DISORDER EFFECTS ON THERMOPOWER OF COPPER ALLOY FILMS

by

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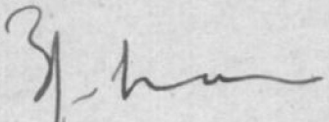

(A.P. Thakoor)

ABSTRACT

The effects of structural, electronic, spatial, compositional, and magnetic disorder incorporated in vapour-deposited copper and copper alloy films on their thermoelectric power (TEP) and other electron transport properties (resistivity, Hall coefficient, and their temperature coefficients) have been studied. Varying degree of structural (defect) disorder was introduced in pure copper films by controlling different deposition parameters, particularly the temperature of deposition and post-deposition annealing. Enhanced electronic disorder was created in copper films by dissolving small amounts (1, 2, and 5 at.%) of Al, Sn, or Ge as substitutional impurities in copper. Spatially disordered (amorphous) $Cu_{0.5}Ag_{0.5}$ films were prepared by vapour-quenching of the alloy onto glass substrates held at 80 K during deposition. Also, controlled degree of structural, alloying (compositional), and magnetic (spin) disorder were simultaneously frozen in vapour-deposited Cu_xNi_{1-x} ($0 \leq x \leq 0.25$) films by suitably choosing their deposition conditions and alloy composition.

The observed apparent size effects in the TEP and the annealing kinetics of structurally well-characterised pure copper films having a wide range of concentration and distribution of frozen-in structural defects in them have been utilised to establish the important role played by the structural disorder in determining the electron transport properties of the films. It has been further established that the presence of point defects (mainly monovacancies) in copper films reduces their diffusion TEP whereas the extended defects (line/plane dislocations) increase it. In case of copper-based dilute alloy films, the observed considerable reduction in the TEP has been analysed in terms of the Nordheim-Gorter relation. Further, from the data,

the characteristic TEP values associated with the impurities and the structural defects have been estimated. The anomalously large, temperature independent values of the TEP ($\sim +40\ \mu V/deg$), resistivity ($\sim 100\ \mu ohm\ cm$) and a small mobility ($\sim 0.5\ cm^2/V\ sec$) exhibited by vapour-quenched amorphous $Cu_{0.5}Ag_{0.5}$ films have been understood in terms of enhanced scattering by quenched-in structural disorder, or by suitably chosen pseudopotentials anchored onto the randomly situated copper and silver ions. In case of ferromagnetic Cu_xNi_{1-x} ($0 \leq x \leq 0.25$) films, the composition and temperature dependence of the resistivity and TEP and their anomalous behaviour at the Curie temperature have been understood in terms of thermal and structure-induced spin-disorder scattering. The contributions to the resistivity of the alloy films due to the structural, alloying, and magnetic (spin) disorder have been separated out. The TEP has been separated into two terms, one corresponding to the structural disorder and the other due to the alloying and magnetic disorder effects.

The present study has revealed that the various types of disorder distort the topography of the Fermi surface of copper in different ways which, in turn, strongly affect the energy dependence of the conductivity at the Fermi surface and hence the TEP. Monovacancies in pure copper films tend to reduce the degree and extent of curvature at necks of the Fermi surface whereas the dislocations increase the degree without altering the extent appreciably. The TEP of dilute alloy films suggests progressive shrinking of the neck radius of the Fermi surface of copper with increasing impurity concentration above 1 at.%. The anomalous behaviour of the large TEP and other transport properties of the highly disordered Cu_xAg_{1-x} and Cu_xNi_{1-x} films indicate anomalously large modifications in the topography of the Fermi surface.

The investigations reported in this thesis have shown that a wide range of positive as well as negative thermopower values with a variety of temperature dependence can be obtained by introducing selective and controlled disorder in metal films. These effects can be utilised in the fabrication of highly sensitive thin film thermocouples and bolometers.

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