Rare-earth Information Center Insight

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Ferromagnet with No Net Magnetic Moment

Our concepts of magnetic order start out fairly simple. If the atomic moments are aligned parallel, it is a ferromagnet; if they are all equal, and aligned in some sort of anti-parallel pairing, it is an antiferromagnet. If there are two different sublattices with different net moments, which are aligned antiparallel, we have a ferrimagnet. This last case is interesting because the two sublattices may have different temperature dependencies. As a result, there is the possibility of a compensation point, a temperature where the magnitude of the magnetizations of the two lattices are equal, resulting in zero net magnetization. Compensation points are quite useful in such applications as magneto-optical recording. Early on in our study of magnetism, we learned that the atomic moment results from unpaired electrons, which have both spin and orbital moments. In transition elements, the orbital moment is usually quenched by interactions with the lattice, but in the rare earth elements, the 4-f electrons are shielded from the lattice. There is some crystal field splitting of the 4-f levels, but the total moment of the ground state, J, is given by Hund's rule, which states that J =L-S for the light rare earths and J=L+S for the heavies, where L is the orbital moment and S is the spin. This picture plays an important role in the magnetization of rare earth intermetallics. The coupling of a rare earth spin to a transition element spin is antiferromagnetic and, thus, in order to have a ferromagnet, we must have a light rare earth coupled to the transition element so that the total moment, J, of the rare earth is parallel to the spin of the transition element. (This is fortunate since it means that the best permanent magnets are Nd-Fe-B not Er or Tb-Fe-B. Since the light rare earths are much more abundant, they are also much cheaper so we can afford to us them.) If we think about a ferromagnetic light rare earth transition metal intermetallic, such as $REAl_2$, the rare earths couple indirectly through the conduction electrons. We might hypothesize that we have magnetic lattices, a spin lattice and a lattice of orbital moments, which are coupled antiferromagnetically, a sort of a self-ferrimagnet. Generally, we do not think of rare earths in these terms because L and S are tightly coupled, and J is a good quantum number. However for Sm^{3+}, the spacing of the J multiplets is small enough that the states are mixed, and L and S may have different temperature dependencies. If the size of the two moments is comparable, it should be possible to have a compensation point, however, no compensation point has been observed for Sm compounds. Recently, H. Adachi and H. Ino {*Nature*, **104**, 148-60 (1999)} have adjusted the relative magnetizations of the spin and angular moment lattices by substituting a small amount of Gd for Sm in $SmAl_2$. Gd has a pure spin moment, which appears to follow the temperature dependence of the Sm spins. The Sm orbital moment has a different temperature dependence. The result is a compensation point in a material that is ferromagnetically ordered on the atomic scale, a ferromagnet with no net magnetic moment.

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Yttrium, Cerium and Corrosive Wear

Corrosive wear combines the effect of mechanical wear with corrosion. It is a difficult problem since many of the steps that are normally made to improve wear performance result in multiphase microstructures, which are prone to electrolytic corrosion. On the other hand, corrosion resistance is often imparted by elements, which produce a tenacious oxide layer. Mechanical wear has a tendency to break up this layer so that fresh surface is continuously exposed. Worse yet, the oxide particles may result in potential differences on the surface, enhancing corrosion. Interestingly, the addition of small amounts of yttrium or cerium to stainless steel has been shown to enhance its performance under conditions of corrosive wear. Now a study {*J. Mater. Sci.*, **35**, 633-41 (2000)} of additions of these elements to lubricants has shown a reduction in corrosive wear. The studies were conducted in relatively standard pin on disk experiments. A dilute H_2SO_4 solution was added to the lubricants to provide the corrosive environment, and Y or Ce particles were also added. The remarkable result is that the H_2SO_4 - Y - oil and H_2SO_4 – Ce - oil wear was less than that for just oil. Very little definitive is said about mechanism in the paper, but a number of puzzling questions arise for those who are familiar with rare earths. First, the rare earths were added as metallic powders, 420 μm for Y and 250 μm for Ce. It is hard to imagine that these powders do not immediately fully react in this environment, and it is tempting to speculate that they neutralized the acid. That, however, would not account for the reduction of the wear below the oil test. It seems equally unlikely that RE_2O_3's have the same lubricating properties as MoS_2 or other dry lubricants, though Ceria is used as a polishing compound for optics where it is believed to be active, both mechanically and chemically. Since the chemistry is poorly defined in these tests, it is difficult to say what rare earth compounds form under the test conditions, however, a number of rare earth compounds, such as CeF_3, YF_3, and $CePO_4$ are known to be high temperature lubricants. It would appear likely that similar compounds are forming here.

Hydrogen Sensor Based on SnO2:La_2O_3

Solid state gas sensors are of considerable interest for applications in process control, environmental monitoring and safety. Semiconductor devices exhibit a change in electrical conductivity when exposed to various gases, and the challenge is to make gas specific sensors. When SnO_2 is exposed to oxygen, the resulting chemisorbed oxygen layer creates a layer with high electrical resistivity. If the chemisorbed oxygen is removed by a reducing gas, the resistivity decreases in a manner that be calibrated to yield the concentration of the reducing gas. Thus, the detection of H is rather simple. However, pure SnO_2 is not gas specific, any reducing gas will have a similar effect. A considerable amount of research has been directed at finding dopants, which enhance the sensitivity to one specific gas while reducing the sensitivity to others. The addition of La_2O_3 to SnO_2 has been shown to be advantageous in this respect {*J. Electrochem. Soc.*, **147**, [1], 390-3 (2000)}. The La_2O_3 is believed to be important, both in the chemistry and microstructure of the sensor. The La_2O_3 prevents grain growth at elevated temperature, stabilizing the surface area of the sensor while at the same time it stabilizes the surface oxygen sites. The addition of Pd to the sensor is thought to produce a catalytic effect for the oxidation of H_2. A SnO_2 sensor made with 2 wt% La_2O_3 and 0.5 wt% Pd can detect 1000 ppm H_2 in air at room temperature.

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