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Structure and Resistivity of FeNi Binary Alloys

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Abstract : The crystal structure and resistivity of polycrystalline alloys viz. $Fe_{0.5}Ni_{0.5}$, $Fe_{0.4}Ni_{0.6}$, $Fe_{0.3}Ni_{0.7}$, $Fe_{0.1}Ni_{0.9}$ obtained by arc-melting are investigated by x-ray diffraction and four probe methods respectively. Structural studies on the alloys indicated a structural transformation from bcc to fcc with composition. Alloys with Ni content less than 30% are in bcc phase stabilized by bcc iron and alloys of Ni content more than 30% are found to be in fcc phase stabilized by fcc Ni. Metallicity is found to increase with the increase of Ni content in these alloys. Residual resistivity decreases with Nic concentration.

Keywords: Arc-melting, resistivity, phase diagram, phase transition

1. Introduction

Iron-nickel alloys have historical significance. They might be the first ferrous materials used by man in the form of metallic meteorites. They are valuable, malleable and tough, so highly used as stone tools and weapons. Industrial use of iron nickel alloys have been started 100 years back. Extensive use of iron nickel alloys are found in transportation industries-automotive, railway, aviation, marine and in communication industries-telephone, telegraph and radio. These alloys exhibit anomalous physical and chemical properties which are not well understood till date.

Since the discovery of Earth's core about a century ago, Fe is observed to be the dominant component of the core as has gained firm support from geochemical observations, seismic data, the theory of geomagnetism and high pressure studies (1–9). The body centered cubic (bcc) phase is observed to be stable through recent experiments and proposed theoretical calculations at the conditions of

Earth's core (6, 7, 10, 11). Cosmochemical data and studies of iron meteorites provide evidence that Earth's core contains substantial (5 to 15%) amounts of Ni (8, 9). Although the study of pure Fe at multimegabar pressures has drawn considerable attention and provided rich experimental data, knowledge about the behaviour and properties of Fe-Ni alloys at the conditions of Earth's core is still limited. At ambient pressure, Fe-Ni alloys with up to 25 atomic % (at %) of Ni have bcc structure, whereas higher Ni contents promote crystallization of the face-centered cubic (fcc)–structured phase. The compression of bcc-structured alloys at ambient temperature results in their transformation to the hexagonal closed-packed (hcp) phase at pressures between 7 and 14 GPa (10–14) However, the presence of Ni substantially affects phase relations in the Fe-Ni system at high temperatures and pressures (10, 14, 15). The Fe–Ni system is very important for the understanding of steels and other ferrous alloys. Since Ni is a c-stabilizer in Fe, Fe–Ni alloys offer an ideal model system to study processes in commercial austenitic steels. Fe–Ni alloys are also of interest in connection with the Invar effect and the martensitic transformation from face-centered cubic (fcc) austenite to body-centered cubic (bcc) martensitic at low temperatures. The accepted version of the Fe–Ni phase diagram contains α phase (bcc) up to 30% of nickel content and from α+γ (bcc+fcc mixed phase) to γ (fcc phase) from 40% nickel content to 90% nickel content.

In this paper we will present the results of resistivity measurements for $Fe_{0.9}Ni_{0.1}$, $Fe_{0.7}Ni_{0.3}$, $Fe_{0.5}Ni_{0.5}$, $Fe_{0.3}Ni_{0.7}$ binary alloys. We want to check how increment in the nickel concentration in the iron –nickel binary alloy affects the resistivity properties Fe–Ni alloys.

2. Experimental

The polycrystalline $Fe_{0.5}Ni_{0.5}$, $Fe_{0.4}Ni_{0.6}$, $Fe_{0.3}Ni_{0.7}$, $Fe_{0.1}Ni_{0.9}$ are prepared by arc-melting stoichiometric quantities of high purity Fe and Ni metals in argon atmosphere. The ingots were re-melted several times to ensure homogeneity. After the formation of ingots, those are annealed for 48 hours up to 600K in an arc furnace. During annealing process the ingots were first wrapped with molybdenum foil and sealed in quartz tube. Molybdenum isolates the alloys with different compositions and avoids inter diffusion among them. The quartz tube has been pumped 10^{-6} Torr pressure using diffusion pump and then sealed using flame. The vacuum sealed samples have been annealed for 48 hours at 600K. Temperature was not allowed to go above 600K to avoid the formation of ordered alloys. Annealing helps in making alloys homogeneous. Resistivity measurement has been performed using four probe methods from 5K to 300K both in heating and cooling cycles. Resistivity was also measured subjecting the samples to magnetic field.

3. Results and discussion

Resistivity data of few alloys of FeNi is shown in Fig.1. Resistivity of all the samples studied exhibits a linear dependence on temperatures above 50K indicating metallic behaviour of the alloys. Below 50K resistivity comes to a minimum value. Resistivity at any temperature decreases with increase of Ni concentration of the alloys. The linear dependence of resistivity on temperature for a wide range indicates electron-phonon scattering is the dominant scattering mechanism in these materials. The effect of electrons correlations or electron-electron scattering seems to be negligible in the temperature range studied. The residual resistivity below 10K decreases with increase of Ni concentration as shown in fig.1 which indicates that Fe acts as impurity in Ni matrix.

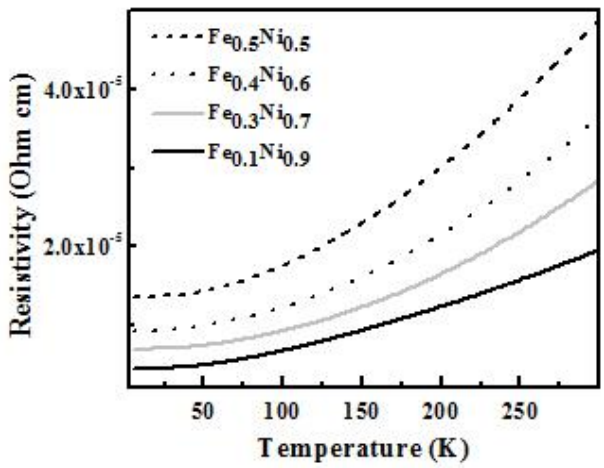

Fig.1: Temperature dependence of resistivity

4. Conclusion

Resistivity of polycrystalline alloys viz. $Fe_{0.5}Ni_{0.5}$, $Fe_{0.4}Ni_{0.6}$, $Fe_{0.3}Ni_{0.7}$, $Fe_{0.1}Ni_{0.9}$ is measured from 5K to 300K using four probe method. Structural studies on the alloys indicated a structural transformation from bcc to fcc with composition. Metallicity is found to increase with the increase of Ni content in these alloys. Residual resistivity decreases with Ni concentration. Fe atoms act as impurities in pure Ni metal.

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