DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

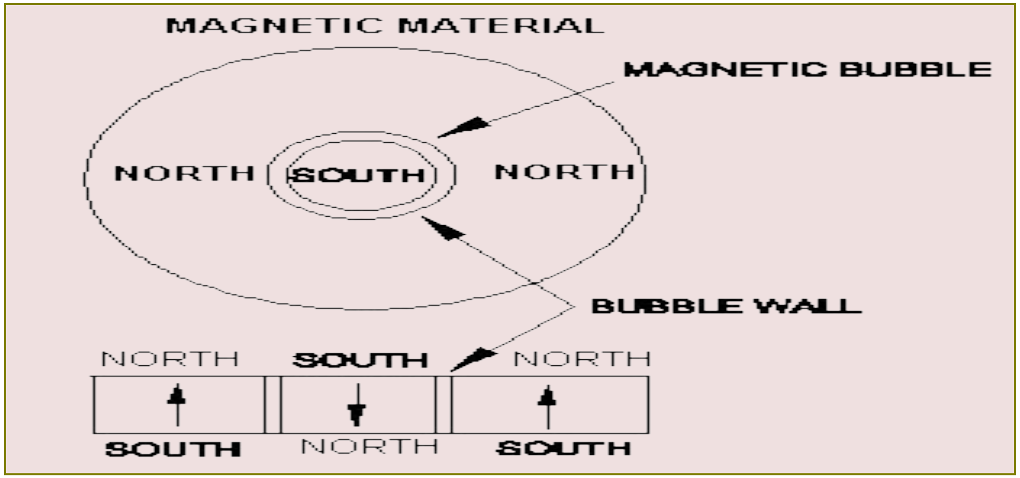
Module II- Lecture-8

Concept of Magnetic bubbles, Discussion on Magnetic thin films

Magnetic bubbles
Definition

- It is a tiny movable magnetized cylindrical volume in a thin magnetic material that along with other like volumes can be used to represent a bit of information (as in a computer).

- A thin wafer of Ferromagnetic Garnet reveals its magnetic domain alignment as light and dark serpentine patterns when viewed between crossed polarizer. These domains can be flipped by an external magnetic field, changing the pattern structure



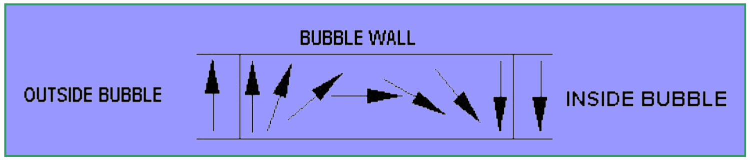


Fig. Formation of Magnetic bubbles

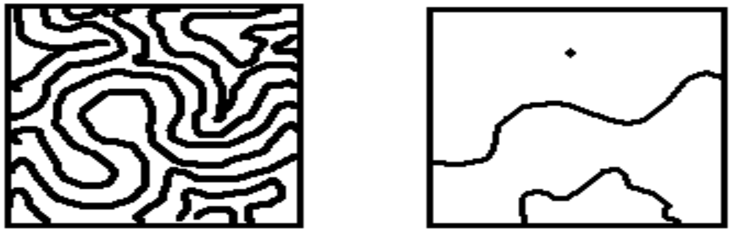


Fig. Serpentine patterns of magnetic bubbles

Faraday effect- the rotation of the plane of polarization (plane of vibration) of a light beam by a magnetic field.

Working

- The magnetic bubble apparatus consists of a thin (8-12μm) single crystal film of Ferromagnetic Garnet (FMG) sandwiched between a pair of crossed Polaroids.

- The FMG crystals are magnetically anisotropic, that is, they have a strong tendency to orient themselves in fixed directions under the influence of an external magnetic field.

- The preferred or "easy" axis of orientation is perpendicular to (in or out of) the crystal surface. With no external magnetic field, the domains in the crystal orient up or down in roughly equal amounts.

- Polarized light passing through the crystal will have its plane of polarization rotated by due to interaction with the magnetic field of the domains (an effect called Faraday rotation).

- For the 'up' domains, the light will be crossed with respect to the exiting Polaroid therefore appearing dark, and for 'down' domains uncrossed (or vice versa) so appearing bright.

- The domains appear as serpentine patterns of alternating bright and dark. Application of an external magnetic field (provided by a built-in electromagnet) flips the domains to one preferred orientation.

- As the field is increased, the serpentine patterns gradually disappear and isolated magnetic bubble may be available.

Applications and Advantages of Magnetic bubbles

Applications

A memory device is formed by lining up tiny electromagnets at one end with detectors at the other end. Bubbles written in would be slowly pushed to the other, forming a sheet of Twisters lined up beside each other. Attaching the output from the detector back to the electromagnets turns the sheet into a series of loops, which can hold the information over long duration.

Bubble memory is a non-volatile memory. Even when power was removed, the bubbles remained, just as the patterns do on the surface of a disk drive. Better yet, bubble memory devices needed no moving parts: the field that pushed the bubbles along the surface was generated electrically, whereas media like tape and disk drives required mechanical movement.

Finally, because of the small size of the bubbles, the density was theoretically much higher than existing magnetic storage devices. The only downside was speed; the bubbles had to cycle to the far end of the sheet before they could be read.

Advantages of bubble memories

The future growth of distributed process systems will be greatly impacted by magnetic-bubble memories. These microprocessor-based systems demand high-density mass storage at low cost. Magnetic-bubble memories satisfy all of these requirements with definite advantages over the existing magnetic storage technologies. MBM's advantages over moving-head disks or floppy disks are low access time (the time necessary to retrieve the desired data), small physical size, low user entry cost, no maintenance, and higher reliability.

The advantages of MBM's over random-access memories (RAM's) are nonvolatility, potentially lower price per bit, and more bits per chip. The RAM has the advantage of much better access time, higher transfer rate, and simpler interfacing.

In summary, the main MBM advantages are the low price, nonvolatility, and high-density storage in a small physical space. Because magnetic bubble memories are a solid-state, nonvolatile technology, they are ideally suited for portable applications as well as providing memory for traditional processing systems. Industrial applications include memory for numerical control machines and various types of process control. Solid-state bubble memories are more reliable in harsh environments; they are affected much less by shock, vibration, dirt, and dust than electromechanical magnetic memories. Innovative new products include data terminals, calculators, word processing, voice storage, and measurement equipment.

Magnetic Thin Film

Magnetic thin films are a sheet of magnetic material with thicknesses of a few micrometers or less, used in the electronics industry. Magnetic films can be single-crystal, polycrystalline, amorphous, or multilayered in the arrangement of their atoms. Both ferro and ferrimagnetic films are used. The ferromagnetic films are usually transition-metal-based alloys. For example, permalloy is a nickel-iron alloy, the ferri magnetic films, such as garnets or the amorphous films, contain transition metals such as iron or cobalt and rare earths.

Properties

Thin films have different magnetic properties from their bulk counterparts. This is due to the artificial confinement of the electrons realized in the two-dimensional film geometry. The magnetic thin films are having the following properties compare to the bulk.

- Much lower resistivity
- High magnetic saturation induction
- Optical absorption of the thin films is much higher.
- Much higher saturation flux density, and
- Can have much lower hysteresis loss

Magnetism of thin film

The thickness of a thin film is usually on the order of magnitude of a typical domain wall in the bulk material, up to 100 nm. In principle, there are three possibilities for establishing a domain structure. If the film is thick enough, the domain structure in Fig.a is possible. In the case of only two easy directions perpendicular to the film plan, the structure of Fig.b could be established. This domain structure is important for magneto-optical applications.

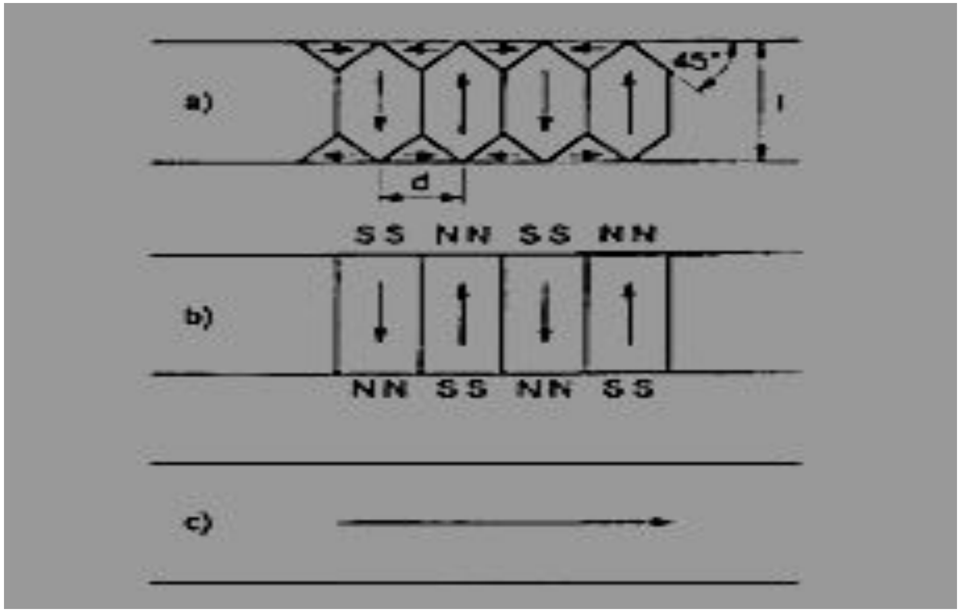


Fig. Possible domain structures in magnetic thin film

In many cases we have to deal with in-plane magnetization as represented in Fig.c The spontaneous magnetization of metallic ferromagnets is so larger than the magnetocrystaline anisotropy energy. If the thickness of the film is below the domain wall width, the rotation of the magnetic moments from one domain to the neighbor domain direction will be occur in-plane as a Neel-type domain wall. Because of the comparatively high wall energy, thin films often appear uniformly magnetized in the film plane, and magnetization reversal can be achieved by coherent rotation.

Magnetic thin film processing

Various techniques are used for the fabrication of thin films, depending on the material and the specific applications. These techniques can be divided into physical vapor deposition (PVD), chemical vapor deposition (CVD), electrochemical deposition, thermal spraying and electro-surfacing. Among these various methods, sputtering (PVD) is the most important deposition technique for magnetic thin films. For example, magnetic films like FeAlSi, CoNbZr, CoCr, FeNiMo, FeSi, CoNiCr and CoNiSi for recording process can be fabricated with this technique.

In common sputtering system positive ions are accelerated from a plasma to a target that is a negative potential with respect to the plasma as shown in Fig. The ions reach the target surface with than energy given by the potential drop between the target and the plasma. The target surface is considered as the source of material from which films are grown. In addition to the sputtered materials liberated from the bombarded surface, which eventually condenses as a film, there are numerous other events that can occur at the target surface that may influence the growth of films profoundly. These includes secondary electron emission, secondary positive and negative ion emission, emission of radiation, reflection of incident particles, heating, chemical dissociation or reaction and others

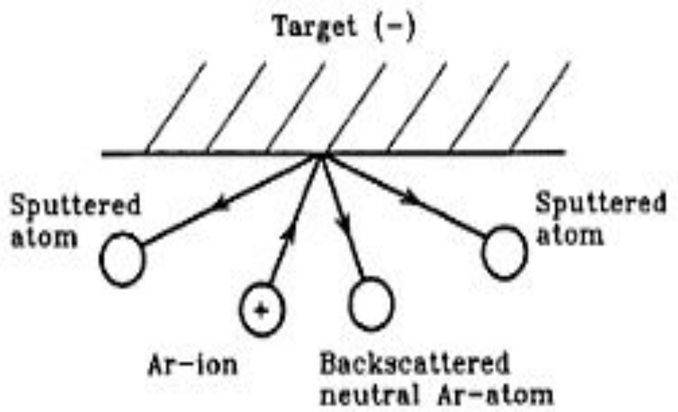


Fig. Principle of sputtering

Applications of magnetic thin films

- The ferrimagnetic properties of the thin films are advantageous in magneto optic applications where a low overall magnetic moment can be achieved without a significant change in the Curie temperature.
- The change in electrical properties, such as the electrical resistance, with a magnetic field is used in sensor elements.
- Magnetic thin film transducers have a wide range of applications, both in the area of sensors as well as actuators.
- It can be used in audio, video and computer memories.
- The most important usage of these films is magnetic read and writes heads.
- Magnetic materials thin films have long been used in data recording and storage media.
- Magnetic thin film materials are used extensively in insulators.

Thank you

Easy axis is the direction inside a crystal, along which small applied magnetic field is sufficient to reach the saturation magnetization. Hard axis is the direction inside a crystal, along which large applied magnetic field is needed to reach the saturation magnetization.