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Effect of Pressure on the Resistivity of Ag–Au Alloys[1])

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The effect of pressure on the resistivity of $Ag_{1-c}Au_c$ solid solutions has been measured up to 4 kbar in the temperature range 4 to 273 °K. Solid and fluid helium were used as the pressure transmitting media. The pressure derivatives of the total resistivity, $\varrho^{-1}\, d\varrho/dP$, for the alloys in the concentration range $c = 0.1$ to 0.9 were observed to be negative and to increase in magnitude with increasing temperature. It is shown that the magnitude and sign of $\varrho^{-1}\, d\varrho/dP$ is primarily determined by the pressure derivative of the residual resistivity. The volume derivative of the residual resistivity, $d \ln \varrho_0/d \ln V$, was found to be positive and concentration dependent. It is suggested that the influence of the filled d-bands on the scattering potential is responsible for the behavior of $d \ln \varrho_0/d \ln V$.

Der Einfluß von Druck auf den spezifischen Widerstand von $Ag_{1-c}Au_c$-Mischkristallen wurde bis 4 kbar im Temperaturbereich von 4 bis 273 °K gemessen. Als Druckübertragungsmittel wurde festes bzw. flüssiges Helium verwendet. Es wurde festgestellt, daß die Druckableitungen des Gesamtwiderstands, $\varrho^{-1}\, d\varrho/dP$, für die Legierungen im Konzentrationsbereich $c = 0{,}1$ bis 0,9 negativ sind und mit steigender Temperatur zunehmen. Es wird gezeigt, daß Größe und Vorzeichen von $\varrho^{-1}\, d\varrho/dP$ vorwiegend durch die Druckableitung des spezifischen Restwiderstands bestimmt werden. Die Volumenableitung des spezifischen Restwiderstands $d \ln \varrho_0/d \ln V$ ist positiv und konzentrationsabhängig. Es wird vorgeschlagen, daß der von den vollbesetzten d-Bändern auf das Streupotential ausgeübte Einfluß für das Verhalten von $d \ln \varrho_0/d \ln V$ verantwortlich ist.

1. Introduction

The effect of pressure on the electrical resistance of many elements and alloys has been studied in detail in the vicinity of ambient temperatures. There have been considerably fewer studies made at low temperatures because of the problems associated with generating nearly hydrostatic pressures. The low temperature region, however, is the most interesting because the lattice resistance is the most sensitive to temperature and pressure in this region and because the effects of alloying can be studied directly at 4 °K. Dugdale [1] has measured the temperature dependence of the pressure derivative of the lattice resistivity, $\varrho_l^{-1}\, d\varrho_l/dP$, for the alkali metals and Cu from 4 to 300 °K using solid and fluid helium as the pressure transmitting media. Similar measurements on Ag, Au, Sn, and In were reported by Goree and Scott [2]. These authors found that $\varrho_l^{-1}\, d\varrho_l/dP$ becomes large and negative at low temperatures in fair agreement with the Bloch-Grüneisen theory.

A few studies have been made on the effect of pressure on the residual resistivity of dilute alloys by direct measurement at 4 °K; however, there has been no work done on concentrated alloys. Dugdale [3] has measured the volume derivative of the residual resistivity, $d \ln \varrho_0/d \ln V$, for dilute noble metal alloys containing homovalent and heterovalent impurities. He suggests from

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the variety of values observed for d ln ϱ_0/d ln V that the details of the scattering potential might be very important. It is one of the purposes of this work to study the concentration dependence of d ln ϱ_0/d ln V in a simple binary alloy system in which both constituents have similar electronic structure. If d ln ϱ_0/d ln V is concentration dependent, then this could be a reflection of subtle changes in the scattering potential. The $Ag_{1-c}Au_c$ alloy system was chosen for this study because: 1. Ag and Au have similar electronic structures, 2. Ag and Au form a continuous series of solid solutions, and 3. there are no complicating magnetic (s–d) types of scattering processes.

In this work the effect of pressure (0 to 4 kbar) on the resistivity of five $Ag_{1-c}Au_c$ alloys ranging in concentration from $c = 0.1$ to 0.9 has also been measured from 4 to 273 °K. The high temperature measurements were made to determine the relative influence of phonon scattering and disorder scattering on the pressure derivative of the total resistivity in a concentrated alloy system, and to determine the magnitude of the deviations from Matthiessen's rule.

2. Experimental Procedure

The alloys were prepared from high purity (99.999%) Ag and Au by melting in a quartz tube. The ingots were homogenized at 1000 °C for one week and then extruded into wires with a diameter of 0.040 in. and a length of 2 in. Internal strains were removed by annealing at 900 °C for 3 h. The resistivity of these alloys was measured at ice, liquid nitrogen, and liquid helium temperatures and plotted as a function of concentration. These plots exhibited the typical parabolic behavior characteristic of a disordered alloy system; it was concluded from this that the nominal concentrations were correct.

Since these experiments were conducted mainly at low temperatures, solid and fluid helium were used as the pressure transmitting media to obtain the best possible hydrostatic pressures. The isobaric freezing technique and the system used to compress the helium up to 4 kbar are described in detail by Schirber [4]. Details of the sample chamber and high pressure bomb are shown in Fig. 1. The current and voltage leads are coiled around the sample for support and electrical insulation. The resistance was measured by the standard four probe technique using a Honeywell model 2768 microvolt potentiometer

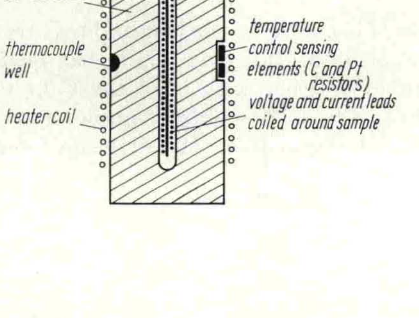

Fig. 1. Sample chamber and high pressure bomb details