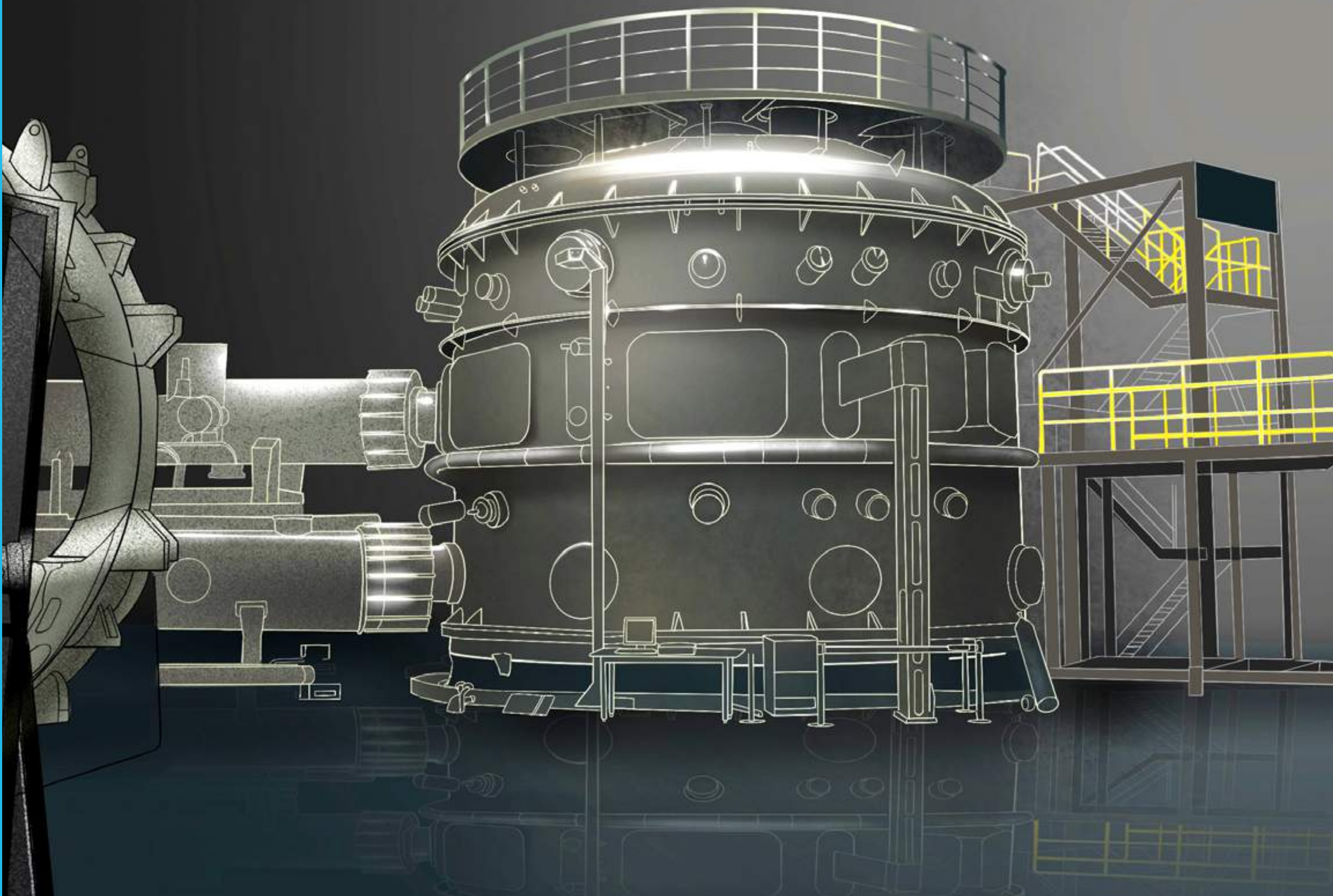
SUPERCONDUCTOR WEEK



JANUARY 3 2021
Vol. 34, No. 12

Cambridge Improves Properties of ReBCO Bulk Superconductors

Researchers from the University of Cambridge have demonstrated a simple, but effective and reliable reinforcement method to enhance the mechanical properties of ReBCO bulk superconductors by incorporating hybrid silicon carbon (SiC) fibers consisting of a tungsten core with SiC cladding within the bulk microstructure. They achieved an improvement in tensile strength by up to 40% without compromising the superconducting performance of the bulk material.

"High tensile strength and melting temperature greater than the sintering temperature make SiC a valuable option," commented Cambridge researcher Kysen Palmer. "The conjecture is that silicon in the SiC fiber would 'passify' further reaction between the HTS component melt and the SiC fiber by forming a layer of silicon dioxide. This would allow the single crystal HTS to form around the SiC fiber leading to the unreacted SiC long continuous fiber reinforcing the final single crystal HTS."

Bulk ReBCO Exhibits Poor Mechanical Properties

Bulk high temperature superconductors based on ReBCO have the potential to be applied in a variety of engineering and technological applications such as trapped field magnets, rotating electrical machines, magnetic bearings and flywheel energy storage systems. A significant factor for most practical applications of bulk superconductors is the product of the maximum current density that can be supported, which correlates directly with the maximum achievable trapped magnetic field, and the physical length scale over which the current flows.

Unfortunately, however, bulk ReBCO superconductors exhibit relatively poor mechanical properties due to their inherent ceramic nature. Consequently, the performance of these materials as trapped field magnets is limited significantly by their tensile strength, rather than critical current and size, given that the relatively large Lorentz forces produced in the generation of large magnetic fields can lead to catastrophic mechanical failure.

Researchers have sought to enhance the properties of the brittle cuprates by incorporating reinforcing oxide and non–oxide fibers. Recent work has demonstrated the possibility of achieving significant improvement in terms of mechanical strength and stability by reinforcing ceramics with both SiC and carbon nanotubes. The current study extended these findings to ReBCO superconductors, addressing the challenge of contrasting to non-functional ceramics the incorporation of mechanical reinforcement without compromising the superconducting properties of the parent single grain.

Three Types of Fibers Tested

The Cambridge researchers used the top seeded melt growth (TSMG) technique to fabricate single grain, YBCO bulk superconductors of 16 mm, 20 mm and 25 mm diameters. They incorporated three types of fibers into the superconductor: metallic tungsten (W), SiC, and hybrid fibers consisting of SiC-clad tungsten cores. They investigated the samples using thermogravimetry/differential thermal analysis (TG-DTA) under air up to temperatures of 1200°C with heating and cooling rates of 10°C per minute.

The material was melt processed in a box furnace to a temperature of 1055 °C and then cooled slowly at a rate of 0.5 °C–0.7 °C/h, which enabled the nucleation and growth of a YBCO single grain. The samples were subsequently oxygenated in a tube furnace at a temperature of 450 °C under oxygen gas flowing at a rate of 100 ml min^{-1}.

Optical micrographs under both low and high magnification revealed that both W and SiC fibers underwent reactions and disintegrated, either partially or completely, while the hybrid SiC fibers containing W in the core retained their physical characteristics. The team demonstrated that SiC does not react with the superconducting matrix during processing at elevated temperatures and is thermally stable, meaning that this is both a practical and effective reinforcement technique. They found that introducing the fibers to the precursor at an early stage of sample growth makes the application of the fully processed material more straightforward than competing approaches based on external reinforcement.

‣ "The other fibers did not show increased mechanical strength," Palmer said. "It is likely that deterioration occurred due to the addition of the other materials."

Lau Superconductors Formed to Advance Process

Researcher Wayne Lau, who originally conceptualized this process, has founded Lau Superconductors to develop it further and explore commercial opportunities. Palmer has joined the company as CTO.

"The breakthrough was with a single one-inch diameter sample with only three SiC fibers," Lau said. "The next step would be to repeat the breakthrough with more fibers to establish a clear relationship between more internal reinforcement and higher HTS strength. After that, other aspects of what internal reinforcement fiber can do, such as heat conduction and flux pinning, will be explored.

Lau Superconductors has filed patent applications in the U.S. (patent application Nos: 16/656,200, 17/100,609, 17/100,613, 17/100,616, 17/100,620, and 17/100,621), and internationally (PCT application Nos: PCT/US19/56815; and PCT/US20/61636). ■

Team Fabricates SQUID in Graphene Heterostructure

Researchers with the University of Basel, Budapest University of Technology and Economics, and Japan's National Institute for Material Science (NIMS) have fabricated a compact SQUID in a double-layer graphene heterostructure (doi.org/10.1021/acs.nanolett.0c02412). The tiny device for measuring magnetic fields is only around 10 nm high, roughly a thousandth of the thickness of a human hair. The instrument can trigger supercurrents that flow in minuscule spaces.

"Our novel SQUID consists of a complex, six-layer stack of individual two-dimensional materials," said Basel professor David Indolese. "Inside it are two graphene monolayers separated by "a very thin insulating layer of hexagonal boron nitride (hBN) crystal. If two superconducting contacts are connected to this sandwich, it behaves like a SQUID and can be used to detect extremely weak magnetic fields."

Graphene Layers Serve as Weak Links

A typical SQUID consists of a superconducting ring interrupted at two points by an extremely thin film with normal conducting or insulating properties. These points, known as weak links, must be so thin that the electron pairs responsible for superconductivity are able to tunnel through them. Researchers recently have begun using nanomaterials such as nanotubes, nanowires, or graphene to fashion the weak links connecting the two superconductors.

In this device, the graphene layers are the weak links. In contrast to a regular SQUID, they are not positioned next to each other, but one on top of the other, aligned horizontally. The configuration allows the SQUID to have a very small surface area limited primarily by the constraints of nanofabrication technology.

The novel SQUID's sensitivity can be adjusted by changing the distance between the graphene layers. With the help of electrical fields, the researchers are also able to increase the signal strength, further enhancing the measurement accuracy.

SQUIDs Ideal for Analyzing Topological Insulators

The team's primary goal in developing the novel SQUIDs was to analyze the edge currents of topological insulators. Topological insulators are currently a focus of countless research groups all over the world. On the inside, they behave like insulators, while