Superconductivity of A 15- and σ-Phase of Nb–Ir

H. R. Khan and Ch. J. Raub

K. Lüders and Z. Szücs
Institut für Atom- und Festkörperphysik, Freie Universität Berlin, D-1000 Berlin 33, Fed. Rep. Germany

Received 15 June 1978/Accepted 28 December 1978

Abstract. The superconducting properties of A 15-, σ-, and tetragonal phases of the system Nb–Ir were investigated. The alloys were prepared by sintering and arc melting. They were subjected to optical and scanning electron microscopy. The lattice parameters were determined by x-ray diffraction technique. Superconducting transition temperatures, \( T_c \), as well as upper critical fields, \( H_{c2} \), were measured inductively and resistively. The \( T_c \)-values of the σ-phase vary between 2.15 and 2.40 K whereas for the A 15-phase they vary between 1.83 and 2.73 K. The \( T_c \)-value of the tetragonal phase is 3.81 K. The upper critical fields of the tetragonal and the A 15-phase are nearly the same (≈ 13 kG) and lower compared with that of the σ-phase (≈ 18 kG). Several theoretically predicted values of \( H_{c2}(0) \) are evaluated and compared with the experimental ones.

PACS: 74

Earlier investigations of A 15- and σ-phases of the systems Nb–Al and Nb–Pt showed different electronic and superconducting behaviour [1,2]. The difference in the electronic structure and its influence on the superconductivity was found to be larger for the Nb–Al system as compared to the Nb–Pt system. For example, Nb3Al (σ-phase) has a superconducting transition temperature of \( T_c = 0.74 \) K [3] and Nb3Al (A 15-phase) of \( T_c \approx 18 \) K. Replacing of the non-transition metal Al by the transition metal Pt leads to a reduction of the difference: \( T_c \) of Nb62Pt38 (σ-phase) is 2.14 K and of Nb3Pt (A 15-phase) 8.97 K. The upper critical field at zero temperature, \( H_{c2}(0) \), shows an analogous behaviour. It seems, that these differences can be explained by the different lattice structures: the presence of three orthogonal Nb atomic chains in the A 15-phases as compared to linear atomic chains only in one direction for the σ-phase.

In the present paper we have extended the structure and superconductivity investigations to σ- and A 15-phases of the system Nb–Ir. This system is of interest because of the following reasons. The literature values of \( T_c \) differ considerably: between 1.3 and 2.07 K for the A 15-phase and between 2.2 and 9.8 K for the σ-phase [4–8]. Flükinger et al. have classified A 15-alloys of Nb–Ir as “atypical” type [9]. To our knowledge no critical field data are available up to now. Detailed measurements of \( T_c \) as well as \( H_{c2} \) as a function of lattice parameters were performed for the homogeneity ranges of both the phases. From the temperature dependence of \( H_{c2} \) several theoretical zero temperature upper critical fields, \( H_{c2}(0) \), have been calculated for the σ- and A 15-phases and in addition for the tetragonal phase.

1. Sample Preparation and Structural Investigation

The phase diagram of the Nb–Ir system, as investigated by Blecherman et al. [10], is shown in Fig. 1. A homogeneity range for the σ-phase exists between 33.5 and 40.5 at. % Ir and is formed peritectically. A homogeneity range of the A 15-phase exists between 21.5 and 28.5 at. % Ir. Several alloys of σ- and A 15-structures as well as an alloy of tetragonal structure
of composition Nb-52.5 Ir were prepared by sintering pressed powders. The sintering was performed over periods of 20 h at 1000 °C in a vacuum of \( \sim 10^{-5} \) Torr. The alloys were arc melted on a water cooled copper hearth in an argon atmosphere. All the alloys were homogenized by giving a heat treatment of 1600 °C for a period of 6 h in vacuum. No attempt was made to study the influence of heat treatment on the degree of order. The composition of the alloys was corrected under the assumption that losses during arc melting were due mostly to the evaporation of Ir metal. The homogeneity of the alloys was checked by optical microscopy. A typical micrograph of the alloy with composition Nb-40.28 Ir (\( \sigma \)-phase) is shown in Fig. 2. The heat-treated alloy is fairly homogeneous but still small amounts of other phases are present which could be the Nb-solid solution or A 15-phase. This is also confirmed by x-ray diffraction data. Scanning Electron Microscopy was used to check the spatial distribution and it was found that Nb and Ir are homogeneously distributed. SEM photographs of three alloys are shown in Fig. 3. The dark lines are cracks in the samples. The lattice parameters of the annealed alloys are shown in Fig. 3. The dark lines are cracks Cu-K\(_\alpha\) radiation and a Guinier camera. Typical x-ray diffraction photographs of \( \sigma \)- and A 15-structure alloys are shown in Fig. 4. The lattice parameters of all the alloys are listed in Table 1.

### 2. Superconducting Properties

#### 2.1. Measuring Technique

The superconducting transition temperatures \( T_c \) were measured inductively using lock-in technique. As \( T_c \), that value of temperature is used where a sharp change of the magnetization occurs. By this technique we were able to detect amounts of superconducting phase of order of 10\( \mu \)g. For some of the samples \( T_c \) was also checked by a dc four probe method. The determination of the temperature was performed by means of a carbon-glass thermometer. \( T_c \) was determined with an accuracy of about 2%.

#### 2.2. Results and Discussion

The results of the \( T_c \)-measurements are summarized in Fig. 5, where \( T_c \) is plotted as a function of composition for the A 15-, \( \sigma \)-, and tetragonal phases. \( T_c \) of the A 15-phase increases from 1.83 to 2.73 K with increasing Ir concentration. For comparison, \( T_c \) values measured by Flükiger [7] are also plotted. They are lower, which might be due to different compositions and heat treatments as well as homogeneities of the phases. The \( T_c \) values of the \( \sigma \)-phase