A multilayer, \([\text{Ni}(100\text{nm})/\text{Fe}(100\text{nm})]_3\), has been investigated for the structure and low temperature resistivity. The resistivity increased with increase in temperature. The residual resistivity ratio (RRR) and the temperature coefficient of resistivity (TCR) were determined. The power law variations of resistivity with temperature were established. The contributions to resistivity for \(T\) above 80K are attributed to be predominant by electron-phonon and electron-magnon scatterings and for below 30K they are ascribed to be predominant by electron-electron and electron-defect scattering.

© 2012 Trade Science Inc. - INDIA
Structural investigations were carried out by grazing incidence X-ray diffraction (GIXRD) studies using Brucker-D8 advance diffractometer with Cu-Kα radiation of 1.5406 Å wavelength. The microstructure of the films was probed using Cambridge Instruments Stereoscan (Model 150) Scanning Electron Microscope. The low temperature (4.2K to 300K) resistivity, ρ has been measured by adopting four probe method in an Oxford Instruments make resistivity setup.

RESULTS AND DISCUSSION

Grazing incidence X-ray diffraction (GIXRD) studies

The GIXRD spectra for 2θ between 42° and 48° for the present film is shown in Figure 1(a) and the Gaussian fit to the peak is depicted in Figure 1(b). The observed single sharp peak does not exactly represent any plane in Fe or Ni crystals and therefore considered to be representing a mixed phase (Ni(111)/Fe(110)) of Fe and Ni. The average grain size is estimated using Scherrer’s formula[6]. The interplanar spacing, d was calculated using the Bragg’s relation.

The structure around the peak has been analyzed. The grain size and inter-planar spacing were determined to be 22.74 nm and 2.0167 Å respectively.

Scanning electron microscopy (SEM) studies

The recorded SEM image of the film shown in Figure 2 have been used for examining the microstructure of the film. The SEM image appear smooth, compact and fine in structure which indicates a high content of nanocrystalline particles.

Resistivity variation with temperature

The ρ increased with increasing temperatures. The ρ varied between 0.480 μΩm and 0.823 μΩm for the temperature range from 5K to 300K. The room temperature (300K) ρ is greater by an order of magnitude than the bulk ρ values of the two components (Ni ~ 0.072 μΩm and Fe ~ 0.09 μΩm). The larger ρ measured for this film can be due to intermixing of layers at the interface[10] and this was also evident from GIXRD results.

The temperature coefficient of resistivity is determined to be $1.732 \times 10^{-3}$ K$^{-1}$. The positive TCR points.
to the metallic nature of the film. The residual resistivity ratio, RRR is 1.71. The small RRR value observed in this films can be attributed to enhanced electron-electron, interfacial, grain boundary etc., scatterings.\(^5\)\(^,\)\(^11\)

Variation of \(\rho\) with \(T\) revealed that there exist three different power laws for the measured temperature range. Hence, the expressions, \(\rho(T) = \rho(0) + a_1 T^k\) for \(T = 30K\), \(\rho(T) = \rho(0) + a_2 T^m\) for \(30K = T = 80K\) and \(\rho(T) = \rho(0) + a_3 T^n\) for \(80K = T = 300K\), were fit to the data. Here, \(\rho(0)\) is the residual resistivity which is taken to be equal to the measured value at 5K in all the films. By non linear curve fitting, the coefficients \(a_1\), \(a_2\) and \(a_3\) and exponents \(k\), \(m\) and \(n\) were determined. The fit parameters thus obtained are \(a_1 = 0.284 \mu\Omega \cdot m\ K^{-k}\), \(a_2 = 1.282 \mu\Omega \cdot m\ K^{-m}\), \(a_3 = 3.556 \mu\Omega \cdot m\ K^{-n}\), \(k = 5.03\), \(m = 2.82\) and \(n = 1.22\). The fit curves are shown in Figure 3(a-c).

In the temperature range, \(80K = T = 300K\) the coefficient, \(n\) is obtained to be slightly more than unity which reveals the predominance of electron-phonon scattering. In Fe/Ni multilayer\(^3\), the resistivity was found to vary as \(T^{1.44}\) for the temperature range from 80K to 300K and this was attributed to additional electron-magnon (s-d) scattering, where s electrons were expected to scatter by magnons in to d band holes. In the temperature range, \(30K = T = 80K\), the exponent, \(m\) is found to be 2.82 and that agrees with a magnetic layer\(^\text{[3]}\) and deviates from White and Woods value of 3.3 for bulk Fe\(^\text{[13]}\). For the temperature, \(T = 30K\), the exponent, \(k\) is found to be 5.03. This result points out that in this range of temperature major contributions are from electron-electron and electron-defects (which includes impurity) scatterings.

**CONCLUSIONS**

The structure and grain size of a multilayer \([\text{Ni}(100nm)/\text{Fe}(100nm)]_3\), have been investigated. Electrical resistivity in the temperature range from 4.2K to 300K has been measured. Resistivity increased with increasing temperature. The power laws for the resistivity variation with temperature were established. Based
on the exponent values obtained, it is concluded that in this film, electron-electron and electron-defect scatterings are predominant below 30K and, electron-phonon and electron-magnon scatterings are predominant above 80K.

ACKNOWLEDGEMENT

Authors also gratefully acknowledge the experimental help received from Dr.R.Rawat and his coresearchers in his group and Prof.Ajaya Gupta, Director of UGC-DAE consortium for Scientific Research, Indore.

REFERENCES