Scientific Article

Superconducting Wires and Tapes for High Field Magnets and Energy Applications

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Various new methods are being developed for improving the critical current density of superconducting tapes and wires based on Nb_3Sn for high field NMR magnets, and (Bi,Pb)2223 tapes and MgB_2 for energy applications above 20 K. An unique device has been built for measuring the effect of the stresses caused by the Lorentz forces on the critical current densities of industrial superconducting wires and tapes in magnets operating at fields of 17 T and above, whilst carrying up to 1'000 A.

Research Group

The group of Prof. R. Flükiger is active in various domains of fundamental and applied materials research. A major objective is the preparation of high purity polycrystals and single crystals of complex metallic and oxide superconducting materials. Various techniques, e.g. SQUID magnetometry and magnetization as well as electrical resistivity, are used to characterize their physical properties, at fields up to 17 T.

A second activity is focused on the development of superconducting Nb_3Sn wires and (Bi,Pb)2223 tapes in view of their application in industrial magnets producing magnetic fields well above 21T. The activity also involves new developments on MgB_2 wires. This work is performed in collaboration with Bruker Biospin (Fällanden, CH), the world leader in high field magnets for Nuclear Magnetic Resonance (NMR).

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References

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Introduction

The development of advanced superconducting tapes and wires is of considerable industrial interest for various kinds of magnets. The main activity is concentrated on magnets for Nuclear Magnetic Resonance spectroscopy (NMR), an analysis technique with growing potential for research in pharmacology, biology and biochemistry. Since a higher resonance frequency (allowing a higher resolution) is correlated to the magnetic field strength, B, there is an evident need for magnets producing the highest possible fields. The highest field achieved so far is 21 T at 2 K (corresponding to a frequency of 900 MHz) in an NMR magnet from Bruker BioSpin (Fällanden, ZH) which consists of Nb_3Sn wires. A worldwide effort is underway to reach 1 GHz, which is a very challenging goal.

On the other hand, future energy applications, such as transformers, power cables, motors or fault current limiters can only be economically operated at temperatures well above 20 K, which can be obtained by two-step refrigerators, i.e. without liquid Helium. Superconducting materials such as Bi,Pb(2223) or $YBa_2Cu_3O_7$, with T_c values of 110 and 92 K, respectively, are the appropriate choice, while the recently discovered MgB_2 seems to be reserved to niche applications.

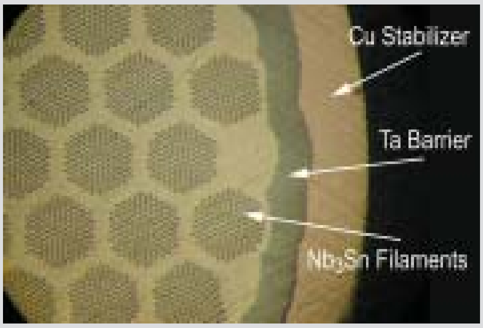

Fig 1. Cross section of a $(Nb,Ta,Ti)_3Sn$ wire fabricated in our laboratory (GAP).

Nb_3Sn Multifilamentary Wires for High field NMR magnets

Nb_3Sn has an excellent magnetic relaxation behavior and is at present the only superconducting material allowing a magnet to operate in the so-called "persistent mode", i.e. in a closed superconducting circuit. Quaternary $(Nb,Ta,Ti)_3Sn$ wires produced by the bronze route are currently optimized to reach the ultimate limits of current capacity at B > 21T. As an example, the whole fabrication process of a wire with 14'641 filaments, including 3-fold hot hydrostatical extrusion and the subsequent wire drawing to a final diameter of 1.25 mm, was performed in our laboratory (Fig. 1). A record critical current density of J_c (non-Cu) = 285 A/mm² at 17 T and 4.2 K was obtained. Further progress is expected by using improved Cu-Sn bronzes.

Bi,Pb-2223 Tapes and MgB_2 Wires

Ag sheathed (Bi,Pb)2223 tapes with 19 filaments have been fabricated, and the variation of J_c vs. strain has been measured for the first time on an industrial, high current tape, exhibiting 700 A at 4.2 K, 0 T. In contrast to Nb_3Sn wires, the tape geometry is essential, due to the anisotropy of the (Bi,Pb)2223 phase. The tapes with the highest J_c values, 3.5 x 10^4 A/cm² at 77 K and 0 T, present a high degree of texturing for the *c* axis (≈ 5°), while no texture has so far been achieved in the *a*,*b* plane. Further developments are under work to find new solutions to this problem.

Strong anisotropy effects on J_c have also been observed in Fe/MgB_2 tapes: at 6 T and 4.2 K, a decrease by a factor of 20 was observed for B perpendicular to the filament surface. A new result is that the textured grains are only located at the filament surface, as a consequence of the deformation process. Since the surface grains in round wires have their *c* axis oriented in the radial direction, i.e. normal to the surface, it follows that a round wire symmetry is preferable for MgB_2 conductors.

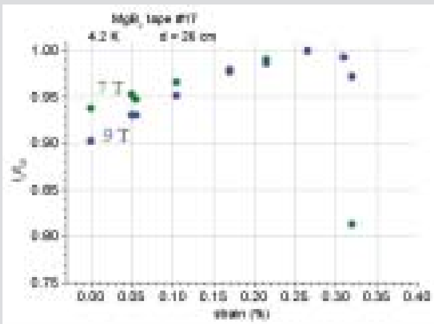

Fig. 2 J_c vs. strain for a Fe/MgB_2 tape at 4.2 K and various applied fields.

Fe sheathed MgB_2 wires have been prepared with J_c values of 1x10^4 A/cm² at 4.2 K and 7 T. The variation of J_c versus strain for Fe/MgB_2 wires is similar to that of Nb_3Sn and shows a maximum at 0.26% strain, (Fig. 2), thus indicating a potential for applications. Future improvements will involve a higher degree of texturing deeper inside the filaments, as well as in-situ reaction techniques, allowing the addition of SiC nanopowders.