



# Rare-earth Information Center **INSIGHT**

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## Nd-Fe-B "Battery" to Power Electric Car

One of the solutions to meet the 1998 California mandate that a small percentage of cars sold must be non-polluting is to use a device called a "flywheel battery" to power electric and hybrid vehicles. The flywheel is made of graphite fibers and contains Nd-Fe-B permanent magnets. As the wheel revolves, up to 100,000 revolutions per minute, the magnetic field of the permanent magnets generate an electric current in coils adjacent to the wheel — much like an electric generator. The term "battery" comes about from the fact that the spinning flywheel, once it gets up to speed, stores a considerable amount of angular momentum energy, which can be tapped when desired. That is, the flywheel battery is the mechanical analog of a chemical battery we are so familiar with and utilize daily. The flywheel levitates on magnetic bearings centered by a thin wire. The wheel is housed in a vacuum container, thereby reducing its friction to nearly zero, thus allowing it to spin for weeks at a time before coming to rest. One of the biggest problems is to control the spinning of the wheel and the withdrawal or the addition of energy. But with today's compact and fast computers, and advanced switches and sensors, the solution is at hand. A hybrid vehicle (one which has both an internal combustion engine and an electric motor) would probably have only one flywheel battery, but an all-electric car would require two or more flywheels. One of the advantages of the flywheel battery is that much of the energy lost by braking can be recaptured by speeding up the flywheel. The flywheel batteries are expected to last as long as the car.

Besides the automobile manufacturers, companies which make large electric generators are looking into the flywheel battery concept to help level the daily energy load, and to smooth out power glitches. Presumably these flywheel batteries would be much larger than those used in electric or hybrid vehicles.

## Er Improves MoSi<sub>2</sub>

MoSi<sub>2</sub>, which is an ordered intermetallic compound, is receiving a great deal of attention as a structural alloy for high temperature applications. Recent studies by D. K. Patrick and D. C. Van Aken have shown that Er<sub>2</sub>Mo<sub>3</sub>Si<sub>4</sub> is an effective reinforcement agent for strengthening MoSi<sub>2</sub>. Both the hardness and creep resistance were improved in a hot-pressed MoSi<sub>2</sub> compact containing 20 vol.% Er<sub>2</sub>Mo<sub>3</sub>Si<sub>4</sub>. The improved creep resistance was thought to be due to a lower SiO<sub>2</sub> content and the presence of hard particles (Er<sub>2</sub>Mo<sub>3</sub>Si<sub>4</sub> and Er<sub>2</sub>O<sub>3</sub>) in the MoSi<sub>2</sub> grain boundaries which limited grain sliding. More recently, these authors [*Scripta Met. Mater.* **30**, 981 (1994)] showed that a directionally solidified Er<sub>2</sub>Mo<sub>3</sub>Si<sub>4</sub>-MoSi<sub>2</sub> eutectic (which occurs at 39 vol.% MoSi<sub>2</sub> and at a melting temperature of 1790 ± 10°C) had excellent creep resistance at 1300°C and a compressive strength greater than 625 MPa at 1300°C and greater than 450 MPa at

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1400°C. They also pointed out that the flow stress was much larger than that reported for other MoSi<sub>2</sub>-based materials. The high strength of the eutectic mixture was attributed to the Er<sub>2</sub>Mo<sub>3</sub>Si<sub>4</sub> phase.

In addition, the authors suggested that Er<sub>2</sub>Mo<sub>3</sub>Si<sub>4</sub> compound in itself may have good high temperature mechanical properties. This ternary phase melts at 1930 ± 20°C and has a monoclinic structure with a density of 8.25 g/cm<sup>3</sup>, which is comparable to the densities of other refractory silicide compounds (e.g. Mo<sub>5</sub>Si<sub>3</sub> has a density of 8.25 g/cm<sup>3</sup>). However, little else is known about this compound.

We believe these results are a harbinger for the utilization of the rare earths in silicide-based materials for high temperature applications.

### Cellular Phones Take-Off

As reported in the December 1, 1992 issue of **RIC Insight** (5, [12]), cellular phones (wireless telephones) were expected to have a major impact on the rare earth permanent magnet and yttrium iron garnet (YIG) markets. This has been realized and has even exceeded the most optimistic projections. Eighteen months ago the USA had about 10 million subscribers and about 7,000 cellular phones were being sold each day. Today there are about 20 million subscribers and 14,000 phones are being sold daily. About 40 percent of the phones in use are for personal use. The major driving force is the tremendous price reduction since the first cellular phones became available in 1983. At that time, some of the more expensive models when installed in an automobile cost \$5000. Today they are available for as low as \$50, installation charges are extra. In addition, they have become more compact, and the monthly charges, although still quite expensive (about \$60 per month), have dropped about 30% in the past six years.

Although the amounts of rare earths used in each cellular phone is small, the number of phones is quite large. We must remember that this revolution is still in full-swing in the USA, and that the rest of the world will be embracing this technology, especially as the economies recover in Europe and Japan.

### China Statistics for 1993 Available

The May 1994 issue (No. 33) of **China Rare Earth Information** arrived a few days ago. According to this newsletter, 1993 proved to be an excellent year, the best since 1989. The Chinese produced 22,720 tons of rare earth products (in rare earth oxide [REO] equivalent), up 8.2%. Of this amount, 44% was consumed in the People's Republic of China and 56% was exported. The main increase in the international market was the demand for rare earth chlorides and mischmetal for rare earth-nickel hydrogen batteries.

Bastnasite accounted for the major production of the ore products; monazite and xenotime production was quite small (~7.5%) and slightly more than half that of the ion-type mineral ores (~13%).

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