news and views

Fermi surface of magnetic rare earths

THREE physicists at the University of Birmingham have reported direct measurements of the Fermi surface of gadolinium metal (Young, Jordan and Jones, *Phys. Rev. Lett.*, **31**, 1473; 1973). This is the first experimental observation of the Fermi surface of a magnetic rare earth element, although there have been some preliminary measurements reported by workers at the Ames Laboratory in the United States on a sample of non-magnetic lutetium (Hoekstra and Phillips, *Phys. Rev.*, **B4**, 4184; 1971).

In a metal some of the electrons are lost by the atoms to the conduction band. If these electrons were perfectly free they would have a quasicontinuous range of allowed energies up to a maximum energy, the Fermi energy. The electrons move through the periodic lattice of the positive ions, however, and these cause the formation of allowed and forbidden energy bands. In anisotropic three-dimensional materials the energy bands are also anisotropic and the Fermi surface, the energy surface formed by the Fermi energy in three-dimensional reciprocal space, also becomes non-spherical. These concepts of band structure and Fermi surface are vital in understanding the magnetic, electrical and thermal properties of metals.

There have been several very careful calculations of the band structure (Keeton and Loucks, *Phys. Rev.*, **168**, 672; 1968; Jackson, *Phys. Rev.*, **178**, 949; 1969; Dimmock and Freeman, *Phys. Rev. Lett.*, **13**, 750; 1964), and hence the Fermi surface, of the rare earth metals. In particular the magnetic properties have been interpreted in terms of very small variations of apparently insignificant parts of the theoretical Fermi surface (Evenson and Liu, *Phys. Rev.*, **178**, 783; 1969). Obviously before more detailed theoretical calculations are started there has been a need for some supporting experimental evidence.

Problems have arisen, however, because techniques which allow measurements of the Fermi surface require very pure single crystal materials. It is only in these samples that the electrons can traverse reasonable distances of the Fermi surface without suffering scattering. The rare earths have proved difficult to purify for a variety of reasons. The elements in the series all have identical outer electronic structure and hence chemical separation is difficult. Relatively pure samples of rare earth oxide can best be obtained by ion-exchange techniques and the metal produced from the oxide by a conversion to the fluoride followed by a calcium reduction of the fluoride. Added to this the individual elements are highly reactive, readily forming nitrides, hydrides, oxides and carbides both during preparation and on subsequent exposure to the atmosphere. Until very recently samples more than 99% pure with respect to all constituents were very difficult to manufacture.

The Birmingham workers have used the technique of solid state electrolysis in ultra-high vacuum (UHV) to improve the purity of their gadolinium samples, particularly with respect to the gaseous and carbon impurities. The initial material is taken in the form of a polycrystalline rod and placed between electrical contacts in a UHV system. A current of 500 A cm^{-2} is passed through the sample heating it to 1,100° C. The metallurgy of this process is not well understood but it is thought that during the electrolysis the oxygen impurities among others migrate to the anode end of the sample, while the hydrogen is simply released in the UHV heating. Hence a section cut from the centre of the sample is found to be purer than the starting material. If this subsample is reprocessed the purity improves still further. An added advantage of this purification process is that preferential grain growth takes place in the centre of the rod, producing single crystals with dimensions of some millimetres.

A simple, though for the rare earths a sometimes unreliable, method of checking the purity of the materials is to measure the resistance ratio (the ratio of the electrical resistance at 300 K to that at 4.2 K). The higher this value the purer the sample. The resistance ratio for these latest Gd samples (240) is an order of magnitude better than for previous material. The Ames lutetium had a resistance ratio of 21.

The de Haas–van Alphen technique, in which on cooling the sample to about 1 K it is found that the magnetisation is periodic with increasing internal magnetic field, has been used to study the Fermi surface of the pure Gd. The frequency of the periodicity can be associated with the frequency of a particular electron orbit around the Fermi surface. Young *et al.* were able to observe four separate de Haas–van Alphen frequencies for a magnetic field applied in the base plane of the hexagonal structure and a further three frequencies for a magnetic field applied along the hexagonal axis.

The higher experimentally observed frequencies can be associated with orbits round the theoretically predicted Fermi surface. For example, the theoretical Fermi surface is basically columnar in shape and oscillations around the trunk of the column can be observed and the diameter of the column estimated. The lower frequencies reported cannot, however, be explained with the theoretical Fermi surface at present established. As happens at regular intervals in developing areas of research, it seems that the tables have been turned. Until this paper was published theoreticians were demanding measurements of the Fermi surface to check their calculations. Now the experimentalists would like more sophisticated theory to explain their results.

Of course, these pure samples of single-crystal rare earth elements will start a new series of measurements on those physical properties that depend on purity. Already Wells, Lanchester and Lee at the University of Southampton have measured the specific heat of Gd at low temperatures and found no evidence for the anomaly at 3–4 K reported by previous workers. This anomaly can now be clearly attributed to Gd_2O_3 impurity present in the previous samples.

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Immunity to measles and canine distemper viruses

THE role of cell-mediated immunity in recovery from virus infection is a subject which is currently receiving considerable attention. It has long been recognised that dysgammaglobulinaemics—persons with deficiencies in their ability to produce humoral antibodies—recover normally from certain virus infections and can be immunised successfully against