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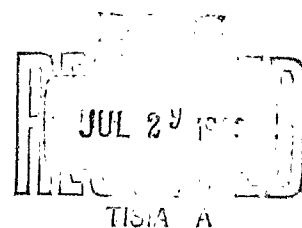
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Effect of Impurities on the Electrical Resistivity
Increase During Elongation of Cadmium at 78°K

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Introduction

Observations have been made that the electrical resistivity of metals increases during plastic deformation¹. The increase is associated with changes in the concentration of point, line and planar defects. Further experiments have demonstrated that prior deformation and recovery² as well as impurity concentration³ affect the slope of the resistivity-elongation curves. It is the purpose of this report to present some data obtained on cadmium containing impurities. The influence of lead, magnesium and copper, in particular, are discussed.

Experimental Procedure and Results

Polycrystalline cadmium wire which for most experiments was 1 mm in diameter was obtained in various stages of purity as indicated in Table I. All specimens were annealed in argon one hour at 100°C, cooled, chemically polished as indicated in previous reports⁵, and mounted on the deformation apparatus described elsewhere⁵. Cadmium wires were then resistance welded to the specimen approximately 10 cm apart to serve as potential leads. The total length of specimen was approximately 14 cm. The specimens were deformed in liquid nitrogen and the resistance change was measured potentiometrically as a function of elongation strain as determined by calibrating the cross head movement with a direct measurement of increase of length by means of a traveling microscope. A dummy specimen in the liquid nitrogen served as measure of bath temperature fluctuations. A more detailed description of the experimental technique is available in reference 5.

Assuming constant volume during deformation the fractional resistivity change, $\Delta\rho/\rho_0$, may be calculated from

$$\frac{\Delta\rho}{\rho_0} + 1 = \frac{R}{R_0} \frac{1}{(1+\epsilon)^2}$$

where R_ϵ is the resistance at strain ϵ and R_0 the initial resistance.

The results of the deformation experiments at liquid nitrogen are shown in Figure 1. The closed and open squares represented by curves A and B are data on the same 59 Cd specimen measured while the load was on and after the load was removed, respectively. Part of the difference between A and B can be attributed to the elastic recovery which is estimated to be less than 0.1%. However, the greater part of the difference is undoubtedly due to the presence of the stress and its subsequent effect on the scattering of conduction electrons. It can be seen that both A and B show a linear dependence on strain. The data for cadmium doped with Cu, Pb and Mg also fall on curve B although the cadmium containing Pb shows some deviation. Curve C shows some results for some unpublished data obtained earlier in this laboratory for cadmium of commercial purity. These latter specimens were 5 mm in diameter and their resistance was measured using a Kelvin Double Bridge. Only one point of this data is shown on Figure 1. Other data obtained from this experiment indicate a linear behavior to approximately 13 percent elongation.

Curve C represents the average data of 49 cadmium of data obtained from eighteen different specimens. The deviation from the average value noted on the plot is insignificant.

Discussion

It is interesting to note that the addition of slight amounts of copper has very little influence on the ρ vs ϵ curves over what is observed for high purity cadmium. Additional impurities such as magnesium, at least at a concentration of 1000 ppm, shows no effect. Lead, however, does affect the slope of these curves. At very low concentrations the slope is what is expected for high purity cadmium or cadmium containing some copper and/or magnesium. As the lead concentration increases, however, the slope abruptly drops off and then slowly increases toward the high purity slope as the lead concentration approaches 1000 ppm.

The effect of other impurities such as silicon, iron, silver and aluminum is not very clear. Nevertheless, the 49 cadmium contains all of these elements and does have the lowest ρ vs ϵ slope. Whether it is primarily the lead or these other elements that is influencing this behavior must wait further study.

It is recognized that impurities in copper and other metals influence defect formation such as stacking faults. It can be speculated that the behavior noted in cadmium is associated with twin formation, stacking faults, influence of impurities on preferred orientation and the like. Obviously, a more complete study is necessary to elucidate this phenomenon.

Table I

Emission Spectrograph Analysis of Cadmium Impurities (ppm)

Sample Impurity	69 Cd +1000ppm Pb	69 Cd +1000ppm Mg	69 Cd + 10 ppm Cu	Commercial Cd	49 Cd	59 Cd
Pb	1000	<1	<1	100	3	<1
Mg	<1	1000	<1	<1	10	<1
Si	<1	<1	<1	<1	10	<1
Fe	<1	<1	<1	<1	10	<1
Cu	10	10	10	10	3	<1
Ag	<1	<1	<1	3	10	<1
Al					10	
Total Impurities (Nominal)	1000ppm Pb 10ppm Cu	1000ppm Mg 10ppm Cu	10 ppm Cu	110 ppm	56 ppm	1 ppm
Slope approx.	<3.4	3.4	3.4	1.8	1.2	3.4

