Rare-earth Information Center
Insight

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Physics of High-temperature Superconductors

It has been fourteen years since the discovery of the first high-temperature superconductors by Bednorz and Muller, and the understanding of the materials is not yet complete. However, a recent paper in *Science*, **288**, 468-74 (2000) reviews the current state of knowledge and covers some rather interesting concepts. High-temperature superconductors, even above T_c, are not normal metals. When the materials are undoped, they form something called a Mott insulator, which is not a normal insulator. In a normal insulator, the highest occupied electron band has every orbital occupied with a spin up and a spin down electron. Since there are no empty states for an electron to change its energy, it must be excited above the band gap. In a Mott insulator, the band is only half full, and the Pauli exclusion principle should allow each orbital to contain another electron of opposite spin from the one that is already there. However, the coulomb repulsion between the electrons is high enough to keep a second electron out. For a Mott insulator, the conductivity goes to zero as T goes to zero. Doping the Mott insulator, in the case of high-temperature superconductors with holes, provides sites where electrons can move so that the material becomes a conductor. This behavior has been observed in various systems but did not result in high-temperature superconductivity. There is increasing evidence that the high-temperature superconductors are even more unusual. Normally, in a metal we think in terms of a uniform distribution of conduction electrons. However, in high-temperature superconductors, it appears that there is an inhomogeneous spin and charge ordering. These ordered regions, or stripes, are in most cases not static, but rather fluctuate with time. This feature makes them rather hard to observe. However, doping of $La_{(2-x)}Sr_xCuO_4$ with Nd introduces a distortion, which results in pinning of the stripes so that there is a static spin density wave, which has been observed in neutron diffraction. The paper reviews the extensive evidence for the widespread existence of stripes, discusses their consequences and lays out the remaining problems to understanding high-temperature superconductors.

Radiation Tolerance of Complex Oxides

The disposal of radioactive waste is an ever increasing problem. Even if there is no widespread use of nuclear power reactors, wastes generated from medical applications or even mining heavy rare earths must be disposed of. The problem of finding a suitable form in which to contain high level wastes is further complicated by the fact that the radioactive decay of these wastes may result in radiation damage to the crystal structure of the material in which they are contained. The defects produced destabilize the crystal structure, resulting in phase transformations that may involve significant volume changes. This results in the formation of microcracks, which raise the surface area, making the material more susceptible to leaching. Recently, K. E. Sickafus et al. {*Science*, **289**, 748-51 (2000)} have investigated the radiation tolerance of a class of complex oxides called pyrochlores, which typically have the general formula $A_2B_2O_7$, where A and B are metallic cations. The pyrochlore structure is capable of containing Th, U, or Pu on the A site. For the purposes of the investigation, the large A-site ions were La, Nd, Sm, Eu, Gd Y, Er, Yb, and Lu. The B site requires $^{4+}$ions; Ti, Ru, Mo, Sn, Zr, Pb and Ce were investigated. Calculations and experiments support the hypothesis that a material that posesses both complex chemistry and complex structure and an inherent tendency toward lattice disorder should tolerate a displacive radiation environment.

Solid State Fluorine Sensor

Increasing environmental concerns have produced regulatory requirements for environmental monitoring of a growing number of materials. For some, such as fluorine, statutory limits may be extremely low, 0.1 ppm in Germany. These levels are not only difficult to detect, but the detection must take place outside of a laboratory in a field environment. Currently, electrochemical cells that employ a liquid electrolyte are used, but this clearly has its problems in the field. Clearly, an all-solid-state sensor would be advantageous. Recently, a semiconductor sensor has been developed where the sensor is effectively a field-effect transistor containing a LaF_3 layer. The major problem with the sensor has been a lack of reproducibility, but that has now been addressed. The sensor was produced on a Si substrate using thin film technology. The sensitivity of the sensor depends on the logarithm of the fluorine concentration, and a sensitivity of 116 mv/decade was exhibited.

Sm-Co-Cu-Ti High-temperature Permanent Magnets

Last month, I reported on $Sm(Co_wFe_vCu_xZr_y)_z$ high-temperature permanent magnets. It appears that this combination of modifications is not unique in controlling the Sm-Co structure for high temperature performance. Recently, J. Zhou et al. {*Appl. Phys. Lett.*, **77**, [10], 1514-6 (2000)} have reported that $Sm(Co_xCu_{0.6}Ti_y)$ (x=6.4, y=.025) has a coercivity of 8.6 kOe at 500 °C. Again, the increased coercivity at high temperature results from enhanced domain wall pinning.

Company News

Treibachner Industrie AG, the parent company of Treibachner Auermet, has been purchased by the August von Finck group. Treibaucher Auermet has a production capacity of 8000 tons per year of rare earth alloys and chemicals, and this capacity is undergoing a gradual expansion. The new owner is a family-owned industry holding company.

CERAC, Inc. has been purchased by the company CEO and the marketing VP, along with a private equity group Facilitator Capital Fund. CERAC offers metals, alloys, rare earth compounds and other high purity materials.

Conference Announcements

The Japan Association of Bonded Magnet Industries is organizing "2000 BM Symposium" on December 1, 2000 in Tokyo. For information on the one-day symposium, which will offer simultaneous translation, contact: Takeo Tada, JABM Managing Director, Fax: 81-03-5811-6892, Email: JDY04537@nifty.ne.jp.

RARE EARTHS' 2001 will be held in Sao Paulo, Brazil September 22-26, 2001. Topics range from environmental impact, toxicology, and biomedical applications to chemistry and materials science. Processing, applications, and fundamental physics will also be covered. Abstracts are due in January, 2001. For more information email RE2001@iq.usp.br or visit http://www.iq.usp.br/geral/congress.html.

Sincerely,

R. W. McCallum
Director CREM/RIC