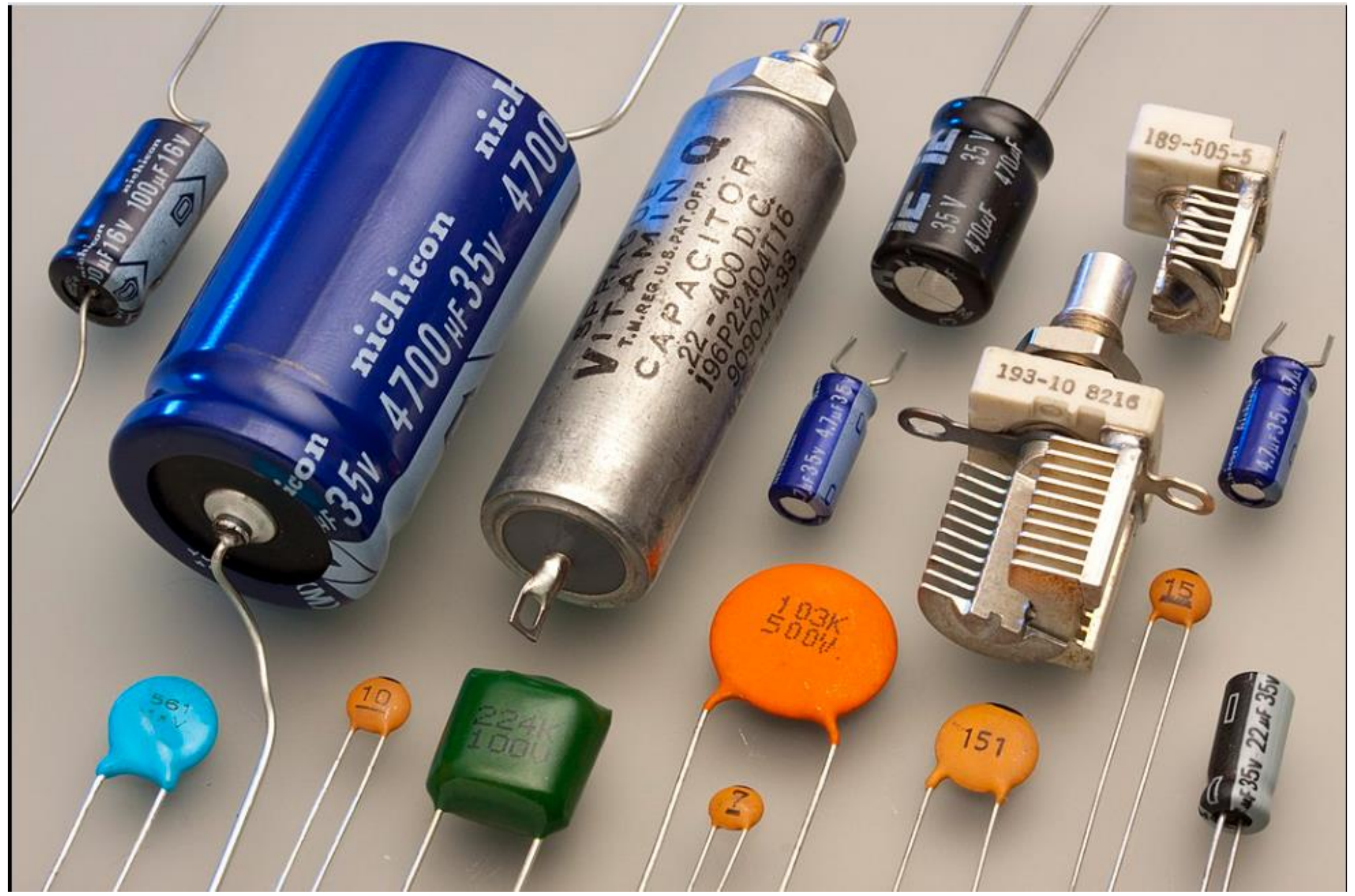
➢ It is composed of semiconductor material, usually with at least three terminals for connection to an electronic circuit. Ex: MOSFET (**metal-oxide-semiconductor field-effect transistor**) and OFET (**Organic Field Effect Transistor Memory**)

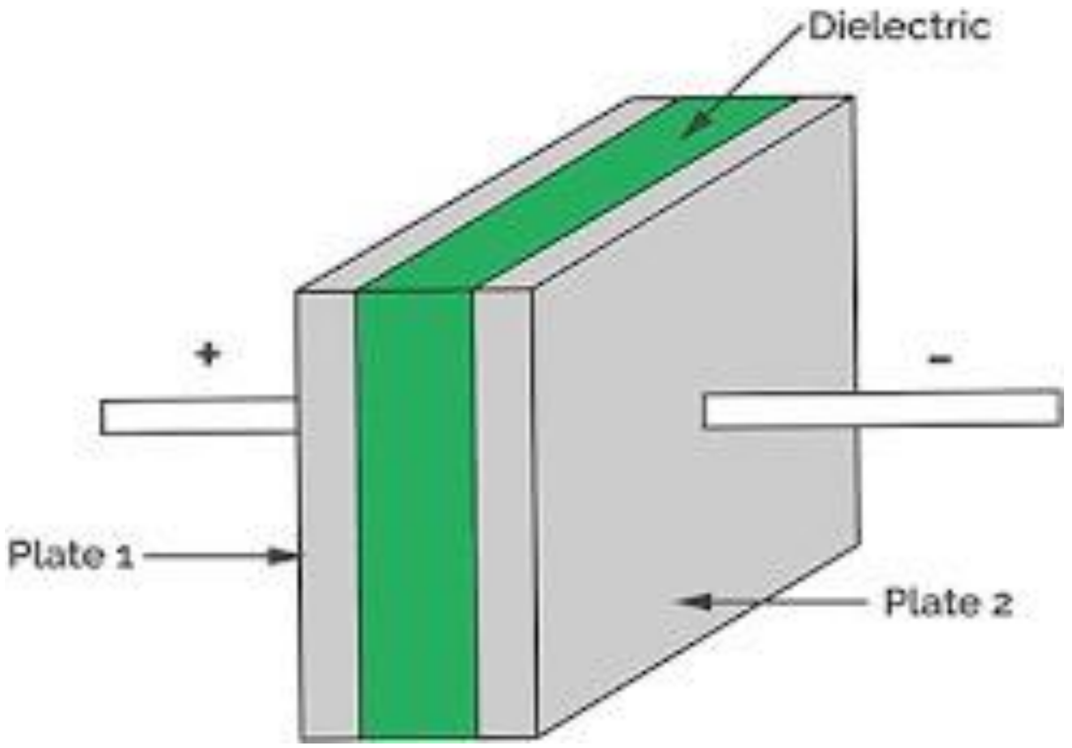


2. Capacitor - Type Electronic Memory

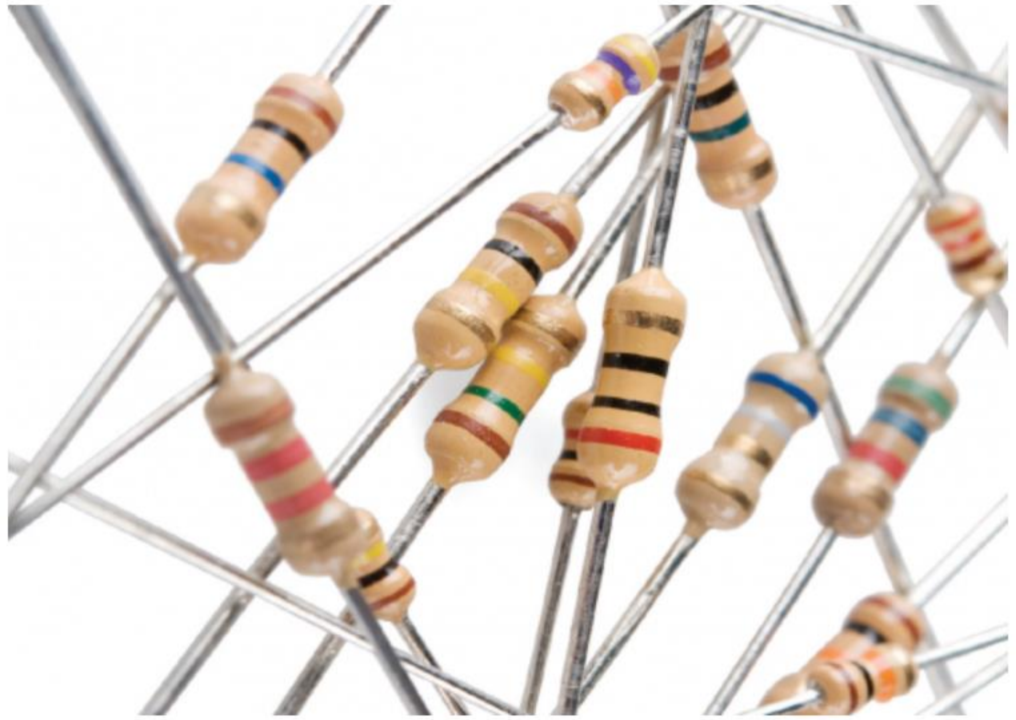
Capacitors can store charges on two parallel plate electrodes under an applied electric field. Based on the amount of charge stored in the cell, the bit level (either “0” or “1”) can be encoded accordingly. When the medium between the electrodes is merely a dielectric, the stored charge will be lost eventually. Organic and polymeric ferroelectric materials can be used in capacitor- type electronic memory device.

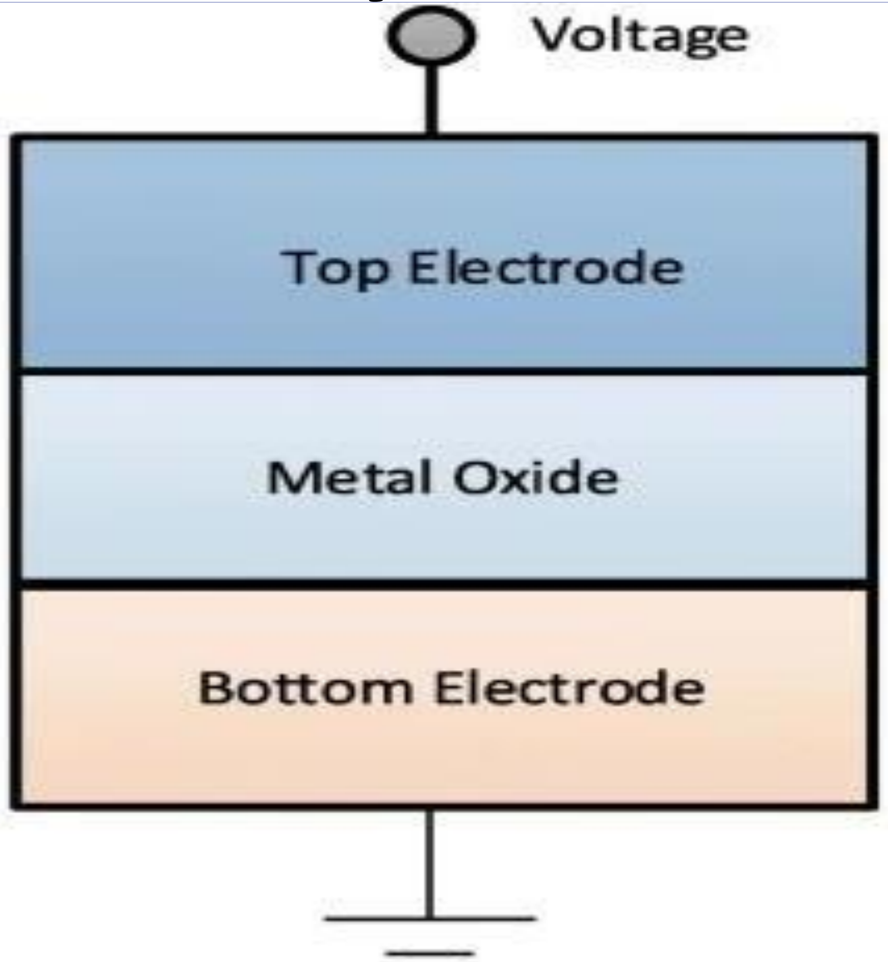
Example; DRAM (Dynamic Random Access Memory) using a dielectric capacitor is volatile memory ferroelectric capacitors, (FeRAM) is non-volatile memory





3. Resistor-type Electronic Memory





The memory cell consists of a resistor-type material that can change its resistance when an electric field is applied. The resistance can be set to high or low states, representing binary values (0 or 1).

- The resistors are arranged in a particular pattern to store the information.
- Unlike transistor and capacitor memory devices, resistor-type memory does not require a specific cell structure (e.g. Field Effecting Transistor) or to be integrated with the CMOS (complementary metal-oxide-semiconductor) technology.

4. Charge transfer type electronic memory device

Charge-transfer type electronic memory devices typically involve the movement of charge carriers (usually electrons) within the device to store and retrieve data.

• This type of electronic device is based on the Charge Transfer Effects of a charge transfer complex. A charge transfer (CT) complex consists of two parts, one electron donor and other an electron acceptor.

• It is also called as a donor–acceptor (D– A) complex. The conductivity of a CT complex is dependent on the ionic binding between the D–A components. In CT complex, a partial transfer of charges occurs from donor part to the acceptor part.

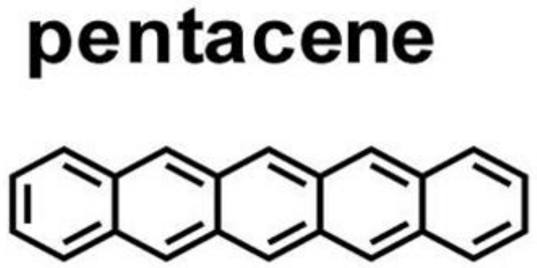
• This results in difference in conductivity. CT complexes exhibit bistable states due to difference in conductivity. This behavior is used to design molecular electronic devices.

Types of organic memory materials

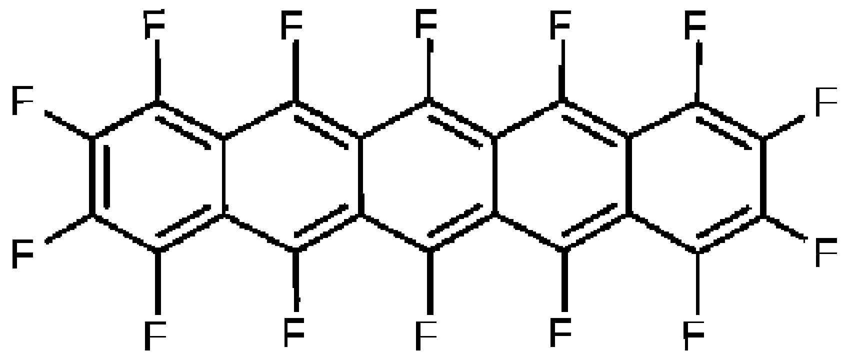
I) Organic molecules II) Polymeric materials III) Organic- inorganic hybrid materials

I) Organic molecules used for memory device

a) The p -Type Organic Semiconductor Material “Pentacene”
An Organic molecule with π conjugated system and possesses holes as major charge carrier is called p-type semiconductor. Example: Pentacene



b) The n -Type Organic Semiconductor Material “Perfluoropentacene” Perfluoropentacene is a derivative of pentacene where all hydrogen atoms in the pentacene structure are replaced by fluorine atoms



Perfluoropentacene

2. Electronic memory devices based on polymeric molecules

Polymer memory refers to memory technologies based on the use of organic polymers. The molecular structure of polymeric materials can be tailored using electron donors and acceptors. The properties of polymer memory are low-cost and high-performance, and have the potential for 3D stacking and mechanical flexibility.

Polythiophenes: Example: Poly(3-hexylthiophene) (P3HT)
Polyfluorenes: Example: Poly(9,9-dioctylfluorene) (PFO)
Polyphenylene Vinylenes (PPVs): Example: Poly(2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene) (MEH-PPV

Electrical memory devices based on inorganic/organic nanocomposites

Generally, organic–inorganic hybrid materials are composed of organic layers containing fullerenes, carbon nanotubes, graphene, metal nanoparticles, semiconductor nanoparticles or inorganic quantum dots (QDs).

Non-volatile memory devices based on hybrid inorganic/organic nanocomposites have emerged as excellent candidates for promising applications in next-generation electronic and optoelectronic devices. The simplest structure for a hybrid memory device fabricated utilizing the solution method is a single-polymer layer embedded with inorganic nanomaterials and sandwiched between two metal electrodes.

Generally, the hybrid nanocomposites are formed by dissolving inorganic nanomaterials and a polymer matrix simultaneously in a certain organic solvent with a relatively high volatility. Fabrications of single-layer-structured nonvolatile memories based on various organic/inorganic hybrid nanocomposites have been reported.

a) **Organic-Inorganic Nanocomposites**:
Example: Organic polymers combined with inorganic nanoparticles (e.g., metal nanoparticles or quantum dots).

b) **Metal-Organic Frameworks (MOFs):**
Example: MOFs incorporating organic ligands and metal ions or clusters.

c) **Hybrid Organic Ferroelectric Materials**:
Example: Organic ferroelectric polymers combined with inorganic ferroelectric materials.

Biocomposites for memory

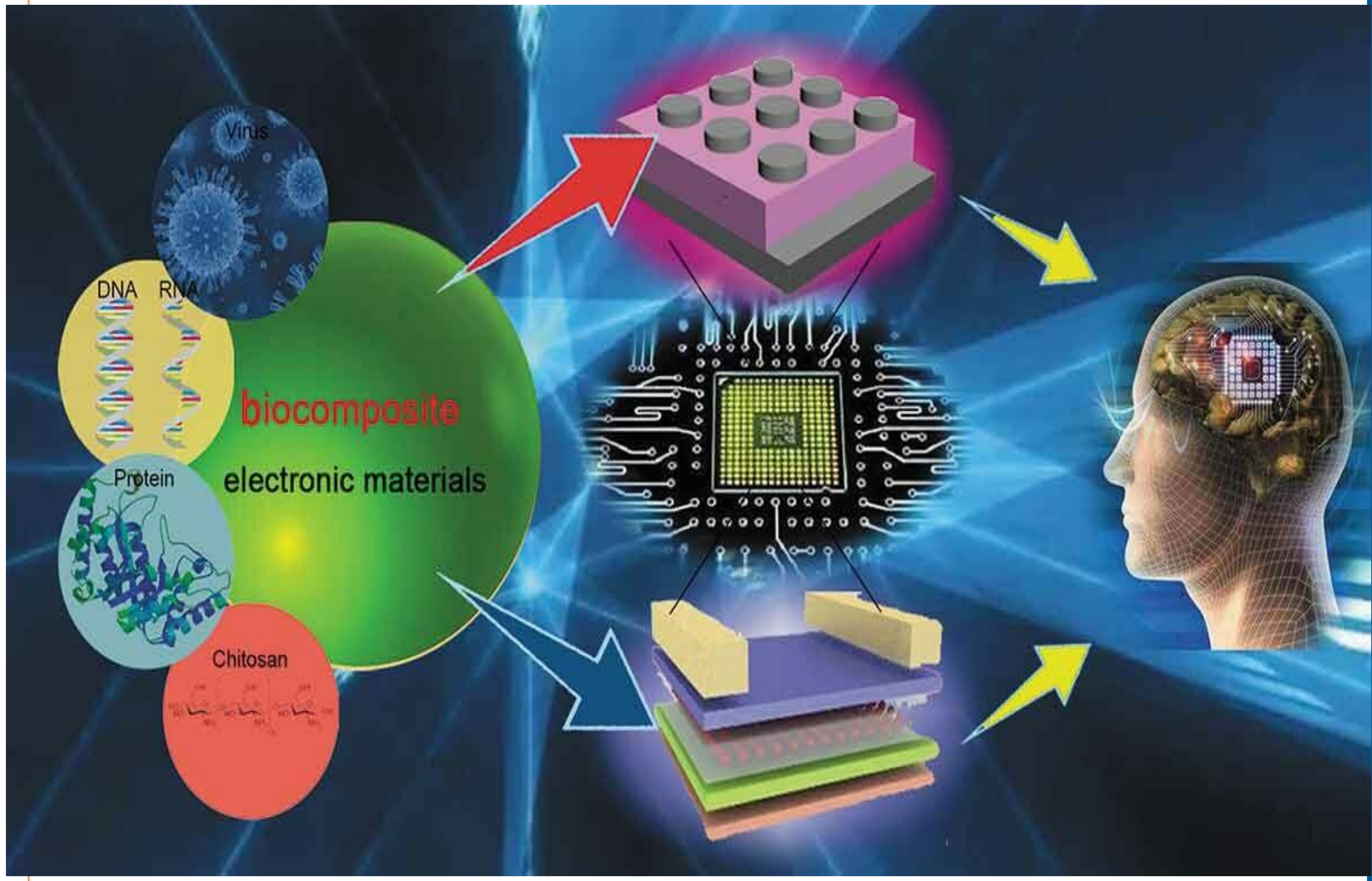
With the popularization of mobile phones, digital cameras and other portable electronic devices, nonvolatile memory is playing an increasingly important role in modern human’s daily life.

With progresses of science and technology, the application of new nonvolatile memory will bring a qualitative change to the performance of computers and people’s operating habits.

Biocomposites provide an excellent choice for the future application of organic electronics.

Biocomposites, especially the combination of nanoparticles and biomaterials, are very attractive research projects.

Bio composites that combine the unique properties of nanoparticles and biomaterials provide a new type of material for physicists, chemists, biologists, and materials scientists.



Bio-composite based memory devices

Bio-composite-based memory devices represent a fascinating and emerging area of research at the intersection of materials science, biology, and electronics. These devices leverage bio-inspired or bio-compatible materials to create memory storage components.

a) DNA-Based Memory Devices:

Material: DNA (deoxyribonucleic acid)

Application: DNA has been investigated for use in non-volatile memory devices. DNA strands can be used to store information through sequence variations or by exploiting the inherent charge and structural characteristics of DNA.

Properties: DNA is known for its information-carrying capacity and ability to self-assemble. Researchers are exploring its potential for data storage.

b) Protein-Based Memory Devices:

Material: Proteins, such as bacteriorhodopsin

Application: Bacteriorhodopsin, found in the membranes of certain bacteria, has been explored for use in optical memory devices. It can undergo reversible photochemical reactions, making it suitable for information storage.

Properties: Bacteriorhodopsin exhibits light-sensitive properties, allowing for the creation of bio-composite-based memory devices with potential applications in optical storage.

c) Peptide-Based Memory Devices:

Material: Peptides

Application: Peptide-based materials are being investigated for their potential in resistive switching memory devices. These devices use changes in resistance to store information.

Properties: Peptides offer a wide range of structural and functional diversity, making them attractive for designing novel memory devices.

d) Cellulose-Based Memory Devices:

Material: Cellulose and cellulose derivatives

Application: Cellulose, a natural polymer found in plant cell walls, has been explored for use in flexible and biodegradable memory devices.

Properties: Cellulose-based materials are abundant, renewable, and environmentally friendly. They have potential applications in sustainable and biocompatible memory devices

Advantages

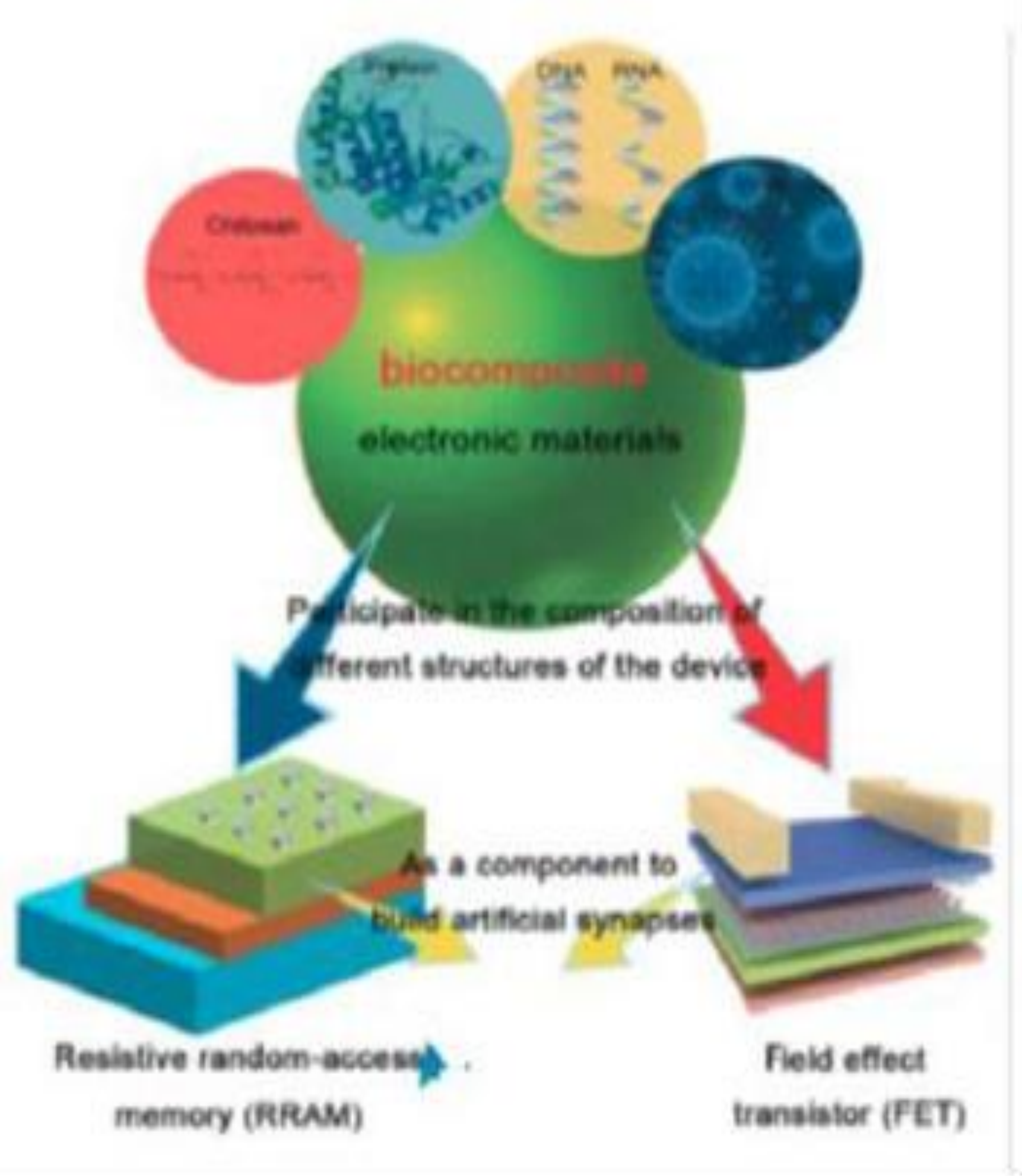
Several basic advantages of the biomaterial-nanoparticle hybrid system:

(these materials extremely attractive for future bioelectronics applications)

I. The biomaterial-functionalized nanoparticles are water-soluble and have a high specific surface area.

II. The unique optical and electrical properties of nanoparticles can be adjusted and controlled by the size of the nanoparticles, and various properties of bioelectronic devices can be controlled and optimized by controlling the properties of the nanoparticles.

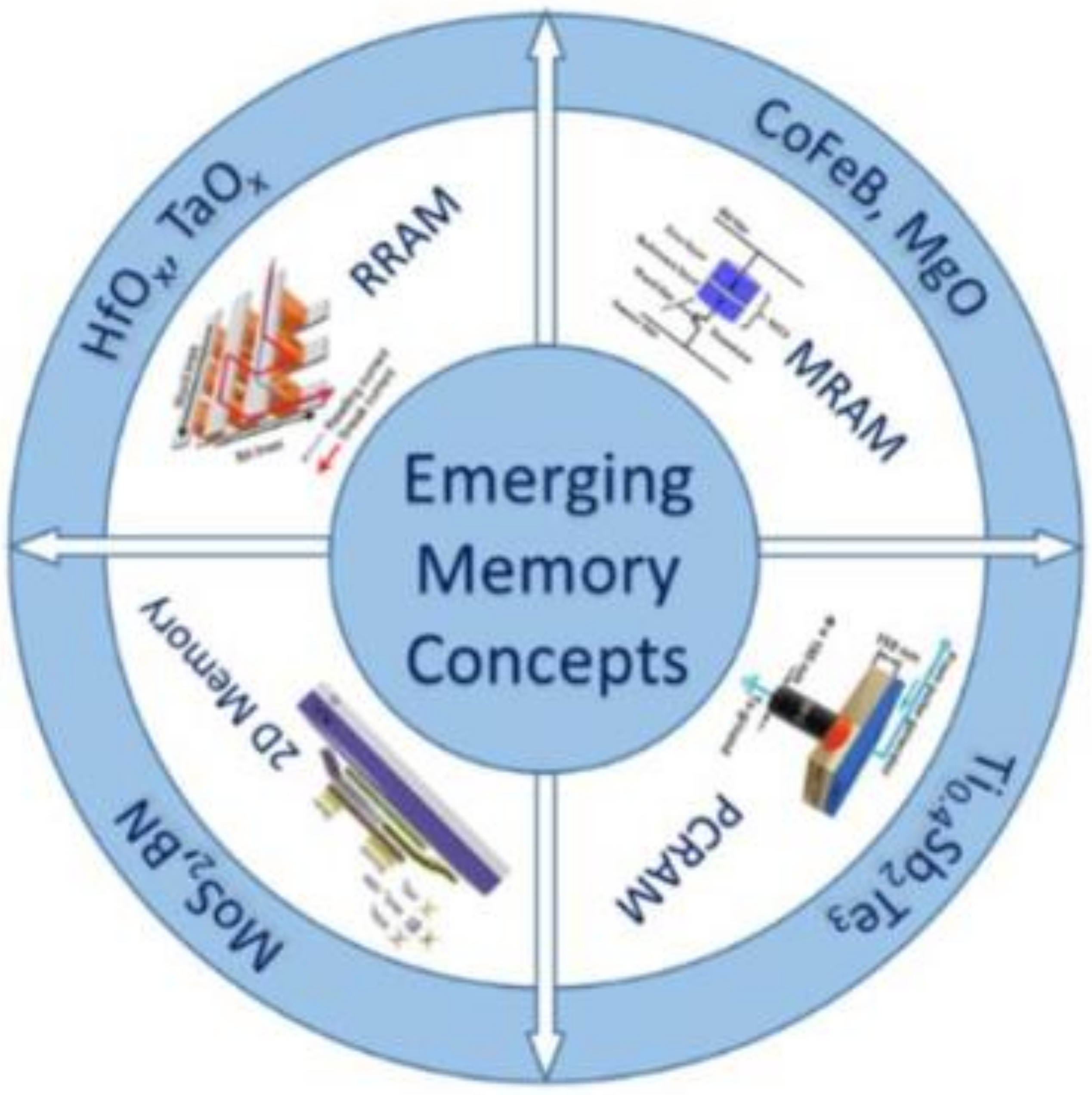
III. Biocomposites have good sustainability, biodegradability and biocompatibility.



Disadvantages:

Biomaterials have a weak electron transfer function and are not compatible with traditional semiconductor device manufacturing processes; therefore biomaterial-based degradable electronic products have many difficulties to overcome in order to achieve industrial feasibility.

Display Systems: Photoactive and electroactive materials



Photoactive materials - materials that actively interact with light are tuned and optimized to achieve effects

- Light emission (LEDs and lasers)
- Light detection, with related signal amplification (e.g., in photomultipliers) and processing operations.
- To develop light-sensitive circuits and switches- (photoresistors),
- Convert light into an electrical signal (photodiodes – PV Cells)
- Photo and electro active materials for memory devices

Optoelectronic Memory
copper indium selenide (short retention time 50s)
molybdenum disulfide (MoS_2) (retention time 104s)

Electroactive materials are substances that can undergo reversible changes in their electrical properties when subjected to an external electrical stimulus, such as an electric field or voltage. These materials find applications in various technologies, including sensors, actuators, batteries, and capacitor.