Magnetization

The behavior of a ferromagnetic material is often reported in terms of three technical parameters. The saturation magnetization (M_S) is the magnetic moment per unit volume when all atomic moments are aligned parallel to an external applied field. After material saturation, if the field is reduced to zero there will be a remanent magnetization (M_r). In order to reduce the magnetization to zero, an applied field in the opposite direction equal to the coercivity (H_C) must be applied. Together, these three parameters describe the basic features of a hysteresis loop, which is a plot of the magnetization between positive and negative saturation, and back again shown in Figure 1. Magnetite Fe_3O_4 is a ferrimagnetic iron oxide having cubic inverse spinel structure with oxygen anions forming a fcc closed packing and iron (cations) located at the interstitial tetrahedral (A-site) and octahedral (B-site) sites. Fe^{3+} ions on the A and B sites are aligned antiparallel so that the net magnetic arise from the Fe^{2+} ions, with a magnetic moment of 4 μ_B per atom. Magnetite (Fe_3O_4) exhibit ferrimagnetism at room temperature, with the saturation magnetization is 92 emu/g.

Remanence:

The magnetization obtained after applying a large field to the material and then removing it. It is the matural quantity expressing the fact that a ferromagnet can be spontaneously magnetized even in the absence of external actions. The order of magnitude of Mr is that of the spontaneous magnetization Ms but various geometrical or structural features may contribute to decrease Mr well below Ms.

Coercivity

The applied magnetic field needed to bring the magnetization from remanent value to zero. The coercive field measure the order of the magnitude of the fields that must be applied to a material in order to reverse its magnetization. Coercivity value determines stability of the remanent state and gives rise to the classification of magnets into hard magnetic materials (permanent magnets), semi-hard materials (storage media) and soft magnetic materials. The coercivity of magnetic samples has a striking dependence on their grain size. As the grain size decreases, the coercivity increases to maximum and then decreases. The change in coercivity is attributed to its change from the multidomain nature to single domain superparamagnetic state by further decrease in grain size results in an unstable state where spin fluctuations dominates. In the multidomain region where magnetization changes by domain wall motion, the variation of coercivity with grain size is expressed as

(1)

where *'a'* and *'b'* are constants and *'D'* is the diameter of the particle. Hence in the multidomain region the coercivity decreases as the particle diameter increases. The Coercivity of Fe_3O_4 ranges from 2.4 (typical of disk drive recording media) to 20.0 (permanent magnetic realm) KA/m.

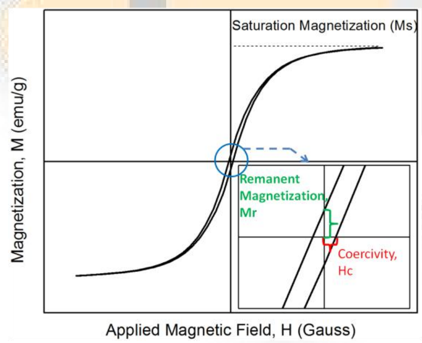

Figure 1. Magnetization versus applied magnetic field loop depicting saturation magnetization Ms, remanent magnetization Mr and Coercivity, Hc of soft ferrite.

Susceptibility

Susceptibility of a material is the extent to which any material is magnetized by applying magnetic field. The equation of susceptibility is defined as:

(2)

where M is the magnetization of the material, H is the applied magnetic field and is the susceptibility of the material. The magnetic specific mass susceptibility of magnetite (72% Fe) with particle size ranging from 0.012 µm to 0.069 µm is 500-1000 (10^{-6} m^3-Kg^{-1}) and for 1-250 µm particle size specific mass susceptibility is 390-580 (10^{-6} m^3-Kg^{-1}).