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Nb₃In: A β -TUNGSTEN STRUCTURE SUPERCONDUCTING COMPOUND

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(Received 18 December 1961)

Abstract—High-pressure techniques were employed to synthesize a new compound, Nb₃In having the β -tungsten structure (*A15*) with a lattice parameter $a_0 = 5.303 \text{ \AA}$. Its superconducting transition temperature was found to be $9.2 \pm 0.1^\circ\text{K}$.

INTRODUCTION

NIOBIUM forms a number of superconducting compounds⁽¹⁾ with the β -tungsten structure (*A15*). Among them, Nb₃Sn⁽²⁾ has the highest superconducting transition temperature (18°K) of all superconductors known to date. The niobium compounds Nb₃Ga and Nb₃Al also exhibit high superconducting transition temperatures (14°K and 16.5°K , respectively). The corresponding compound of niobium with indium has not been prepared. MATTHIAS⁽³⁾ has predicted that if this compound (Nb₃In) were formed it should have a superconducting transition temperature of near 30°K .

Attempts to synthesize Nb₃In in this Laboratory and elsewhere by conventional powder metallurgy and arc-melting techniques were not successful. No explanation can be advanced for the failure of this synthesis. However, the anticipated increase in density in going from a mixture of the elements to the compound Nb₃In suggested the use of ultra-high pressure techniques for its synthesis.

SYNTHESIS AND STRUCTURAL CHARACTERIZATION

Intimately mixed powders (approximately 40μ particle size) of niobium and indium (3:1 atomic ratio) were compacted at room temperature to near their theoretical density. The cylindrical compacts were then placed in high-pressure cells

lined with quartz. Two types of ultra-high pressure apparatus were employed: a tetrahedral anvil and an arrangement of two opposed anvils. In the former apparatus, the compacts were approximately 1.2 cm in diameter and 1.5 cm long; in the latter they were 0.5 cm in diameter and 1 cm long.

High pressures ranging from 40,000 to 70,000 bars (taking the thallium I-II transition to be at 37,000 bars) were employed and temperatures ranging from 800° to 1500°C . In this pressure range, the optimum temperature for maximum reaction between niobium and indium was approximately 1100°C .

The high-pressure samples were similar in appearance and mechanical behavior to arc-melted Nb₃Sn. X-ray powder patterns of the samples revealed the presence of a β -tungsten compound. Depending upon the conditions of the synthesis, there was a variation in the amount of unreacted niobium and indium. Under optimum conditions, the reaction was nearly complete. The reasons for which the reaction does not proceed to completion are not understood at present. The compound underwent no changes when annealed at 800°C under vacuum for 75 hr. It decomposed, however, when heated at 1150°C for 16 hr.

The lattice parameter of the β -tungsten compound measured in nine different samples containing broadly varying amounts of the unreacted elements (as indicated by the X-ray patterns) was found to be $a_0 = 5.303 \text{ \AA} \pm 0.003$. Among these

* Operated with support from the U.S. Army, Navy, and Air Force.

nine samples, one had a nominal composition of 4 Nb+1 In and another 2 Nb+1 In. Examination of the intensity ratios of the β -tungsten structure lines indicated no changes in the various samples. The observed constancy of the lattice parameter is analogous to that found for other β -tungsten compounds such as Nb₃Ga, Mo₃Ga,⁽¹⁾ and Nb₃Sn⁽⁴⁾ synthesized in the presence of excess of either of the reactants.

The above results show the formation of a β -tungsten structure compound which has a well

the superconducting transition temperature reported below is not necessarily at variance with the temperature near 30°K predicted by MATTHIAS for Nb₃In.⁽³⁾

SUPERCONDUCTING TRANSITION TEMPERATURE

Superconducting transition temperatures of the pressed samples were determined from measurements of relative permeability employing a self-inductance technique with an oscillator operating

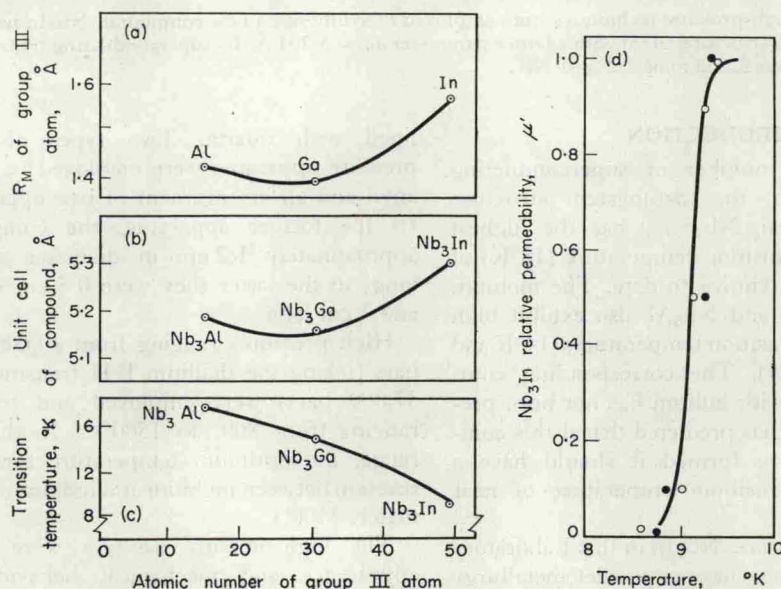


FIG. 1(a) and (b). Comparison of the metallic radius (R_M) of the Group III elements with the lattice parameter of the corresponding β -tungsten structure compounds of niobium with these elements. (c). Variation of the transition temperature of the above compounds with the atomic number of the Group III elements. (d). Relative permeability, μ' , of Nb₃In as a function of absolute temperature.

The superconducting transition temperature is 9.2°K.

defined stoichiometric composition with no tendency to vary in the presence of excess niobium or indium. It is believed that this compound is Nb₃In. The measured lattice parameter of Nb₃In is consistent with the lattice parameters of Nb₃Ga and Nb₃Al and the corresponding metallic radii of the group III elements as shown in Fig. 1 (a) and (b). As in intermetallic compounds in general, the possibility of deviation from the stoichiometric composition Nb₃In exists, in which case

at 500 c/s. The frequency change was recorded as a function of temperature. Typical frequency changes were about 40 c/s.

Figure 1(d) shows typical results obtained on two individual samples with relatively high content of Nb₃In. No variation in the superconducting transition temperature (9.2°K) was observed in seven of the nine samples tested. The other two samples exhibited a transition temperature of 8.4°K, for reasons which are not understood at