Uncovered

Superconducting stacks

In search of superior superconductors

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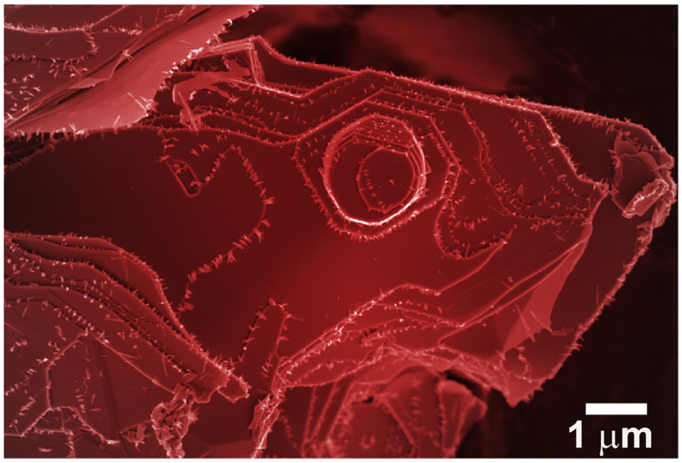

Since the discovery of superconductivity phenomena in mercury at 4.2 K in 1911, great efforts have been employed to find superconducting materials that are able to operate at room temperature. Unfortunately, in spite of the discovery of different superconductors, at present, the so-called high-temperature superconductors (HTSC) maintain their superconducting behavior only a little above liquid nitrogen temperature (77 K).

Superconducting materials are characterized by their ability to transport electrical currents without losses when they are used below their critical temperature, critical current density, and critical magnetic field. Consequently, a good superconductor should have very high values of these parameters. At present, the highest critical temperatures are found in some well-known ceramic materials, such as $Bi_2Sr_2CaCu_2O_x$ (Bi-2212, 80–96 K), $Bi_2Sr_2Ca_2Cu_3O_y$ (Bi-2223, 110 K), or $YBa_2Cu_3O_z$ (Y-123, 90 K). All these materials are characterized by a large crystallographic anisotropy, with preferential grain growth along their *ab*-planes. This anisotropy is reflected in the electrical transport properties, which are higher along the CuO planes of the structure. As both the preferential growth planes and the CuO planes are parallel, the alignment of these planes with the current transport direction is useful to increase their current transport capability. The increase in their critical magnetic field can be achieved by the formation of very small insulating particles homogeneously dispersed along the superconducting matrix. These particles will then act as pinning centers for the magnetic flux lines crossing the material, avoiding their movement, which would lead to energy dissipation.

When considering the use of the Bi-based superconducting materials as current leads or fault current limiters, one of the main parameters to be enhanced is their critical current density. For this purpose, many techniques have been applied to align the superconducting grains along the current transport direction; namely, the laser floating zone (LFZ), electrical assisted laser floating zone (EALFZ), or the hot uniaxial pressing techniques [1–3]. Among them, the hot uniaxial pressing process requires less expensive and complex equipment than the others. On the other hand, some additives have been used in this solid-state process, providing small amounts of liquid between the grains and helping to produce samples with large and well-aligned grains. Moreover, some of these additives have been found to be beneficial to increase the electrical conductivity by enhancing the grains' electrical connectivity, as well as the mechanical properties of the bulk polycrystalline materials [4].

At the Institute of Materials Science of AragÆn (ICMA), a Joint Research Institute of the Universidad de Zaragoza, and the Spanish High Research Council (CSIC), research work on superconducting materials has been active since 1990. Our group has developed and optimized different synthesis methods to produce highly homogeneous precursors, leading to high-performance materials. Moreover, we are pioneers in the use of the LFZ in the production of highly oriented polycrystalline bulk materials

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of the Bi-2212, and Bi-2223 superconductors. However, in spite of the higher critical temperature in the Bi-2223 system, the best transport properties are achieved in the Bi-2212 materials, making them more attractive for practical applications. Additionally, Bi-2212 possesses other advantages, such as higher thermodynamic stability, broader compositional range, and quicker formation kinetics [5]. Consequently, the hot uniaxial pressing process is appealing in order to produce highly dense and well-oriented bulk polycrystalline materials, leading to high critical current densities. Furthermore, in order to aid in material densification, and in the grain gliding, metallic Ag can be used. Because a homogeneous Ag distribution in the bulk material is difficult to achieve in the classical solid-state route, samples have been prepared through a sol–gel method via nitrates described in detail elsewhere [4]. The powders obtained after the gel decomposition were calcined twice, at 750 and 800 °C for 12 h, with an intermediate manual milling to decompose the alkaline earth carbonates. After the thermal treatments, the powders were cold uniaxially pressed in the form of disks (24-mm diameter, and 5-mm thickness) under 400-MPa applied pressure. These pellets were subsequently subjected to a uniaxial hot-pressing process for 6 h, under 25 MPa at 800 °C, leading to very dense (around 98% of the theoretical density) disks (34-mm diameter, and around 2-mm thickness) with high electrical transport properties at 77 K. Moreover, these bulk samples are formed by very large grains which can reach, in some cases, more than 100 μm along the *a*-, and *b*-directions. These large grain dimensions are very useful to decrease the number of weak links appearing between superconducting grains and also to extract relatively large single grains from the bulk samples.

The image shown on the cover of this issue of *Materials Today* shows a stack of superconducting grains with fish-like shape recorded with secondary electrons in a FESEM (Carl Zeiss Merlin), obtained by exfoliating a hot uniaxially pressed sample. When observing the exfoliated particles in detail, in some cases, the remains of neighbor grains may become stacked on the main grain, leading to the formation of curious and unusual shapes, such as this fish-shaped structure.

Further reading

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