Chapter 1

Introductory Chapter

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1. Introduction

1.1. Magnetism and magnetic materials

Magnetism is one of the oldest phenomena known to mankind. For example, iron used to be magnetized by stroking it with another magnet or simply by placing it in the proximity of a strong magnet. The oldest magnetic compound, so-called mineral of magnetite (Fe_3O_4) was initially found in the district of Magnesia of modern Turkey. The word "magnet" is a Greek word. The magnetic properties of materials are entirely governed by the motion of electrons of the atoms. The simplest form of an electromagnet can be produced by wrapping copper wire into the form of a coil and connecting the wire to a battery. A magnetic field is created in the coil, but it remains there only while electricity flows through the wire. There are different types of magnetism existing today. They can be categorized into paramagnetism, ferromagnetism, ferrimagnetism, and antiferromagnetism. The applications of magnetism are many including data storage, magnetic switches, and in the medical field like magnetic resonance imaging (MRI). In 1905, Langevin explained the theory of diamagnetism and paramagnetism but was unable to explain the ferromagnetism. In 1906, the ferromagnetism theory was developed by Weiss. The first commercial steel magnets were made available in 1919 and were quench-hardened steel magnets. In 1930, I. Mishima produced the first Alnico magnet that contained an alloy of iron, aluminum, and nickel. Furthermore, Hermann Kemper studied the use of magnetic fields in conjunction with trains and airplanes. In 1952, J.J. Went et al. invented the first ceramic magnets based on barium, lead-iron oxides, and strontium at the Philips Company. In 1966, rare-earth magnets with high-energy product were reported by Karl J. Stmat. NdFeB magnets have significantly boosted the development of computer peripherals such as voice coil motors and actuators, in both downsizing and enhancing their performance characteristics. For example, in 1984, computer disk drives of ≈10 MB size were in use. Today, external hard drives of much smaller physical dimensions, but with a storage

capacity of a few hundred GB or TB, have become common. More importantly, these hard drives are available at affordable costs.

Some of the magnetic materials exhibit the so-called hysteresis behavior between magnetization and the applied magnetic field. Based on the hysteresis curve, the magnetic materials can be further divided into soft and hard magnetic materials. Magnetic materials, like ferromagnets, demonstrate the domain patterns. The domains are separated from each other by a domain wall.

1.2. Modern magnetism

In modern times, magnetism has put forward many peculiar and interesting phenomena in front of the scientific fraternity. The examples include magnetism at nanoscale, spintronics, magnetization reversal, magnetocaloric effect, exchange bias, multiferroicity, and so on. With the advance in the field of material growth techniques, it is now possible to control magnetism up to few nanometer length scale and grow artificially engineered magnetic materials. For example, with the thin films of ferromagnetic materials exhibiting perpendicular magnetic anisotropy and nano-sized magnetic domains, it is possible to produce ultra-high storage density.

Magnetic domain memory (MDM) is the ability for a ferromagnetic film to retrieve its particular magnetic domain pattern after an external magnetic field has been applied and erased the pattern. Furthermore, the single-domain behavior of magnetic nanowires with diameters below 100 nm is experimentally observed with Lorentz force microscopy, magnetoresistance measurements, and magnetic force microcopy. These methods confirm magnetization switching by domain wall motion without any intermediate magnetization states.

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