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Electric Transport Properties of the B2 to R Phase Transition in TiNiFe Alloy

A. Canales, F. Morales, R. Escudero and D. Rios-Jara

Instituto de Investigaciones en Materiales, UNAM, Apdo. postal 70-360, 04510 México D.F., México

ABSTRACT.

Electric transport measurements were performed as a function of temperature across the B2 to R phase transition in a TiNi-5wt% Fe alloy, by means of electric resistivity, thermoelectric power, magnetic susceptibility and point contact spectroscopy. The first derivative of resistivity, magnetic susceptibility and thermoelectric power with temperature shows a peak at the same characteristic temperature. At lower temperatures, the resistance vs. temperatures curves revealed a small minimum at about Tc≅9K, that could be associated with some electronic transition. The dV/dI vs V curves, taken from the point contact experiments, also show asymmetric behavior at low temperatures (about 10K), indicating a kind of electronic scattering. No martensitic transformation occurred in this high Fe content alloy.

INTRODUCTION

TiNi alloys with addition of Fe show two well separated transitions, first between the B2 cubic phase to a rhombohedral R phase and next to a martensitic phase. With increasing Fe content, the B2 to R phase transition temperature decreases gradually, but the transition temperature from the R to the martensitic phase is more strongly decreased. This characteristic makes it easy to study both transitions separately, and to have some approach about their nature.

Up until now, no clear explanation about the origin of the B2 to R phase transition has been given. Wayman et al. [1], have studied this transition in great detail and advanced a possible origin for this transition. They proposed a prior incommensurate to commensurate charge density wave (CDW) transition, that finally results in the rhombohedral R phase. Such an explanation is based on the observation of an incommensurate superlattice net in transmission electron diffraction patterns, that appears in addition to the B2 diffraction spots, during in-situ cooling observations. The superlattice becomes commensurate to the B2 lattice at lower temperatures and finally built up the diffraction reciprocal lattice of the R phase. Also, x-ray diffraction patterns have been obtained during those transitions [2], that indicates a gradual increase in intensity of the diffraction peaks. All this experiments are compatible with a possible CDW origin of the transitions, but give no definitive conclusion about it.

In the present work a search for electronic transport properties associated to the B2 to R phase transition was made. In particular, the dV/dI Vs V was obtained from point contact spectroscopy experiments, in order to look for possible effects in the electronic density of states, as well as other indications for a CDW transition. Preliminary results of these experiments are presented.

EXPERIMENTAL

A polycrystalline rod with a nominal composition $Ti_{50}Ni_{45}Fe_5$ at% was prepared by induction melting. The alloy was homogenized for 24 hours at 1173K in an evacuated quartz tube, then quenched to room temperature. A heat treatment of 1 hour at 773K allowed the precipitation of the $Ti_{11}Ni_{14}$ phase. The bulk composition of the alloy was measured by x-ray fluorescence spectroscopy and resulted in 42.9wt% Ti, 50.7wt% Ni and 5.1wt% Fe (48.4at% Ti, 46.6at% Ni and 4.9at% Fe). The rod was then cut by means of a low speed diamond saw to obtain disk shaped samples, from where some thin flat wires were obtained.

Susceptibility measurements were made on a squid based magnetometer from room temperature to 2K. Point contact spectroscopy measurements, using gold as the point contact, were performed at different temperatures down to 5K. Thermopower measurements were made using a D.C. home made system at the GEMPPM laboratories of the INSA, Lyon, France, by applying a 1-3K temperature gradient.

RESULTS AND CONCLUSIONS

Resistivity measurements from room temperature to 4K allowed us to conclude that no martensitic transformation occurs in that temperature range. The B2 to R phase transformation was observed, with a peak on the first derivative of the resistivity at 217K during the cooling and at 219K during the heating, as shown in Figure 1-a) and b). Magnetic susceptibility measurements are presented in Figure 2a). The first derivative of this curve, Figure 2-b), shows a peak at almost the same temperature as the resistivity plot. Thermopower measurements give a positive value at room temperature, that decreases during the cooling of the samples. A small increase in thermopower values is observed during the B2 to R transition, with a monotonous decrease down to the lower temperatures of the measurement, as shown in Figure 3.

No clear indications of phase transitions preceding the B2 to R transition could be deduced from those resistance, susceptibility or thermopower measurements, although other techniques have produced indications of those prior transitions [3].

The dV/dI vs V curves of point contacts at different temperatures are shown in Figure 4. Between 100K to about 10K we observe a normal metallic behavior, which is reflected as a parabolic curve, Indicating that electronic scattering is isotropic around the Fermi surfaces. The small zero bias offset, observed in those curves, can be attributed to the differences of work functions between the two different metals used to perform the experimental setup.

It is interesting to note that the point contact technique allows to detect different kind of electronic interactions that occurs in a metal or alloy close to the Fermi surface. A kind of electronic scattering readily can be observed in TiNiFe when lowering the temperature to about 9K, where we start to note a small anomaly around zero bias in the dV/dI vs V characteristics. This feature is more clearly observed as the temperature is lowering, due to the fact that thermal noise is decreasing.

Figure 5 shows the resistance vs temperature characteristic measured from about 90K to 4K. The inset of this figure clearly reveals a small change in the resistance vs temperature curve, which can be associate to an extra electronic dispersion at around T_C ~9K, corresponding to the small minimum in this curve. According to our point contact measurements, this anomaly can be associated to two possible physical mechanism: a) The opening of an energy gap at the Fermi level, due to the nesting of some regions of the Fermi surface, that in turn involve some portion of the electronic density of states to lower the ground state of the system, by creating a charge density wave (CDW) condensate, and b) The increasing of an extra electronic dispersion by a kind of magnon excitation due to the NiFe content of the alloy. This extra scattering may also be a possible explanation for the features observed in the point contact experiments at low temperatures. However, more work is actually in advance and we hope to have a more clear explanation, for this interesting behavior at low temperatures, in near future.

REFERENCES

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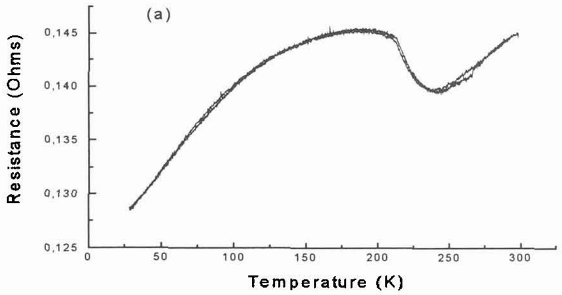
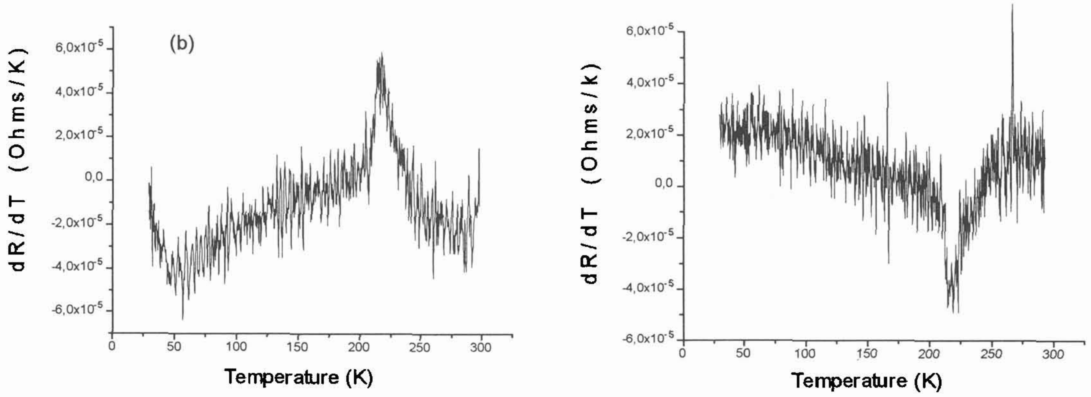


Figure 1. a) Resistance Vs. Temperature of a Ti 48.4,Ni-46.6, Fe-4.9 at % alloy. b) First derivate of the cooling and heating resistance vs. temperature curves.



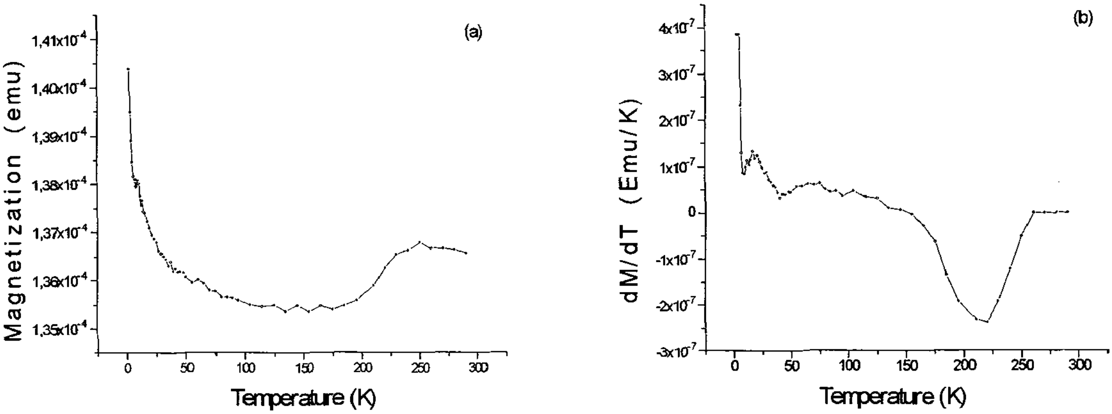


Figure 2 a) Magnetic susceptibility as a function of temperature. b)First derivate of the susceptibility vs. temperature curve.

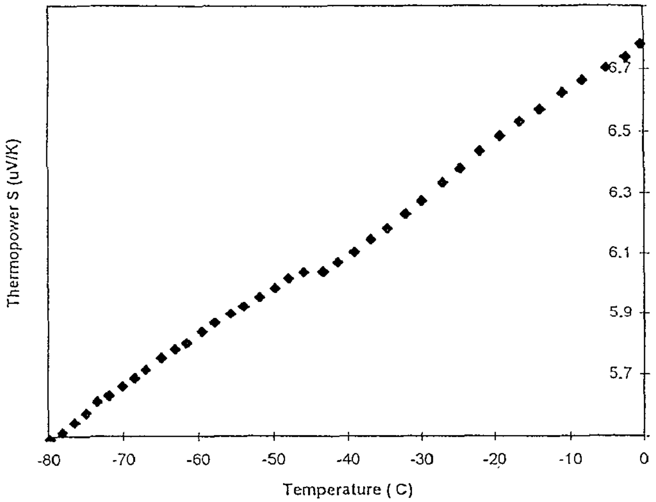
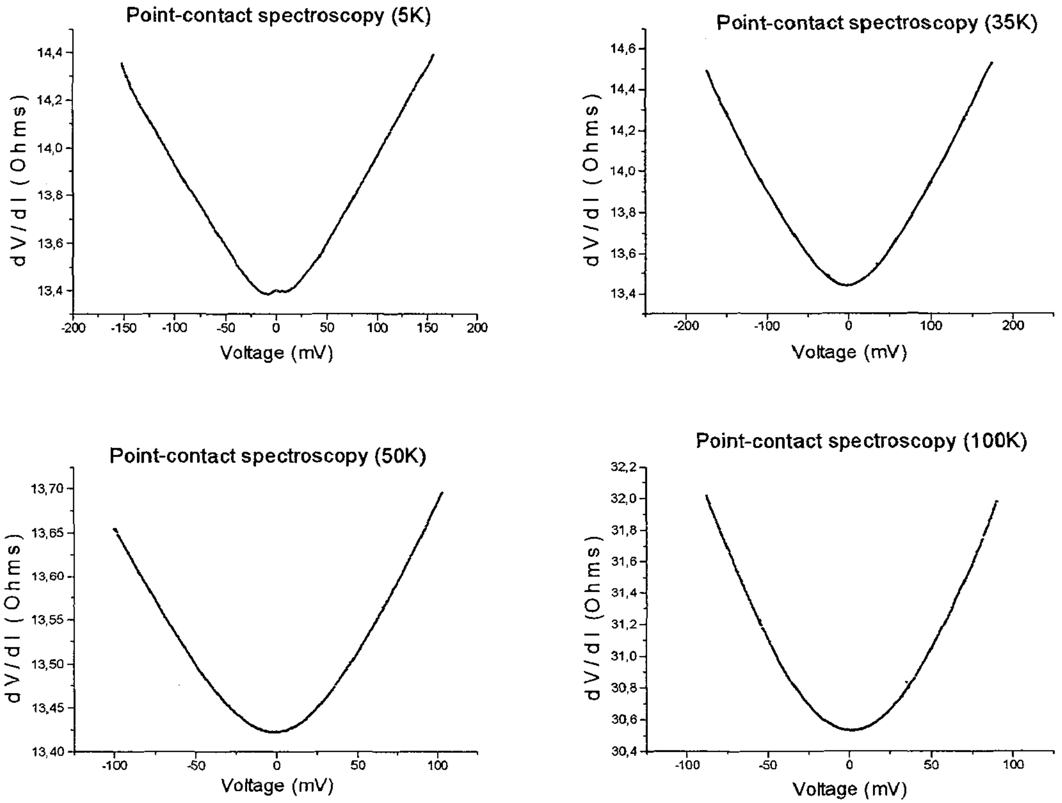


Figure 3.Termoelectric power as a function of temperature


Point-contact spectroscopy (5K)

Point-contact spectroscopy (35K)

Point-contact spectroscopy (50K)

Point-contact spectroscopy (100K)

Figure 4. Diferential resistivity (dV/dI) v. V, at four different temperatures. A small anomaly is clear in the curve at 5K.

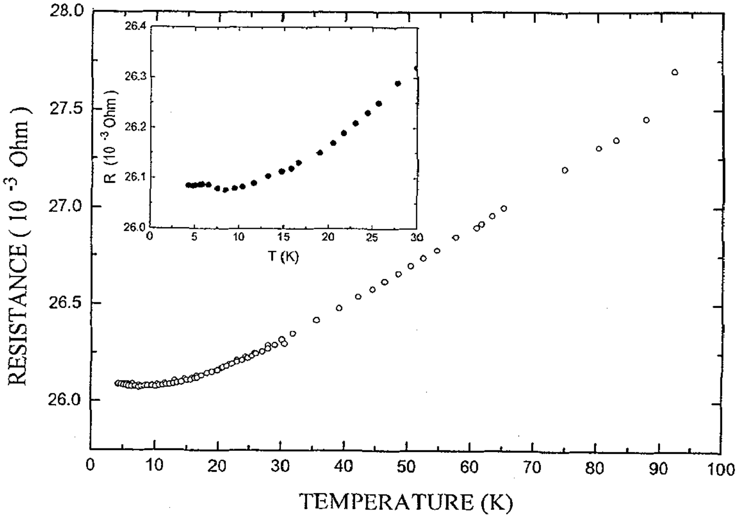


Figure 5. Resistance vs. temperature in the low temperature range. the inset clearly shows a minimun at about 9K.