S.T. Hindu College

Condensed Matter Physics

Origin of Domains & Ferromagnetic domains

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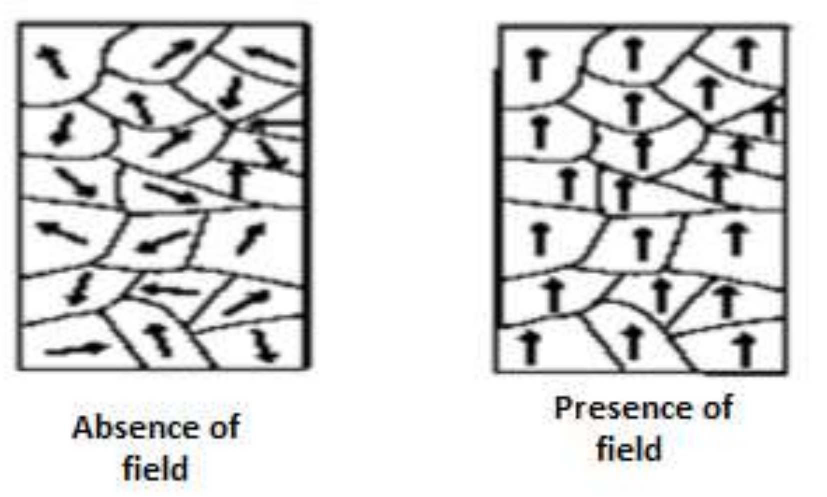
Ferromagnetic domain

The small region within which all spin magnetic moments are aligned in specific direction is known as the magnetic domain. Ferromagnetic material consists of a number of domains. The size of the domain will be in the order of 10-6 m or larger. Each domain acts as a single magnetic dipole and is oriented in random direction. Therefore, in the absence of a magnetic field the net magnetization is zero. Each domain is separated from the other domains by a wall known as bloch wall. When external field is applied, which are parallel or nearly parallel to the field grow in size at the expense of other domains. The domains which are not parallel to the field decreases in size.

Domain theory

- According to Weiss theory, a single crystal of ferromagnetic material is divided into large number of small regions called domains.
- These domains have spontaneous magnetization due to parallel alignment of spin magnetic moments in each domain.
- The direction of spontaneous magnetization varies from domain to domain and the net magnetization of the specimen is zero in the absence of external magnetic field.
- The size of a domain varies from 10-6m to the entire size of the crystal.
- A domain acts as a single magnetic dipole.
- The dipole moments of each and every domain are pointed in random direction and the net magnetization is zero in the absence of field.



- These domains are separated from other domain by a wall known as domain wall or Bloch wall.
- When magnetic field is applied to a magnetic material, the domains that are parallel to the applied field increase in size at the expense of the other domains.
- The size of the domains which are not parallel to the applied field decreases.

When an external magnetic field is applied, there are two possible ways to align a random domain structure.

- 1. By the movement of domain walls
- 2. By rotation of domains

By the movement of domain walls

The fig 2 shows the arrangement of domains in a ferromagnetic material without any external field. When a small magnetic field is applied, the domains with magnetization direction becomes parallel or nearly parallel to the field grow at the expense of others. (Fig 3)

By rotation of domains

As the magnetic field is increased to a larger value (near saturation) further domain growth becomes impossible. Therefore, most favorably oriented and fully grown domains tend to rotate so as to be in complete alignment with the field direction. (Fig :4)

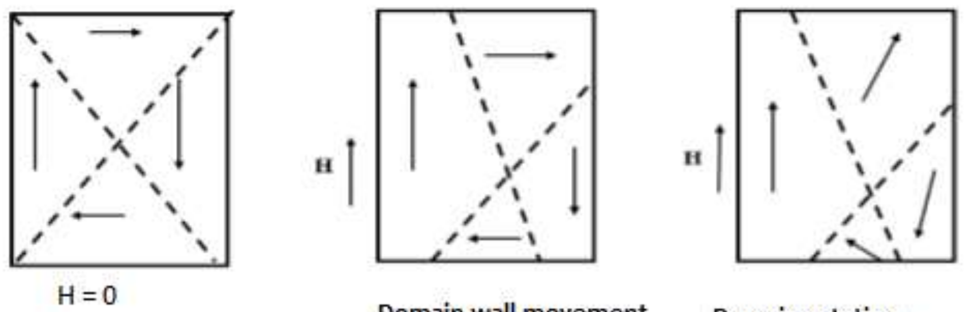


Fig 2

Domain wall movement
Fig 3

Domain rotation
Fig 4

Energies involved in domain growth

The total internal energy of a domain is contributed by the following energies.

1. Magnetostatic energy (or) Exchange energy
2. Crystalline energy (or) Anisotropy energy
3. Domain wall energy (or) Bloch wall energy
4. Magnetostriction energy.

1. Magnetostatic energy

It is defined as the energy required aligning the atomic magnets into a single domain. This work done is stored as potential energy. This energy arises from the interaction of electron spins. This interaction energy makes the adjacent dipoles align themselves. It depends on the interatomic distance.

Consider a single domain in a magnetic material. The orientation of dipole and the direction of magnetic lines of force in a single domain are shown in figure 5. The potential energy stored inside the magnetic material is known as magneto static energy and very high. This energy is reduced by splitting into two domains (fig 6) . The second domain consists of two dipoles with anti spin alignment. The magneto static energy of the domain is further reduced by creating another domain as shown in fig.7. During this process, domain wall known as Bloch wall is created. The energy is further reduced to a larger value by creating larger number of domains (figures 8, 9). The domain attains an optim

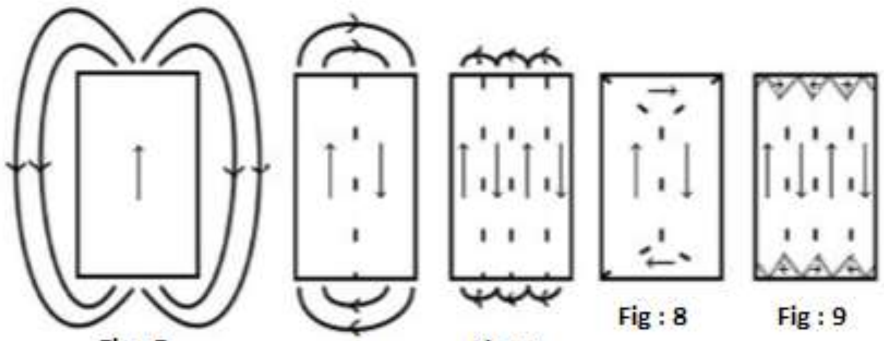


Fig : 5 Fig : 6 Fig : 7 Fig : 8 Fig : 9

2. Anisotropy energy

It is found that the ferromagnetic crystals have easy and hard directions of magnetization.ie) higher fields are required to magnetize a crystal in a particular direction than others. For example, in bcc iron the easy direction is [100], the medium direction is [110] and the hard direction is [111]. In nickel, easy direction is [111], the medium direction is [110] and the hard direction is [100]. The difference between the easy and hard directions is that for producing the same saturation magnetization, stronger fields are required in the h

excess of energy required to

magnetize a specimen in a particular direction over

that required to magnetize it along the easy direction

is called the crystalline anisotropy energy.

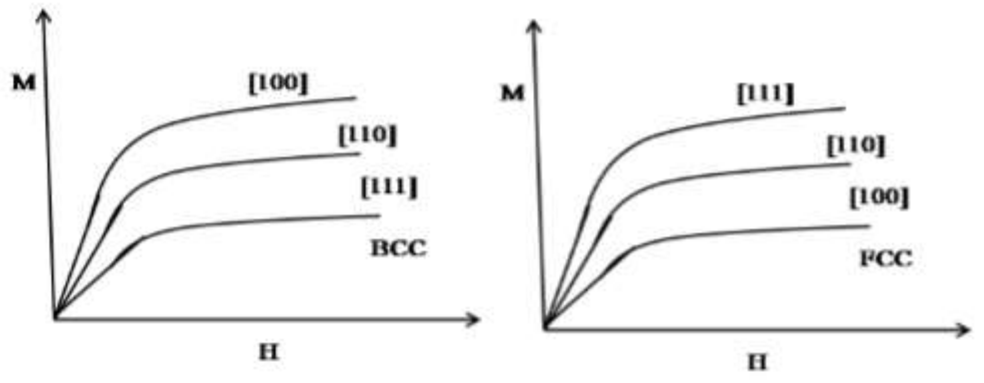


Fig : 10

3. Bloch wall or domain wall

The equilibrium thickness of the domain wall should have a minimum potential energy which is the sum of exchange energy and the anisotropy energy. The minimum potential energy of a domain wall is known as the domain wall energy. Consider a magnetic material consisting of two domains. These two domains are perpendicular to each other. The second domain is obtained by rotating the first domain by 180˚. The domain rotates gradually due to the existence of the exchange force and anisotropy energy. The anisotropy energy demands very less thickness of domain wall whereas the exchange energy demands very large thickness. Therefore, there is a compromise between the two energies.

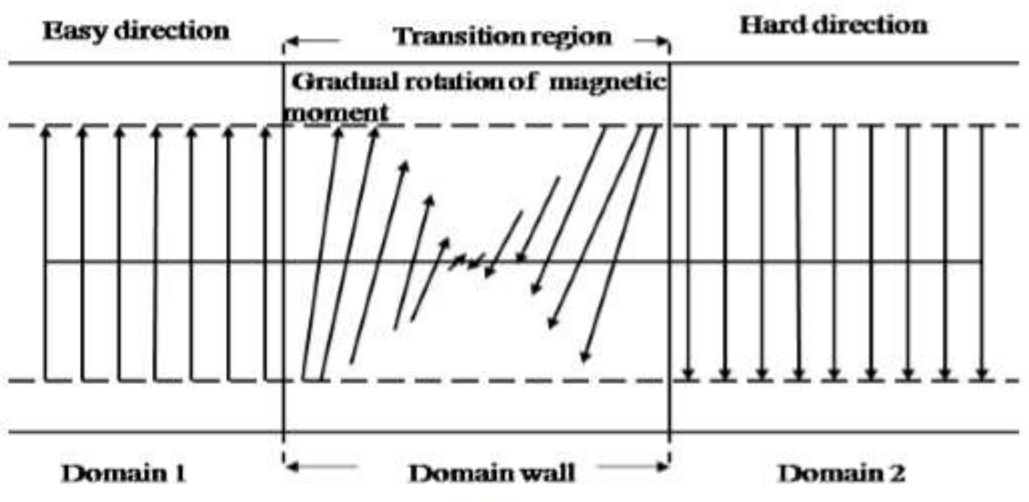


Fig : 11

4. Magnetostriction energy

When a specimen is magnetized it is found that, it suffers a change of dimensions and this phenomenon is known as magnetostriction. When the magnetic field is applied in the hard direction, the material will experience a decrease in length. Let ‘l’ be the original length of the ferromagnetic material and Δl be the change in length.

Magnetostriction constant (λ) =Δl l.

The energy associated with the magnetostriction is called magnetostriction energy.