Rare-earth Information Center

Insight

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Sintering of NdFeB

Sintered NdFeB permanent magnets have become an essential part of modern technology enabling an ever-increasing number of compact energy efficient designs. They are essential for the operation of high-density disk drives. In order to obtain the highly textured fine grain structure required for superior magnetic properties, these magnets are made by powder metallurgical processes where a powder of single grain particles is aligned in a magnetic field, pressed and then sintered. The sintering process is a complex one. The desired microstructure is a uniform arrangement of well-aligned grains with a very thin intergranular phase that decouples the individual grains. Recently, B. E. Davies et al. {*Mater. Chem. Phys.*, **67**, 272-81 (2001)} have published detailed studies of the sintering process. It is well known that the sintering of NdFeB is facilitated by a liquid phase. When the sintering temperature is raised above the melting temperature of the ternary eutectic, sintering begins. Since the liquid wets the NdFeB grains, capillary action exerts a strong force that pulls the grains together so that external pressure is not required. Typical liquid phase sintering exhibits a sharp change in density of the sintered piece when the sintering temperature is increased from just below the liquid formation temperature to just above. This is not the case for NdFeB where the density increases slowly from a green density of about 60% to 98% of full theoretical density as the sintering temperature is increased from 600° to 1100°C. Davies et al. have performed a detailed examination of fracture surfaces of the sintered parts and followed the development of the microstructure for $Nd_{16}Fe_{76}B_8$. Dilatometer measurements indicate that the sintering rate peaks at two temperatures, 750° and 950°C. The authors attribute the fact that sintering does not start to be effective until well above the eutectic temperature where liquid forms due to the presence of an oxide surface layer, which prevents the wetting of the grains below 750°C.

Plating Solution and Corrosion Resistance in $Nd_2Fe_{14}B$

While there has been considerable work on the corrosion resistance of $Nd_2Fe_{14}B$, the majority of the work has focused on the stability of the mass of the magnet in a hot humid atmosphere as a function of alloy composition or surface coating. A limited number of studies have used electrochemical potentiodynamic polarization methods to study the corrosion potential. D. J. Blackwood et al. {*J. Magn. Magn. Mater.*, **223**, 103-11 (2001)} have now applied these methods to studying the effect of the plating solution used to deposit Ni coatings on $Nd_2Fe_{14}B$. It is possible to plate Ni from either an acidic bath or an alkaline one. While the coating deposited from the acidic bath had a smooth gray metallic appearance and was reasonably thick, the alkaline bath produced only thin golden orange coatings. Attempts to grow the alkaline coating thicker resulted in a poorly adhering black powdery coating. The metallic coating provided an appreciable increase in the corrosion resistance while the alkaline coating was only slightly better than the bare substrate. The difference in coating behavior is attributed to the reaction of the $Nd_3Fe_{14}B$ with the alkaline solution so that a passive oxide film is formed between the coating and the substrate.

Creep Resistant Mg-Gd-Sc Alloys

Creep is the deformation that occurs over long periods of time when materials are under a static load. When dislocations occur in the crystal lattice of the metal, if they are free to move, one part of the lattice is free to move with respect to the rest of the lattice. In order to pin dislocations, a fine dispersion of a suitable second phase is required. This is normally achieved by precipitation hardening. In the simplest form of this process, a second metal is introduced into the pure host metal. The second element is selected to have higher solubility in the host element at high temperature than at low temperature. The alloy is first annealed at high temperature in order to produce a uniform solid solution and, subsequently, annealed at low temperature. During the low temperature anneal, the second element precipitates out. However, if the temperature is sufficiently low, diffusion is very slow so that a uniform dispersion of fine precipitates is obtained. In more complex systems, the precipitate may be an intermetallic compound of the two elements. You may recall that I reported on this process for Sc additions to Al in *RIC Insight,* **12**, [6] (2000) where the precipitate is actually coherent with the Al lattice but with a different lattice parameter so that the stain field associated with the precipitate is highly effective in pinning dislocations. Of course, if Al is too heavy for your application, you would like to have suitable Mg alloys. There is a commercially available alloy (Mg-Y-Nd-Zr), which is suitable for sustained operations up to 250°C, but there is considerable interest in extending that range. I. Stulikova et al. {*Mat.-wiss u. Werkstofftech*, **32**, 20-4 (2001)} have investigated binary Mg-Gd alloys and quaternary Mg-Gd-Sc-Mn alloys. For the binary alloys, the solubility limit for Gd in the Mg is fairly high, which necessitates the addition of a considerable amount of Gd. This clearly does not do the weight of the alloy a lot of good. The addition of Sc and Mn were effective in reducing the solubility of Gd at the expense of complicating the phase diagram, producing not only the desired precipitate phase but also two other phases. Nevertheless, the additions were effective in reducing the minimum creep rate one order of magnitude below that of the commercial alloy.

Chemical Composition of the Earth

I do not suppose many of us have given much consideration to how one would determine the chemical composition of the earth; however, it has attracted the attention of such notable scientists as Goldschmidt and Urey. C. Allegre et al. {*Earth and Planetary Sci. Lett.*, **185**, 49-69 (2001)} not only discuss the historical approaches, such as the meteorite data, used by those researchers, but also provide a new approach. Of particular interest is a figure that plots the log of the weight percentage of the elements versus atomic number. The abundance of the individual rare earth elements are scattered about that of Sn and are above that of Ag, which is somewhat less than that of Au. We are requesting permission of the authors to reproduce the figure in an upcoming issue of the *RIC News*.

Conferences

NdFeB Magnets and NdFeB Magnet Systems 2001 is being organized by Gorham Advanced Materials, Inc. and will be held in Atlanta, Georgia, USA May 14-16. Contact www.goradv.com, E-mail gorham@goradv.com. *The 4th International Conference on Rare Earth Development & Application* will be held June 15-20, 2001. The conference is organized by the Chinese Society of Rare Earths. RIC has an electronic version of the third and final circular for the conference that we will be happy to send you (RIC@ameslab.gov).

Sincerely,

R. W. McCallum
Director of RIC