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Modern Trends in Magnetostriction

This month's *Insight* is a little late as I have just returned from a NATO Advanced Study Institute (ASI) "Modern Trends In Magnetostriction Study and Application" that was held in Kiev, Ukraine. The location reflects the NATO effort to hold these institutes in the NATO partner countries. While the ASI covered a wide range of materials, there was considerable discussion of rare earth based thin films and multilayers. Typical applications for such films are those proposed in the area of microelectricomechanical systems (MEMS) where small pumps, valves and other active parts are machined out of Si, using etching techniques. While there has been considerable interest in MEMS, at the current time, it seems to be a technology in search of an application. Other talks focused on rare earth manganites, which in addition to magnetostriction, exhibit colossal magnetoresistance. In some of these materials, there is an interesting transition from a high volume paramagnetic insulator to a low volume ferromagnetic metal. The proceedings of the institute will be published in the NATO Science Series.

Oxide-ion Conductors

Oxide-ion conductors are typically materials in which there are distinct anion and cation sites. If the ratio of anion to cation sites in the crystal lattice is not matched to the ratio of the valences of the two ions, the charge is balanced by vacancies on one of the sites. In this case, oxygen ions can diffuse from an occupied site to a crystallographically equivalent vacant site by overcoming a small energy barrier. Unfortunately, the thermal energy required to overcome even a small energy barrier corresponds to a relatively high temperature. Thus, solid oxide fuel cells, oxygen sensors, etc. must operate at relatively high temperatures. Naturally, there is considerable interest in finding new oxide conductors, and recently, a new structural family has been observed to exhibit fast oxide-ion conduction above 580°C {*Nature*, **404**, 856-8 (2000)}. The material is based on $La_2Mo_2O_9$, which is a low symmetry phase, and is postulated to be monoclinic. While there is significant ion conductivity at 400°C, above a crystallographic phase transition at 580°C, the conductivity increases almost two orders of magnitude. Of, perhaps, more general interest than the paper itself, is the commentary on the paper by J. B. Goodenough {*Nature*, **404**, 823 (2000), which provides a precise overview of oxide conductors.

Stoner-Wohlfarth Behavior

Everyone who has worked with permanent magnets is familiar with the Stoner-Wohlfarth model for the hysteresis loop of a collection of ideal non-interacting magnetic particles with uniaxial anisotropy. This model, which was published in 1948, predicts a coercivity for such a collection of particles to be slightly less than ½ the anisotropy field. For $Nd_2Fe_{14}B$, this would give a coercivity of 3.5 T, well in excess of what is observed. The

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disagreement, between the model and experiment, is attributed to the nucleation of reverse domains, which provides a lower energy path for magnetization reversal than the uniform rotation assumed by the model. In principal, it should be possible to prepare isolated single domain particles, which exhibit Stoner-Wohlfarth type behavior. Now, Er. Girt et al. {*Appl. Phys. Lett.*, **76**, [13], 1746-8 (2000)} have approached S-W behavior in the Nd-Fe-B system. They have taken advantage of the fact that in that system there is a two-phase tie line betwenn $Nd_2Fe_{14}B$ and Nd. Since Nd does not order above 20 K, it is possible to prepare a two-phase mixture of a high anisotropy ferromagnet in a weakly paramagnetic matrix. If an amorphous precursor is prepared and then crystallized, isolated nanoparticles of $Nd_2Fe_{14}B$ may be prepared. From x-ray, line broadening the average size of these particles is between 50 and 70 nm. By varying the Nd to $Nd_2Fe_{14}B$ ratio, the average spacing between particles, and hence, the interaction effects can be changed systematically. The result is an increase in the coercivity with decreasing interaction between particles with a maximum of 83% of the S-W value.

Magnetic Transmission

I recently became aware of a magnetic coupling produced by the MagnaDrive Corporation (www.magnadrive.com). As the coupling has the potential for a wide range of applications and uses Nd-Fe-B magnets, it should be of interest to the rare earth community. The coupling operates on principles similar to that of maglev trains; that is, when a magnet moves across a conducting surface, an image field is generated by eddy currents in the conductor. The force between the magnet and the conduc tor is related to both field strength and velocity. In the MagnaDrive coupling, a magnet rotor assembly, containing rare-earth magnets, is at tached to the load while a copper conductor rotor is attached to the motor. The gap between these two components may be varied so that the torque transmitted can be controlled. This permits stepless speed control. Clearly, there are losses related to eddy current losses in the copper, which result in a heating of the copper plate; but, apparently, these losses are more than compensated for by the fact that the motor can run at the optimum design speed. Presumably, the motor can be sized for the operational torque requirements since the load may be brought up to speed slowly.

Er^{3+} in Si Nanocrystals

Recently, there have been a number of papers showing that Er doping of Si nanocrystals results in intense room-temperature 1.54 μm luminescence. G. Franzo et al. [{*Appl. Phys. Lett.*, **76**, [17], 2167-69 (2000)} explore several effects within this system in order to clarify the picture for the overall phenomenon. Si particles with a diameter of ~1.6 nm were formed by annealing a 0.2 μm SiO_x film grown on a Si substrate. Phase separation of the SiO_x into Si and SiO_2 resulted in particles with a mean spacing of ~5nm. Er^{3+} was ion implanted, using a range of energies in order to obtain a uniform Er concentration over the film thickness. When pumped with a lazer beam, an electron in the Si nanocrystal is excited into the conduction band, and is trapped in a surface state. This state decays emitting a ~0.8 μm photon, which couples well with the Er levels, and a two step decay results in emission at 0.98μm and 1.54μm. Clearly, the nanocrystals are required in order to have a very high number of surface states.

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