

Towards a sustainable superconductor technology with magnesium diboride super magnets

May 1 2023



Scientists at SIT in Japan produced high-performance MgB2 by ultrasonicating boron (B) in 2-propanol for varying durations. The inset displays high magnification FE-SEM images of B particles obtained after 0 and 45 minutes, respectively, with the latter showing 20-50 nm refined grains. Credit: Muralidhar Miryala from Shibaura Institute of Technology (SIT), Japan



Magnesium diboride (MgB₂) is a low-cost, non-toxic superconductor used in field magnets, electric motors, and generators. However, producing nanoscale boron (B) particles to fabricate MgB₂ is expensive. Researchers recently tackled this issue by using high-energy ultrasonication in 2-propanol, a highly viscous solvent, to produce impurityfree, nm-sized B particles. The approach is cost-effective and enables fabrication of bulk MgB₂ with high critical current density, a prerequisite for the sustainable production of high-performance superconducting magnets.

Magnesium diboride (MgB₂), a binary compound, behaves as a superconductor—a substance that offers no resistance to electric current flowing through it—at a moderate temperature of around 39 K (-234°C). This temperature can be achieved using relatively inexpensive liquid hydrogen or neon coolants.

In addition, MgB_2 is inexpensive, lightweight, and non-toxic, and its precursors—magnesium (Mg) and boron (B)—are abundantly available. As a result, it can replace conventional low-temperature superconductors that require expensive liquid helium for cooling and substitute magnets based on neodymium, a rare element, as well as iron and boron.

 MgB_2 finds a wide range of applications, including the manufacture of coils and magnets for <u>magnetic resonance imaging</u>, nuclear magnetic resonance, magnetic drug delivery, fault current limiters, electric motors, and transportation. According to research, MgB_2 is a good candidate for polycrystalline superconducting magnets as it exhibits good critical current density (J_c) and a high trapped magnetic field (TF).

It, however, suffers from weak magnetic flux pinning. To enhance pinning, it is essential to tune the pinning centers in MgB_2 —the boundaries of grains or small crystals that constitute MgB_2 . To this end, researchers have now shown how nano-sized B particles can be used as B



precursors to fabricate nano-sized MgB_2 grains with strong grain boundary pinning and high J_c .

Currently, B nanoparticles are produced by ball milling, pyrolysis, and sintering. These techniques, however, suffer from drawbacks such as low purity output and poor cost-effectivity, necessitating better alternatives. To this end, a group of scientists led by Prof. Muralidhar Miryala from Shibaura Institute of Technology (SIT), Japan recently explored high-energy ultra-sonication as a cost-effective alternative for refining coarse B powder dispersed in 2-propanol up to nanoscale sizes. Their work was made available in the *Journal of Alloys and Compounds*.

"In this technique, ultrasonic vibrations impart high speeds to B particles in the solvent, leading to collisions. The resulting friction and shear tearing, compression, and energy release by the collapse of tiny air bubbles produced during collision break down B particles to nanometer sizes," explains Prof. Miryala.

Using 2-propanol as the solvent for B, the researchers ultrasonically refined cheap commercial B powder for 45 minutes to produce oxide-free nm-sized B particles. They then utilized them to fabricate bulk MgB_2 with scarce oxide and no carbon impurities, which showed superconductivity at around 38.5 K.

Furthermore, it showed high J_c values of 500 and 380 kA cm⁻² at 10 K and 20 K, respectively. The latter of these J_c values marked an 80% improvement compared to that for bulk MgB₂ prepared from cheap B powder and was at par with that for expensive commercial B powder. The observed increase in J_c was due to better grain boundary pinning in MgB₂ as revealed by microstructural analysis, and theoretically supported by the Dew–Hughes theory.

Finally, the researchers performed field cooling magnetization



simulations, predicting that a 40-mm wide and 10 mm-thick MgB_2 disk prepared from ultrasonically refined B powder can exhibit a high TF of 2.5 teslas. "These findings bring MgB_2 superconducting magnets, which can be fabricated in the form of tapes, wires, and films, a step closer to their commercialization," says Prof. Miryala.

More information: A. Sai Srikanth et al, Tuning of grain boundaries in MgB2 by boron ultra-sonication in 2-propanol—A way to low-cost high-J bulk superconducting magnets, *Journal of Alloys and Compounds* (2023). DOI: 10.1016/j.jallcom.2023.170146

Provided by Shibaura Institute of Technology

Citation: Towards a sustainable superconductor technology with magnesium diboride super magnets (2023, May 1) retrieved 27 June 2024 from <u>https://phys.org/news/2023-05-sustainable-superconductor-technology-magnesium-diboride.html</u>

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