High T_c superconducting current leads laser fabrication

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Abstract In this work is described a laser float zone melting method designed in our laboratory to the development of superconductor $Bi_2Sr_2CaCu_2O_8$ current leads. The most relevant results obtained with different grown conditions and the influence of the process parameters in the properties of superconductor leads are presented.

Keywords: **Laser floating zone. High temperature superconductor. Textured materials.**

Fabricación con láser de barras de alimentación superconductoras

Resumen Las barras de alimentación basadas en el superconductor $Bi_2Sr_2CaCu_2O_8$ son de gran interés práctico para la fabricación de criogeneradores capaces de refrigerar bobinas superconductoras a temperaturas inferiores a 77 K e incluso cercanas a 5 K. Las propiedades mecánicas y eléctricas de dichas barras son fundamentales para determinar su grado de fiabilidad, que en última instancia determinar su aplicabilidad a escala comercial. Los parámetros de fabricación utilizando la fusión zonal inducida por láser permiten obtener fibras gruesas de este superconductor capaces de transportar elevadas corrientes a 77 K y a temperaturas inferiores, y con un comportamiento aceptable frente al ciclado térmico y al paso de elevadas intensidades de corriente eléctrica. En este trabajo se describe un sistema de fusión zonal láser diseñado en nuestro laboratorio para el desarrollo de superconductores y se resumen los resultados más significativos obtenidos según las diversas condiciones de crecimiento estudiadas, la influencia de los diversos parámetros de procesado utilizados sobre las propiedades de las fibras superconductoras obtenidas, así como su potencial uso en dispositivos prácticos.

Palabras clave: **Fusión zonal. Superconductores de alta temperatura. Materiales texturados.**

1. EXTENDED ABSTRACT

Superconductivity is a phenomenon in which electric current flows through a material without any appreciable dissipation of energy and magnetic fields are shielded from the material. This behavior is known since 1911, when Kammerlingh Onnes cooled mercury with liquid helium. Following the discovery, several metallic elements and alloys were reported to show superconductivity (1), but temperatures were too low (liquid helium). A revolution was achieved in 1986 with the discovery of the so called "copper-oxide" compunds or high-temperature superconductors (HTS) by Bednorz and Müller (2). As a consequence of their ceramic nature, these materials present many processing problems in comparison to traditional alloys and their electrical behavior is strongly anisotropic. In consequence methods to overcome the intrinsic limitations of these materials are required.

Up to this moment, current leads have become the first commercially available product made with bulk HTS. Textured Bi-Sr-Ca-Cu-O (BSCCO) materials combine high critical current densities, *Jc*, and a low thermal conductivity and are interesting for applications in current lead systems required for superconducting magnets working at cryogenic temperatures as well as to facilitate the development of cryocooled turnkey units.

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Up to now, commercially available current leads have been fabricated using BSCCO materials with major components of the Bi-2212 and Bi-2223 phases textured by mechanical deformation (BSCCO/Ag sheated tapes) and Melt Casting Process (MCP) (3). The Laser Float Zone (LFZ) melting method can be an alternative texturing process for the fabrication of cylindrical current leads. In this technique, a melting zone is induced on a long precursor (ceramic o powder pressed rod) by focusing a power laser beam. Due to the high thermal gradient ($\approx 5 \times 10^5$ Km^{-1}) induced at the solidification interface, growth rates up to 50-100 mm/h are possible. The anisotropic BSCCO crystallites become textured with their a-b plane near parallel to the growth direction (see Fig. 1). The LFZ technique, together with several of its variants, has been described elsewhere in detail (4).

Best results with the LFZ technique have been achieved on Bi-2212 textured materials, in rods with diameters between 1-3 mm. The main parameters of the LFZ fabrication are:

- The characteristics of the precursor
- The laser source
- The growth process
- The annealing process
- The fabrication of contacts

For instance, the use of continuous-wave lasers with different emitting wavelengths has a pronunced effect on the processing of textured BSCCO thin rods or cylinders (5). This has been ascribed to the difference in penetration depth between CO_2 (λ = 10.6 μm and Nd:YAG (λ = 1.06 μm laser radiation. The latter penetrates further into the BSCCO melt, thus reducing substantially the radial temperature gradient typical in LFZ processing and providing conditions for a much flatter solidification interface. A flat solidification interface yields a higher degree of texture, because grain growth takes place parallel to this melt-solid interface.

With this system Bi-2212 textured rods with diameters of 1mm can carry 45 A at 77 K. This number increases by a factor of 9 if the temperature is reduced up to 50 K.

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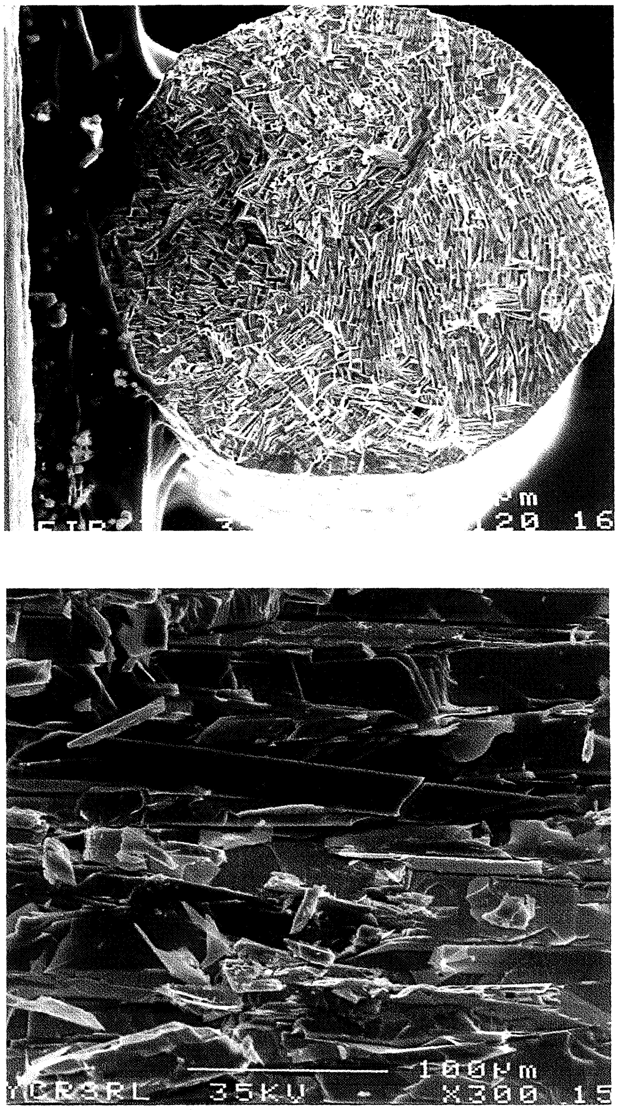

Fig. 1.— Típica textura fibrosa. Sección transversal (*a*) y sección longitudinal (*b*)

*Fig. 1.— Typical fiber texture. Transversal cross section (*a*) and longitudinal cross section (*b*)*

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