GROWTH KINETICS AND SUPERCONDUCTING PROPERTIES OF Nb_3Sn AND V_3Ga SYNTHESIZED BY SOLID STATE DIFFUSION

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CERTIFICATE

This is to certify that the thesis entitled "Growth kinetics and superconducting properties of Nb_3Sn and V_3Ga synthesized by solid state diffusion" by B V Reddi submitted to the Indian Institute of Technology, New Delhi (India) for the award of the degree of Doctor of Philosophy in Applied Mechanics is a record of bonafide research work carried out by him under our joint supervision and guidance. The thesis work, in our opinion has reached the standard fullfilling the requirements for the Doctor of Philosophy Degree. The research report and results presented in this thesis have not been submitted in part or in full to any other University/ Institute for the award of any degree or diploma.

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ABSTRACT

Among all the known superconductors, the materials belonging to A-15 structure are technologically important because they possess superior superconducting properties. Since A-15 superconductors are brittle, indirect fabrication techniques have to be followed. The bronze process, based on the solid state diffusion has been found the most attractive technique to make intrinsically-stable multifilamentary superconductors like Nb_3Sn, V_3Ga and V_3Si. An attempt is made for a better understanding of the growth kinetics and the rate controlling mechanisms in the formation of the A-15 compound layers formed via the bronze route.

Monofilamentary composites, copper-tin/niobium and copper-gallium/vanadium with different concentrations of tin and gallium in the bronze matrix have been made to study the growth kinetics and superconducting properties of Nb_3Sn and V_3Ga. These compounds are formed by diffusion anneals of the composites at 650 - 850°C. The experimental techniques used in this work include arc, electron-beam, rf induction and resistance furnaces for melting and diffusion-anneals, X-rays and SEM for structural studies, four-probe technique for measurement of superconducting transition temperature and superconducting magnet for critical current measurements.

Specific models for the growth kinetics of the superconducting compounds have been developed. The models envisage two basic diffusion mechanisms in the overall growth kinetics of the compound layer, which follow the growth law, $R = kt^n$ where R is the compound layer thickness, k is the rate constant, t is the reaction time and n is the time exponent.

When the diffusion of B atoms in Cu-B (here B is Sn or Ga) bronze matrix is rate controlling, n varies between 1/2 and 2/3. The exact value of n in such a case depends on the effective diffusion distance. For a long annealing time, n tends to approach 2/3. The model also predicts that a higher concentration of B in the matrix leads to a smaller value of n, in the range 1/2 to 2/3. For the first time, our experimental findings have shown that n decreases with increasing tin concentration in the bronze matrix.

When the diffusion of B atoms in the compound layer is rate controlling, n can vary from 1/2 to 1/4. Parabolic growth law (n = 1/2) is expected in either case where the bulk diffusion of B atoms in the layer controls the process. This is valid for a constant grain size or a large initial grain size of the compound. When the grain growth is dominant during the grain boundary diffusion, the time exponent can be as small as 1/4.

The time exponent of unity is expected, when the interface reaction is the rate controlling mechanism.

The models developed in this investigation successfully explain the time exponent values ranging from 1/4 to 1 reported in the literature. It is further identified in this work that the diffusion of tin atoms in the Cu-Sn matrix for Nb_3Sn growth and diffusion of gallium atoms through grain boundaries of V_3Ga are the rate controlling steps in the overall growth kinetics of these compounds.

The highest superconducting transition temperature noted in this investigation is 17.9 K, 0.6 K lower than the value quoted in the literature. The depression in T_c is attributed to the built-in stresses of the composite conductor.

The critical current measurements are analysed and found to support the Kramer model of flux pinning, based on the concept of shearing of flux line lattice. The upper critical field estimated from the measurements of critical currents in the low magnetic field is 14.15 teslas. Such a low value of the upper critical field is attributed to the large volume ratio of bronze to the superconducting compound. The flux shearing parameter is also calculated.

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