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Y_2O_3 Improves NiAl

Various nickel-aluminum intermetallic compounds are being considered as high temperature structural materials. In the case of NiAl, its potential properties have been difficult to realize because of its poor ductility and toughness at room temperature, and its low creep strength at high temperatures. Recent work by T. Cheng from the Beijing Institute of Technology, People's Republic of China [**J. Mater. Sci. Lett. 14**, 1455-1457 (1995)], indicates that some of these problems have been ameliorated, by making a NiAl-based composite containing 2 wt.% TiB_2 and 0.5 wt.% Y_2O_3. The composite was prepared by mechanically alloying nickel, aluminum, TiB_2 and Y_2O_3 to produce a fine powder of about 0.1 µm in size, then hot pressing at 1250°C and 33 MPa (4.8 ksi). The NiAl grain size increased to about 1 µm during the hot pressing, but TiB_2 and Y_2O_3 particles were about 0.1 µm. The yield stress of the composite was 847 MPa (123 ksi), which is nearly three times larger than that of cast undoped NiAl and boron-doped NiAl, and about two and a half times that of carbon-doped NiAl. It was also 40% stronger than a 27 vol.% TiB_2-NiAl composite with a 1-3 µm grain size. The TiB_2-Y_2O_3-doped NiAl had a high rate of work hardening and attained a fracture strength of 1325 MPa (192 ksi). The 3 to 1 improvement of the TiB_2-Y_2O_3-NiAl composite over cast monolithic NiAl was maintained to elevated temperature, i.e. at 1173K (900°C), the former having a yield stress of 162 MPa (23.5 ksi) compared to 50 MPa (7.3 ksi) for the latter. The Y_2O_3 containing composite was slightly more than twice as strong as the 27 vol. % TiB_2-NiAl material at 1173K (900°C). Surprisingly, with this significant improvement in strength, the room temperature ductility of TiB_2-Y_2O_3-NiAl (5.4%) was nearly double that of the baseline NiAl material (2.8%). The author believes that the improved ductility is due to the homogeneous and very fine microstructure, which results in various interfaces with high density, and thus releases the stress concentrations at the interfaces and promotes plastic deformation. The elevated temperature plasticity was also quite good—the testing had to be stopped when the plastic strain reached 10%. These results on NiAl add another material to the list of alloys and compounds whose properties have been significantly improved by the addition of finely dispersed Y_2O_3 [see **RIC Insight 6** [5] (May 1993)]. The use of finely dispersed Y_2O_3 in metal matrices is an important application which can be expected to continue to grow in the foreseeable future.

Optical Cooling by Ytterbium

Normally, shining a light on a sample will cause it to heat up if the light is intense enough, or do nothing if the beam is weak. But recently, scientists have demonstrated for the first time that a solid object can be cooled by shining a light on it. The idea that an object could be cooled by radiation was predicted over 60 years ago, and except for gases, no one has really demonstrated it for solids. In the October 12, 1995 issue of **Nature** (**377** [6549] 500-503), R. I. Epstein and co-workers from the Los Alamos National Laboratory, Los Alamos, New Mexico, USA, report that they were able to cool a ytterbium-doped glass [Zr:Ba:La:Al:Na:Pb fluoride glass with 1 wt.% Yb^{3+}(ZBLANP:Yb^{3+})] by laser-induced fluorescence with an experimental cooling efficiency of 2% at a wavelength of 1015 nm.

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separated by an energy of 1.3eV, which corresponds to a wavelength of about 1,000 nm. Pumping this glass in the long-wavelength tail of the absorption spectrum moves electrons from the top of the ground-state group of levels to the bottom of the excited-state group. This shifts the electron populations in the two sets of energy levels out of thermal equilibrium. Radiative decays from the excited-state to the ground-state produces phonons which carry off the absorbed radiative and thermal energies, and restores the equilibrium concentration of electrons in the two sets of electron levels. Calculations by the authors indicated that this 2% cooling efficiency at room temperature should be maintained down to 60K. They believe that by using an efficient diode laser, a fully solid-state cryocooler, which has an efficiency comparable to commercial mechanical coolers, could be developed. This type of cooler could be used for cooling high T_c oxide superconductors, infrared detectors and other cooled electronic devices. Furthermore, it would be well suited for space-base applications.

It's Still Going Up

Last month, **RIC Insight** asked the question "Where Will It End?" Well, apparently, it did not end last month. The super GMR (giant magnetoresistance) effect set another record in the past month with another order of magnitude increase from 1 x 10^8% to 1 x 10^9%. The latest increase in the super GMR was reported by a French group from the University of Caen, France [A. Maignan *et al.*, **Solid State Comm. 96**, 623-625 (1995)]. They found a drop in the resistivity of eleven orders of magnitude by applying a field of 5T at 30K in the perovskite semiconductor $Pr_{0.7}Sr_{0.04}Ca_{0.26}MnO_{3-\delta}$. This compound was prepared by heating the appropriate amounts of Pr_6O_{11}, $SrCO_3$, CaO and MnO_2 in air at 900°C for 12 hours. Upon cooling, the resulting material was compressed into bars at a pressure of 96 MPa (14 ksi). This was followed by sintering at 1500°C for 12 hours and then slowly cooling to room temperature.

The authors of this paper used the adjective "hyper" to preface the term GMR effect. So, we have now gone from "super" to "colossal" to "hyper". I am not sure that this writer would use these adjectives in this sequence, but this is the way it has developed to date. As more developments occur, we will keep you posted.

Twin-free, <111> Oriented Terfenol

Terfenol is a series of ternary intermetallic terbium-iron compound alloys which exhibit large magnetostrictive strains and have many applications, such as actuators, sensors, magnetic circuits, vibrators, acoustic devices, positioning systems and active damping systems. The best known alloy is Terfenol-D, which has the nominal composition $Tb_{0.3}Dy_{0.7}Fe_2$. Unfortunately, until recently it was difficult to grow single crystal Terfenol-D with a <111> orientation, which is the direction in which the magnetostrictions are the greatest. Usually, single crystals have a <112> orientation, with lamellar twins with the plated face parallel to the {111} planes. Recently, Chinese scientists headed by G.-H. Wu, from the State Key Laboratory for Magnetism, Beijing, People's Republic of China, reported that they were able to grow <111> oriented Terfenol-D by using a Czochralski technique with an induction-heated magnetic levitation cold crucible [**Appl. Phys. Lett. 67**, 2005-2007 (1995)]. A complex procedure was used in the growth process to avoid constitutional supercooling which, if it occurs, will normally give <112> oriented crystals. The procedure involved changing the growth rate, crystal rotation rate, and rf power while maintaining the temperature gradient during the growth of the crystal.

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