Rare-earth Information Center

Insight

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$(Sc_2C_2)@C_{84}$

In January of this year, I reported on bucky balls containing Sc. Two separate groups reported $Sc_2@C_{66}$ and $Sc_3N@C_{68}$. C.-R. Wang et al., {*Angew. Chem Int. Ed.*, **40**, [2], 397-9 (2001)} who reported the $Sc_2@C_{66}$, have now reported the interesting compound $(Sc_2C_2)@C_{84}$. This is the first report of a metal carbide inside a bucky ball. The material was produced using Sc_2O_3/graphite composite rods for the electrodes of a direct-current arc discharge. As in their previous report, one surmises that the current material was part of the 800 g of soot that was produced for the previous paper. This brings the total usable material produced to something less than 10 mg. In this case, 3.5 mg of material was isolated by liquid phase chromatography. These reports make it clear that while it is relatively easy to produce the soot, the separation and analysis of the material is quite difficult. In the latest paper, 240 h were required to obtain the room temperature NMR spectrum, which allowed the bonding in the compound to be evaluated. In order to refine the structure with synchrotron radiation, an image plate was used with an 80-minute exposure. For comparison, my group uses synchrotron radiation for x-ray diffraction on rare earth intermetallics at high temperature, and we require about 2 seconds for an exposure, which can be Rietveld refined.

Room Temperature IR Detector

We are all familiar with infrared (IR) images that are used extensively, both in standard industrial applications, such as locating hot spots on a circuit board, and in critical defense applications, such as missile tracking. Traditionally, IR detectors have been based on photon detectors where an incoming IR photon excites an electron across a band gap. Unfortunately, if an IR photon can excite the electron, then so can a phonon in a material at room temperature. Thus, these detectors must be cooled, using bulky and expensive cryocoolers. A second type of detector is a thermal detector, which actually measures the heat produced in the detector by measuring the temperature rise. Since ther temperature rise is determined not ony by the energy coming in, but also by the effective thermal mass of the detector, there is considerable interest in using unsupported thin films. The films are made from highly temperature dependent ferroelectric materials that have a polarization, and hence net charge transfer that is proportional to temperature. One of the leading candidates for this application is $PbSc_{0.5}Ta_{0.5}O_3$ (PST). The hurdle, which must be overcome, is that in order to obtain single phase PST as a bulk ceramic, the material must be sintered at 1300-1400°C, and thin films must be processed at 800-900°C. As usual, the desire is to put the film on a Si substrate and then reactive ion etch a window in the Si to produce a freestanding bridge. Unfortunately, there is a large mismatch between the thermal expansion of the PST and Si, as well as reactions, which take place at high temperature. While films have been produced by metallorganic chemical vapor deposition (MOCVD) on platinized Si, the films were poorly crystallized and did not exhibit optimal dielectric properties. Now V. Fuflyigin et al. {*Appl. Phys. Lett.*, **78**, [3], 365-7 (2001)} have reported on the growth of high quality PST films on platinized Si substrates, using sol-gel processing. Initially, a 0.02 μm thick layer of $PbZr_{0.52}Ti_{0.48}O_3$ (PZT) was deposited on top of the substrate, using the sol-gel technique. PZT crystallized at 550-650°C and created a template for the PST. Then a 0.25-0.5 μm thick layer of PST was added. The PST films were lifted off the Si substrates and bonded to a second wafer with epoxy glue. Pixels were fabricated by reactive ion etching and ion milling to remove the Pt layer, and electrodes were added, demonstrating the ability to fabricate an imaging detector. The properties of the freestanding films were better than those of the PST films on Si.

Negative Coercivity

For someone who works with permanent magnets, the concept of negative coercivity appears to be an oxymoron. The coercivity of a magnetic material is the reverse field required to reverse the magnetization of a material that has been magnetized to saturation in the forward direction. Since for a ferromagnet the lowest energy state is always with the net moment aligned with the field, a negative coercivity is not possible. The same is not true for an inhomogeneous system containing a ferrimagnet. In a ferrimagnet, there are two magnetic sublattices that have their moments opposing, resulting in a greatly reduced total moment. Since in rare earth transition metal compounds, the coupling of the rare earth moment to the transition element moment is through the spin of the ion and is antiferromagnetic. Light rare earth Fe compounds are ferromagnets, while heavy rare earth compounds are ferrimagnets, which is why Nd-Fe-B and not Tb-Fe-B is found in most houses in the industrialized world. J.-M. L. Beaujour et al. {*Appl. Phys. Lett.,* **78**, [7], 964-6 (2001)} have grown epitaxial superlattices of $DyFe_2/YFe_2$, which we may view as a single crystal with periodically spaced Dy layers. The Fe in the $DyFe_2$ layers is antiferromagnetically coupled to the Dy moments, and the Fe in the YFe_2 layers couples ferromagnetically to these Fe spins. In addition, the Dy is strongly coupled to the crystal lattice so that there is an easy axis. In zero field, the moment from all the Fe is, thus, antiparallel to the Dy moments. The total Fe moments also exceed the Dy moments, so the net moment is antiparallel to the Dy moments. If a magnetic field is applied parallel to the Dy moments, at some point it becomes energetically favorable to introduce what amounts to two domain walls in the YFe_2 layer. Most of that layer is then magnetized parallel to the Dy moments, and the saturated material has a net moment parallel to the Dy moments. When the field is reduced, the moments in the YFe_2 layer reverts to being antiparallel to the Dy moments when the exchange bias from the Fe spins in the $DyFe_2$ layers is stronger than the external field, and the net moment becomes antiparallel to the applied field, causing the hysteresis loop to exhibit negative coercivity. However, the magnetization loop at this point is completely reversible, unlike that of a ferromagnet. The loop does not become irreversible until a large enough reverse field is applied to flip the Dy moments with respect to the lattice.

Superconductivity at 39 K in Magnesium Diboride

MgB_2 contains no rare earth elements, but it may have a large impact on the use of rare earths in superconducting power lines. Recently, the material, which has been used as an additive for strengthing Mg alloys, has been found to be superconducting at 39 K [J. Nagamatsu, et al. {*Nature* **410**, 63-4 (2001)}]. While this temperature is substantially lower than that of the best high T_c superconductors and a factor of two lower than the $REBa_2Cu_3O_7$ materials, the crystal structure is relatively simple. At this time, wires have already been fabricated by reacting commercial boron fibers with Mg vapor [P. C. Canfield et al. {*Phys. Rev, Lett.*} to be published]. The polycrystalline materials exhibit reasonable critical currents at this early stage. The original paper and a commentary are available at http://www.nature.com/nature/prepub/superconductor.html

Industry Note

On February 15, 2001, Santoku Corporation entered a joint venture agreement with Rhodia, Baotou Rare Earth Technology Development Zone and Westlake, a U.S. investment company, to form Baotou Santoku Battery Materials Co. Ltd. (BSBM). Santoku Corporation is contributing 70% of the total registered capital, and the Chairman of the Board and the General Manager for BSBM will be delegated from the Corporation. BSBM will manufacture mischmetal and NI-NH alloys for battery and sales activities in China. Eventually, products will be exported to other Asian countries, including Japan. Currently, there is a rapidly growing demand for Ni-MH batteries for cellular telephones in China.

Sincerely,

R. W. McCallum
Director of RIC