Ferromagnetic substances

Ferromagnetic substances are those in which each atom/molecule/ion has a non-zero magnetic moment, as in a paramagnetic substance. These are the materials which when placed in external magnetic field, get strongly magnetised in the direction of the field for example - Iron, nickel, cobalt and their alloys.

A few important properties of these materials are listed below:-

The ferromagnetic materials show all the properties of paramagnetic substances, but to a much greater degree. For example,

(a) They are strongly magnetised in the direction of external magnetising field in which they are placed.

(b) They have strong tendency to move from a region of weak magnetic field to the region of strong magnetic field i.e they get strongly attached to a magnet.

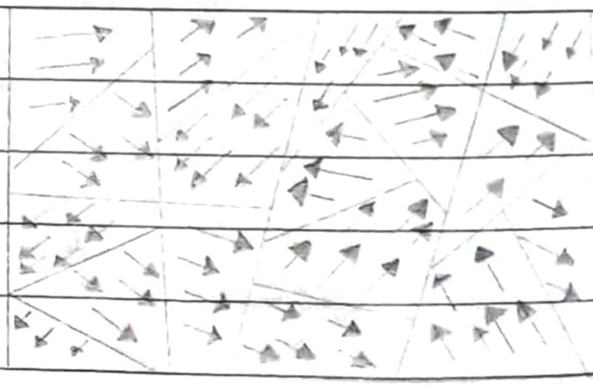
(c) Relative magnetic permeability of ferromagnetic materials is very large ($\approx 10^3$ to 10^6)

(d) The suspectability of ferromagnetic materials is also very large ($\because \chi_m = \mu_r - 1$)
That's why they can be magnetised easily and strongly.

(e) With increase in temperature their (μ) permea-bility decreases and at a certain temperature (T_c) called Curie temperature, it becomes almost equal to μ_0. For temperature more than T_c the material becomes paramagnetic. For Iron T_c is $\approx 770^\circ C$.

Ferromagnetism

In ferromagnetic substances the atomic dipoles of sample exist in groups, called domains. In one domain the direction of all dipoles is same but is different from the direction of dipoles in other domain. The linear dimensions of each domain can be upto 1000 Å.



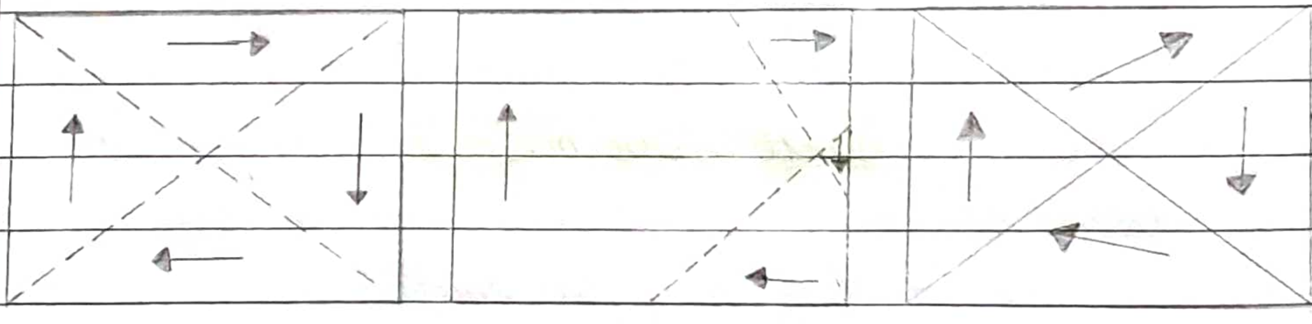
In the absence of external magnetic field, the dipole moments of the domains are randomly oriented, so as to form closed loops so that net dipole moment of the sample is zero.

When material is placed in external field then the domains which are favourably magnetised in the direction of magnetic field, grow in size while other domains reduce in size. As a result material is rapidly magnetised in the direction of external magnetic field. If the external magnetic field is strong enough, then the domains may rotate as a single entity so as to align its magnetic dipole moment in the direction of external magnetic field. When external magnetic field is removed then the domains do not move back to their original position (This is called ~~Hyter~~ Hystersis) thus material becomes a permanent magnet. This explains ferromagnetism. If temperature is increased, it may rupture the magnetic domains and material behaves ~~&~~ like a paramagnetic substances. When external magnetic field is removed, magnetization disappears in some of the materials like soft iron. These materials are called soft ferromagnets. However, in materials like Alnico (an alloy of iron, aluminium, nickel,) the magnetization persists even after removal of external magnetic field. Such materials are called hard ferromagnets. Temperature at which certain magnetic materials undergo a sharp change in their magnetic properties.

Domain theory of ferromagnetism

Ferromagnetism arises when the magnetic moments of adjacent atoms are arranged in a regular order i.e pointing in the same direction.

To explain ferromagnetism, Weiss put forward Domain theory. According to this theory, a single crystal of ferromagnetic solid is divided into a large number of small regions called Domains such that all magnetic dipoles with in one domain are in same direction. Even in thermal agitation at room temperature is unable to disturb the dipoles of one particular domain. However the magnetic domains within each sample are randomly oriented, so that net magnetisation of sample is zero. When external magnetic field is applied across the specimen then material acquires non zero magnetisation. This magnetisation is prominent even if applied field is weak.



(a) Unmagnetised

(b) Magnetisation by domain growth

(c) Magnetisation by domain growth

The material can show magnetisation by two different mechanisms :-

(i) When small magnetic fields are applied then domain pointing approximately in the direction of magnetic field grow at the expense of the domains, which are not parallel to applied field. The magnetisation acquired by specimen is small in magnitude and is illustrated in fig(b). If the applied magnetic field is made stronger, then the magnetisation increases due to further growth of domains in the direction nearly parallel to applied field.

The process continues until all the favourably oriented domains attain maximum volume. At this stage, each domain is still magnetised in what is locally the easiest direction of magnetisation i.e all domains are not in the direction of applied field and magnetisation of the sample is still less than the maximum value, it can attain (called ~~St~~ saturation magnetisation

(ii) If applied magnetic field is increased further then the magnetic domains which are not in the direction of applied field rotate as a single entity. Ultimately at some value of magnetic field, all domains are oriented in the direction of applied magnetic field The magnetisation of the sample is maximum at this stage and its value is called saturation magnetisation. With further increase in H magnetisation remains constant.

If the externally applied magnetic field is decreased then magnetisation of sample also decreases but not in same proportion as was during the magnetisation of the specimen. Thus domains do not return back to original positions on complete removal of magnetic field. Thus material becomes permanent magnet after the removal of magnetic field.