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The critical relationship between microstructure and nanostructure of materials and their magnetic properties has been appreciated for decades. Electromagnetic machinery, permanent magnets, and data recording and electronic devices all have seen steady and sometimes spectacular advances over this period. At the present time the most interesting research in magnetism and magnetic materials arises from new developments in structuring materials on the nanometer length scale. This talk will present recent advances and challenges in furthering this work, with particular attention paid to extremely high density magnetic recording films, exchange-coupled high-energy-product permanent-magnet materials, high-temperature permanent-magnet materials, and self-organized and patterned magnetic nanoarrays.

Future High-Density Recording Media

Present longitudinal recording media are based mainly on CoCrPtX granular alloys and record at areal densities in the 20-50 gigabits per square inch (Gb/in^2) region [1]. Such films are expected to be limited by superparamagnetic and noise considerations to densities of about 100-200 Gb/in^2. Further advances to 1 terabit/in^2 (Tb/in^2) are likely to be provided by high-anisotropy, small-grained films with perpendicular anisotropy [2]. Candidates include $L1_0$ ordered phases as FePt or CoPt, or Co/Pt and related multilayers. Recent development of high-coercivity (~ 12 kOe), small-grain (6-8 nm) films with minimal exchange coupling, and their study with HRTEM will be outlined [3].

Exchange-Coupled Permanent Magnets

The development of significantly stronger permanent magnets, with energy products in the range 75-100 MGOe, through discovery of new compounds or alloys is problematic. However, the concept of nanostructuring hard-soft nanocomposites on the exchange-length scale of about 10 nm is of great interest [4]. The difficulties in this approach involve inventing or adapting synthetic methods to achieve strong exchange coupling between the hard and soft phases, without grain growth of either phase beyond about 10 nm. We have produced prototype FePt:$Fe_{1-x}Pt$ nanocomposites with energy products of about 53 MGOe, very close to those seen in the largest values known (~54 MGOe for $Nd_2Fe_{14}B$) [5]. New ideas and challenges in improving and studying nanostructures of this type will be discussed.

High-Temperature Permanent Magnets

$Sm_2(Co,Fe,Cu,Zr)_{17}$ [Sm_2TM_{17} or 2:17] magnets have been the best permanent magnets for use at temperatures up to about 300EC [6]. Their energy products of about 20 MGOe at 300EC are significantly degraded at T □ 500EC where new applications are sought for the all-electric airplane. The cellular nanostructure of the 2:17 magnets consists of 2:17 grains surrounded by Cu-containing $SmCo_5$-structure boundaries. Recent research has shown a record high temperature coercivity (12.3

kOe) at 500EC in a Sm-Co-Ti-Cu alloy [7]. A physical model for this behavior and relationship to nanostructures as determined by TEM will be discussed.

Self-Organized and Patterned Nanoarrays

A new topic of high interest is the study of magnetic nanoarrays by fabrication methods such as electrodeposition into self-assembled nanopore structures [8], laser-interference lithography [9], and focused-ion-beam synthesis [10]. Future applications have been suggested such as data storage, spin-logic devices, spin electronics, and quantum computing. If time permits one or more of these topics will be discussed.

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