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DISCLAIMER

A POWDER APPROACH FOR MULTIFILAMENTARY NIOBIUM-TIN SUPERCONDUCTING WIRE

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ABSTRACT

Based on powder metallurgy techniques, a process to fabricate Nb_3Sn multifilamentary superconducting wire is described. The current carrying capacity of the wire was above 2×10^5 A/cm^2 at a steady transverse magnetic field of 50 kG and about 1×10^5 A/cm^2 at 100 kG.

A direct powder rolling technique has been applied successfully to produce a practical superconducting tape[1] containing an array of Nb_3Sn filaments in a ductile niobium matrix. The superconducting properties of the tape optimized by morphological control, were reported in a recent publication.[2] Because of the flat rolling employed in the tape-process, the final filaments had a rectangular cross section typically 30 μm×5 μm. From the adiabatic stability criterion[3] for a multifilamentary superconductor with heat capacity s and critical current density J_c, the filament size x is restricted by

$$x^2 < (10^9 \pi s T_o/16\ J_c^2$$

where

$$T_o = J_c/(-dJ_c/dT)$$

This relationship yields a value of filament size of the order of 10 μm or less for most high field applications. Consequently, modifications have been made to adapt the main features of the tape-process for making the superconductor in wire form. A wire form provides an additional advantage besides stability. Suitably clad the single wire can be used as a basic element of a flexible multicored conductor or a multistrand cable to carry large currents.

Niobium powder of 99.92% purity having a particle size range of 44-53 microns was packed in rubber moulds and isostatically compacted at 207 nt/mm^2 (30,000 psi) into rods. These rods were then sintered in a vacuum for 12 min at 2300°C. The resulting system of interconnected pores was filled with tin by immersing the furnace cooled rods for half a minute in a 750°C tin bath. A cross section of a rod as infiltrated is shown in Figure 1. A similar pore structure was also achieved less conveniently, however, by pressureless sintering.

To prevent loss of tin and to provide support during deformation, the infiltrated rods were ensheathed in a copper or monel tube with an intermediate cladding of either niobium or tantalum which served as a diffusion barrier. Assemblies were reduced to wire using one or a combination of the following deformation processes: swaging, form rolling and wire drawing. A metallographic study of wire sections has indicated that whereas swaging results in the least favorable filament morphology, wire drawing produces the best. The wire, whose properties are reported later in the paper, was clad with tantalum and monel, form rolled and then wire drawn to two final sizes: 0.85 mm O.D. with 0.4 mm core diameter, and 0.6 mm O.D. with 0.3 mm core diameter.

To form the superconducting filaments of Nb_3Sn, 60 cm long sections of the cold drawn wires were heated for 2 min at 950°C in an inert atmosphere. Figure 2 shows a longitudinal section of a thermally-treated 0.6 mm O.D. wire. Although, all the pores in the sintered niobium were filled with tin, as may be seen in Fig. 1, some submicron pores in the Sb_3Sn filaments were observed under high magnifications. These pores which are difficult to see in Fig. 2 are to be expected as a result of the volume difference between the Nb_3Sn phase and the reacting component.

Each wire was helically mounted on a 3.8 cm dia bobbin and tested for current carrying capacity in steady transverse magnetic fields of up to 100 kG. The length of wire between voltage taps was 50 cm. The current carrying behavior of the wires as a function of field is shown in Figure 3. The current density (corresponding to a resistivity of the order of 10^{-12} ohm-cm) was computed on the basis of the central Nb and Nb_3Sn core. The overall current density can be increased further by optimizing the relative amounts of various claddings. The superior current density in the 0.6 mm O.D. wire (curve B) was probably due to a near complete reaction of tin with niobium. Metallographic observations of the wires after the 2 min heat treatment indicated little residual tin in the smaller wire, while some free tin was noticed in the larger specimen. The high values of current carrying capacity exhibited by these wires are attributed to a fine grain size induced by the dislocation networks present in the severely cold worked niobium. The critical temperature measured on a tape sample[2] produced earlier was 18.1°K for a similar heat treatment.

Further work is planned to fabricate multicored composites and cables with the addition of stabilizing copper. Magnetization characteristics and mechanical properties of the conductors will be presented in a future report.

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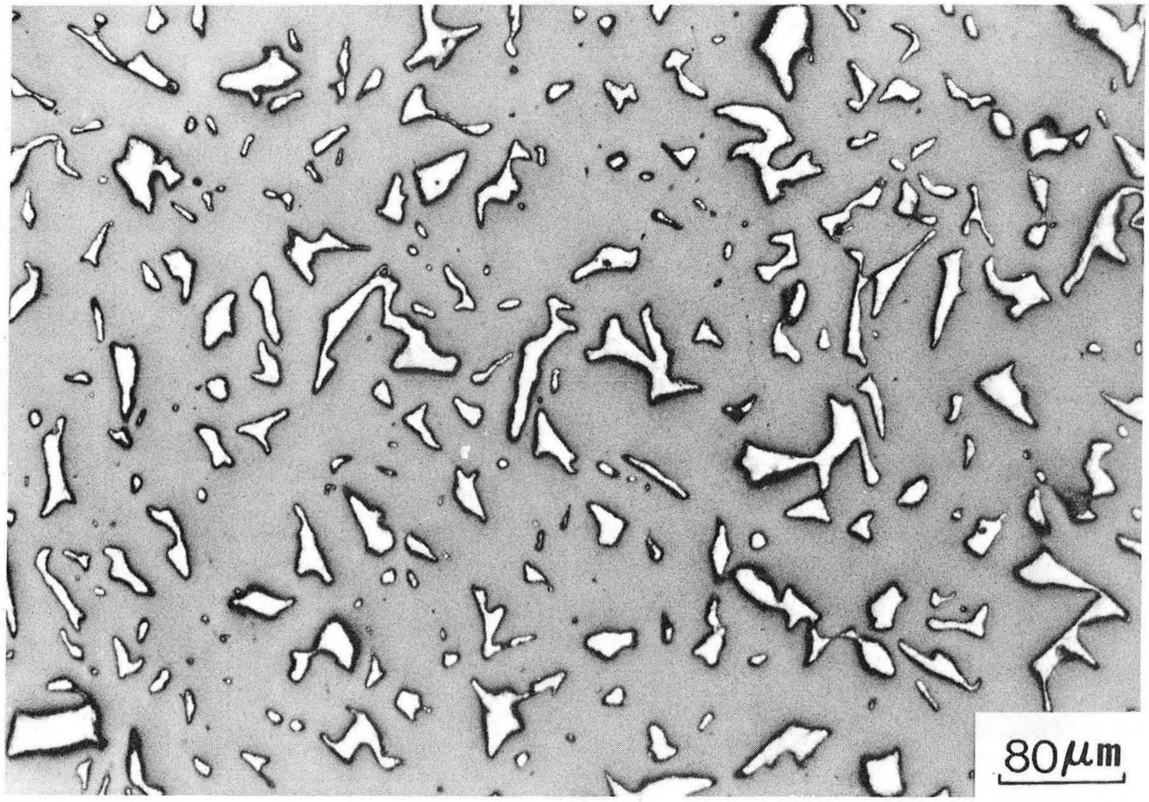
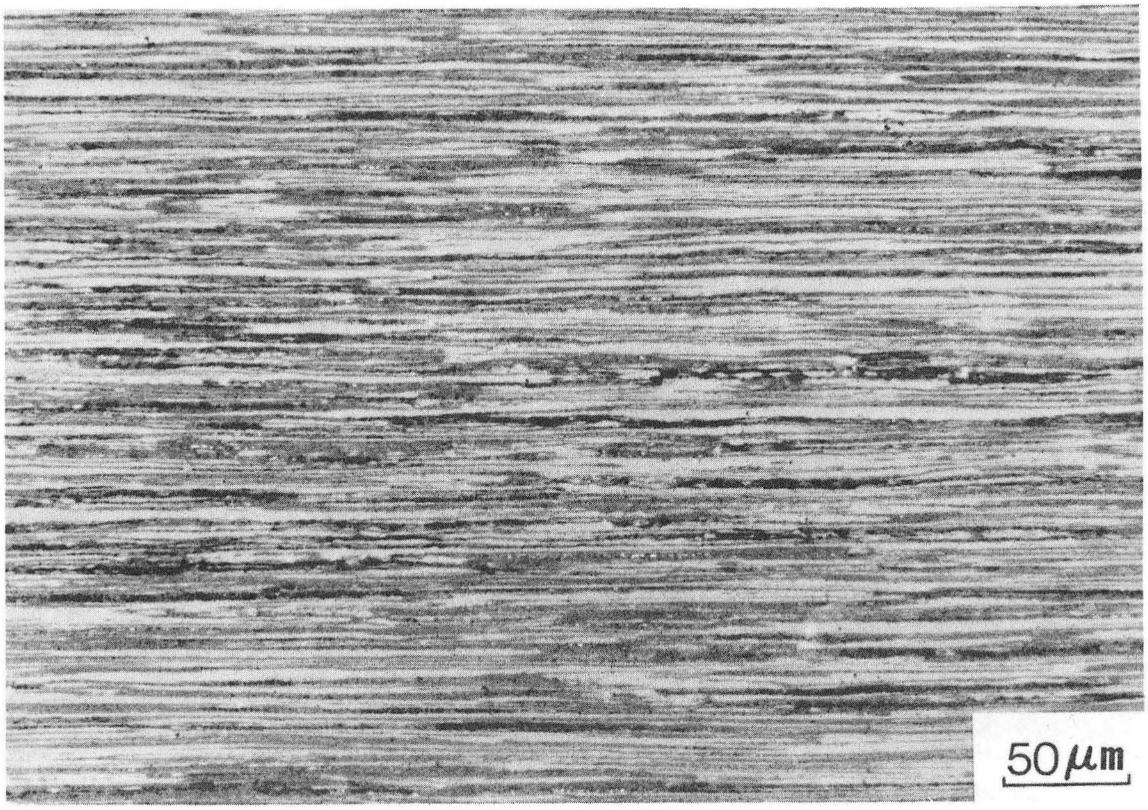
FIGURE CAPTIONS

1. Porous niobium rod as infiltrated with tin (white areas are tin).
2. Longitudinal section of wire after 2 min heat treatment (dark filaments are Nb_3Sn).
3. Steady field dependence of current carrying capacity. Curve A is for 0.85 mm O.D. wire and curve B for 0.6 mm O.D. wire.



XBB 753-3884

Fig. 1



XBB 753-3885

Fig. 2

0 0 0 0 4 3 0 5 6 1 9

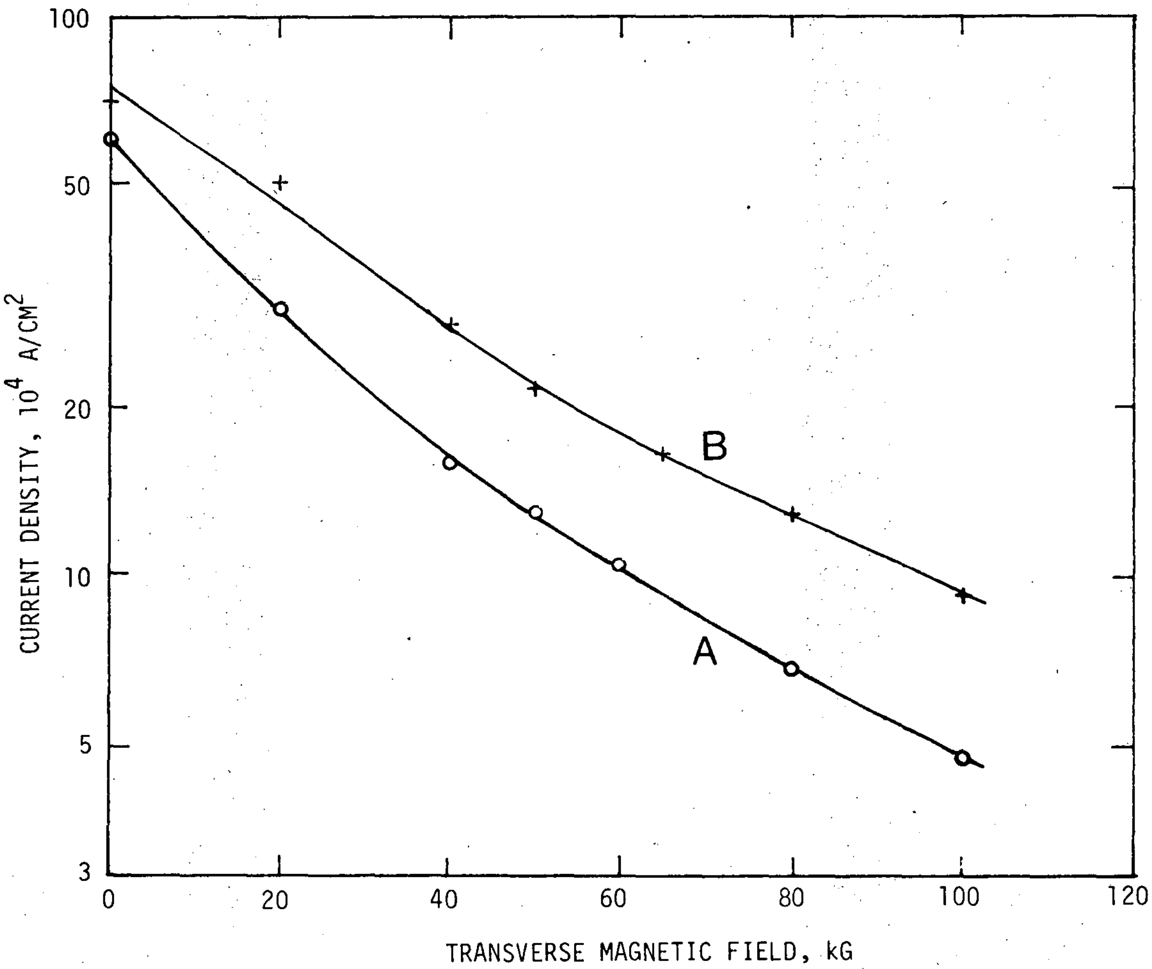


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Fig. 3

0 0 0 0 4 3 0 5 6 2 0

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