COMPOSITE SUPERCONDUCTING WIRES OBTAINED BY HIGH-RATE TINNING IN MOLTEN Bi-Pb-Sr-Ca-Cu-O SYSTEM


In the given communication we report on the principle possibility of the preparation of high-\(T_c\) superconducting long composite wires by short-time tinning of the metal wires in a molten Bi-Pb-Sr-Ca-Cu-O compound. As far as we know the application of this method to the high-\(T_c\) materials is tested for the first time.

The initial materials used for this experiment were ceramic samples with nominal composition \(\text{Bi}_{1.5}\text{Pb}_{0.5}\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x\) and \(T_c = 80\) K (fig.1, curve 1) prepared by the ordinary solid-state reaction, and industrial copper wires from 100 to 400 \(\mu\)m in diameter \(d\) and from 0.5 to 1 m long. The continuous moving wires were let through a small molten zone (~100 mm\(^3\)). The Bi-based high-\(T_c\) ceramics in a molten state is a viscous liquid and it has a strongly pronounced ability to spread on metal wire surfaces. The maximum draw rate of the Cu-wire, at which a dense covering was still possible, corresponds to the time of direct contact of wire surfaces and liquid ceramics for less than 0.1 s. A high-rate draw of the wire permits to decrease essentially the reaction of the oxide melt and Cu-wire. The realised of the given method by simple technical means allowed to make the cylindrical composite wires, consisting of the copper core in a dense covering with uniform thickness of about \(h \approx 5-50\) \(\mu\)m. Composite wires with \(h \approx 10\) \(\mu\)m (\(h/d \approx 0.1\)) sustained bending on a 15 mm radius frame without flexs cracking.

Figure 1

\[ \frac{R(T)}{R(150\text{ K})} \]

\(T\) \(\text{K}\)
The microstructure and electrical resistivity \( R \) of the covering depend on a complicated manner on the covering process parameters. For example, the covering obtained at the draw rate of about 100 mm/s has a strongly marked axial texture consisting of thin plate-like crystals (the axis of the texture is parallel to the wire axis). As-obtained covering has no superconductivity properties. To restore the superconductivity the pieces of composite wires about 5 cm long were subjected to heat treatment at 800°C in air. Figure 1 shows the temperature dependence of the resistivities of the composite wires annealed for 20 (curve 1) and 41 min (curve 2). The electrical resistivity \( R \) was measured by a standard dc four-probe method with silver paste contacts using a constant current of 10 \( \mu A \). According to the resistivity curves the superconductivity transitions started at \( T_{c0} = 90-95 \) K and ended at \( T_{ce} = 68-71 \) K. These values practically coincided with the values of critical resistivity points obtained on the initial multiphase ceramic bar (curve 1).

\[
\begin{array}{c}
\text{X, A.U.} \\
800^\circ C \text{ 20 MIN.} \\
65 \text{ OE}
\end{array}
\]

Figure 2

The direct evidence of composite wires superconductivity followed from their magnetic properties. Figure 2 shows the typical curve of susceptibility vs temperature for composite wires annealed at 800°C for 20 min. These measurements were performed using a SQUID magnetometer. The \( X-T \) curve, similar to \( R(T) \), has only one bend at 90 K. It is supposed that annealing at 800°C results in the predominant formation of only one superconductive \( (T_\text{c} \approx 80 \) K) phase. This concords with the data on the bulk Bi-Pb-Sr-Ca-Cu-O glass-ceramics, produced by the liquid quenching method and subsequently annealed at 750-800°C. Recently, as a result of improving the annealing conditions, we succeeded in preparation of composite wires with the higher zero-resistance temperature.

In summary, long high-\( T_\text{c} \) composite wires where prepared by high-rate draw of flexible bare conductor through molten Bi-based metal-oxide system.