1 Magnetic Anisotropy Effects

We have discussed the energy as a function of the magnitude of the magnetization $|\vec{M}|$, but have neglected the energy dependence of the direction of $\vec{M}$. The Heisenberg Hamiltonian:

$$H = -\sum_{i<j} J_{ij} S_i S_j \tag{1}$$

is completely isotropic and its energy levels do not depend on the direction in space which the crystal is magnetized in. If there is no other energy term the magnetization would always vanish in zero applied field, however real magnetic materials are not isotropic.

1.1 Overview of Magnetic Anisotropies

There are five basic types of magnetic anisotropies:

- Magnetocrystalline anisotropy - The magnetization is oriented along specific crystalline axes.
- Shape anisotropy - The magnetization is affected by the macroscopic shape of the solid
- Induced magnetic anisotropy - Specific magnetization directions can be stabalized by tempering the sample in an external magnetic field.
- Stress anisotropy(magnetostriction) - Magnetization leads to a spontaneous deformation.
- Surface and interface anisotropy - Surfaces and interfaces often exhibit different magnetic properties compared to the bulk due to their asymmetric environment.

1.2 Magnetocrystalline Anisotropy

1.3 Shape Anisotropy

Polycrystalline samples without a preferred orientation of the grains do not possess any magnetocrystalline anisotropy. But, an overall isotropic behavior concerning the energy being needed to magnetize it along an arbitary direction is only given for a spherical shape. If the sample is not spherical then one or more of the specific directions occur which represent easy magnetization axes which are solely caused by the shape. This is known as shape anisotropy.

The relationship $B = \mu_0 (H + M)$ is only valid for infinite systems. A finite sample exhibits poles at its surfaces which leads to a stray field outside the sample. This stray field results in a demagnetizing field inside the sample.

The energy of a sample in its own stray field is given by the stray field energy $E_s tr$:

$$E_{str} = -\frac{1}{2} \int \mu_0 M \cdot H_{demag} dV \tag{2}$$

This can be easily solved for symmetric objects. For a perfect sphere the stray field density $E^s_{str} ph$ is given by:

$$E^s_{str} ph = \frac{1}{6} \mu_0 M^2 \tag{3}$$

From this, it can be seen that the stray field has no directional dependence for a spherical object. For an infinetely expanded thin plate(a = b = inf) the stray field energy density E^{film}_{str} is:

$$E^{film}_{str} = \frac{1}{2} \mu_0 M^2 cos^2 (\theta) \tag{4}$$