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TRANSPORT PROPERTIES OF THE COMPOSITIONALLY MODULATED ALLOY Cu/Ni*

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ABSTRACT

We report preliminary transport measurements; electrical resistivity, thermopower, Hall effect and magnetoresistance, of a number of Cu/Ni composition modulated alloy films over the temperature range 10-300°K and for magnetic field up to 70 kGauss. The results indicate non-monotonic dependence of the transport properties on the modulation amplitude. The Hall coefficient saturates around 40 kGauss in contrast to the transverse magnetoresistance which does not show evidence for saturation up to 70 kGauss.

INTRODUCTION

Recently there has been extensive interest in the properties of Composition Modulated Alloys[1] (CMA). This has been motivated by elastic constant measurements which show an anomalous enhancement of the biaxial modulus as a function of modulation wavelength λ for a number of CMA's. Recent ferromagnetic resonance experiments indicate that the magnetization of Ni in the Cu/Ni CMA is larger below 200°K than the zero temperature magnetization of pure Ni. It was suggested that these results could be an indication of large changes in the band structure of CMA's as a function of wavelength and composition amplitude (A_1). Motivated by these results we undertook preliminary transport merasurements on the Cu/Ni CMA to study the effect of composition modulation on the electronic properties of such systems.

The resistivity and thermopower measurements were performed over the temperature range 10-300°K using a closed cycle refrigerator system. The magnetic transport measurements were performed in liquid helium at 4.2°K using a superconducting magnet.

All of the samples were cut from a master CMA, annealed if necessary, x-rayed and attached to the sample holders using GE 7031 varnish to improve thermal contact. Some of the samples were also x-rayed after the measurements were performed to assure

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that they did not affect the composition modulation in any way. The amplitude and wavelength of the CMA is deduced from the satellite x-ray peaks in the conventional manner.[1]

Figure 1 shows the resistivity as a function of temperature for a strongly modulated Cu/Ni sample (A_1 = (0.32), a totally annealed sample (A_1 = 0) and pure Ni and Cu prepared under similar conditions. The residual resistivity of the fully annealed sample is the highest, indicating that this sample has the largest elastic scattering, as expected. Below 80°K all samples are saturated by the residual resistivity showing that samples prepared by evaporation are quite disordered. Of course, the low resistance ratio is indicative of the same phenomenon. It is interesting to note that the highly modulated sample has a lower residual resistivity than the completely annealed one. This shows that impurity scattering has a large contribution to the resistivity, in addition to the scattering produced by dislocations and boundaries.

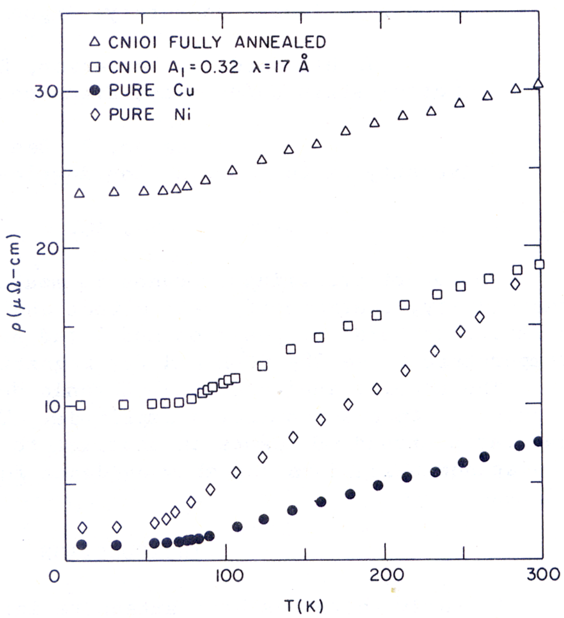

Fig. 1. Resistance versus temperature for Cu/Ni alloys, pure copper and pure nickel.

Pure copper samples obey the Bloch-Gruneisen Law (i.e., linear at high temperatures) and the pure nickel data shows the typical upward curvature arising from a magnetization dependent relaxation rate. In contrast, the modulated sample shows a small but definite downward curvature vaguely resembling the resistivity behavior in the A15 materials. If the non-impurity scattering is mainly due to boundary scattering, and since the films are only a few atomic layers thick (17 Å), one is approaching the Ioffe-Regel limit[2] (mean free path $\sim$ interatomic spacing) which tends to saturate the resistivity at high temperature. This would explain the downward curvature.

Figure 2 shows a graph of the temperature dependent part of the resistivity divided by the temperature, $(\rho-\rho_o)/T$. Here ρ_o is the residual resistivity, ρ is the total resistivity and T is the absolute temperature. Notice that the high temperature slope of the resistivity (as indicated by the saturation in $\rho-\rho_o/T$) depends non-monotonically on the amplitude of modulation A_1; although this is quite a small effect. The only other physical quantity showing non-monotomic behavior as a function of A_1 are the stress-strain curves; demonstrating the importance of nonlinear effects in this system.

Figure 3 shows the thermoelectric power as a function of temperature for a completely annealed sample, two modulated foils and a pure copper film. As expected, the thermopower of the fully annealed and the two modulated samples are much larger than the pure copper sample. Also, the thermopower of the fully annealed sample is appreciably larger than that of the modulated samples. This is in accordance with the idea that most of the temperature dependence of the thermopower comes from impurities. The modulation does not seem to have a large effect on this property.

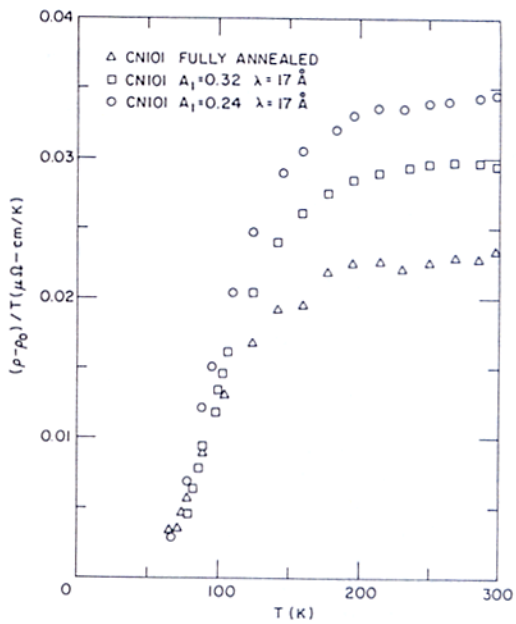

Fig. 2. Temperature dependence of $\rho-\rho_0/T$ for various modulated alloys. Notice the non-monotonic dependence of the high temperature slope on A_1.

Figure 4 shows the magnetoresistance for two modulated samples and a completely annealed sample. The magnetoresistance of the completely annealed sample and of the modulated sample with $A_1 = 0.32$ are typical of a feromagnet.[3] The magnetoresistance is negative and linear and then at high fields becomes positive. In contrast, the magnetoresistance of the $A_1 = .24$ modulated sample is typical of a two band metal below saturation. In this sample the magneto-

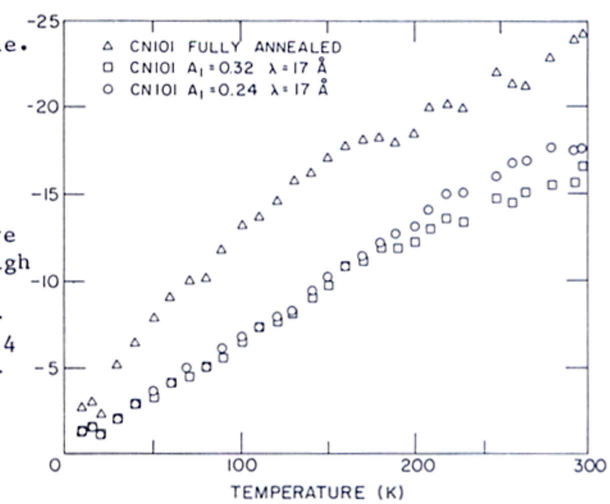

Fig. 3. Thermoelectric power versus temperature.

resistance is quadratic at low fields and then linear up to 70 kG. On the other hand the Hall coefficient (Figure 5) of all three samples is typical of that observed in pure nickel.[3,5,6,7]

In summary, we have measured the electric transport properties of Cu/Ni compositionally modulated alloys. The electrical resistivity and the magnetoresistance show anomalous behavior as a function of modulation amplitude. On the other hand, the thermopower and Hall coefficient show typical behavior of a ferromagnet. More detailed measurements are presently underway in order to clarify these points and their relationship to the anomalous elastic and magnetic properties.

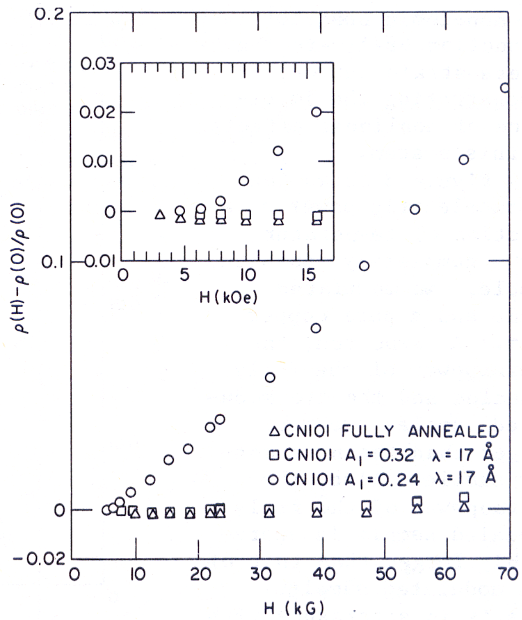

Fig. 4. Transverse magnetoresistance versus magnetic field. The inset shows in detail the low field behavior.

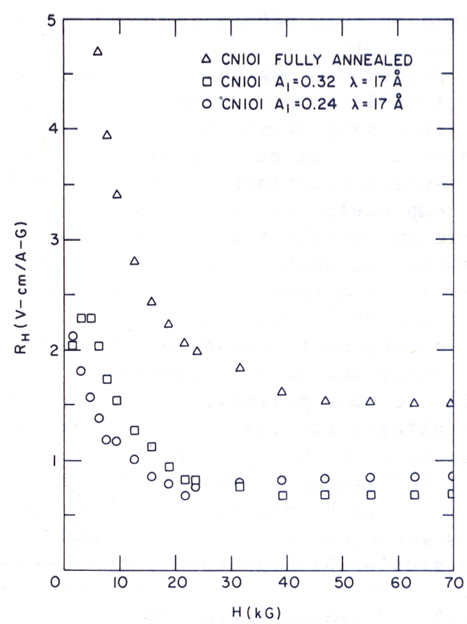

Fig. 5. Hall coefficient versus magnetic field.

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