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ASYMMETRY OF POINT CONTACT SPECTRA OF NdCu*

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We present the analysis of the symmetrical and the asymmetrical parts of the point-contact (PC) spectra together with thermopower and electrical resistivity measurements on bulk samples of NdCu. The negative asymmetrical part of the derivatives dV^{as}/dI has been observed. The different contributions observed in the spectra are interpreted in terms of the different interactions involved in the system.

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1 Introduction

Low symmetry rare-earth intermetallic compounds have attracted a lot of interest because of the competition between magnetic exchange interactions and crystalline electric field (CEF) anisotropy. Among them, NdCu shows an antiferromagnetic ordering at T_N = 10 K. In previous works, the electron-quasiparticle interaction function has been measured by means of point-contact spectroscopy [1], and the magnetic structure and the CEF splitting have been studied very recently by neutron scattering experiments [2].

The resistance of PCs between different materials often reveals an asymmetry with respect to the polarity of the applied voltage V [3]. In the case of simple metals and for the ballistic regime (when the inelastic mean free path l_i of the conduction electrons is greater than the PC effective dimension d) the asymmetry was explained by considering the phonon-drag effect inside the constriction [3]. In the opposite case, when $d >> l_e$ (known as the thermal limit [4]), the energy dissipation in the PC region heats the contact above the bath temperature. This leads to an asymmetry in the differential resistance dV/dI of the heterocontacts connected with thermoelectric effects. An enhancement of the electronic density of states at the Fermi energy, as occurs in

*Presented at 10th Czech and Slovak Conference on Magnetism, CSMAG'98, Košice, Slovakia, August 24-27, 1998 the heavy-fermion systems, could also result into an asymmetry of the $I - V$ characteristics for heterocontacts, as it was evaluated in reference 5. Another kind of asymmetry in ballistic regime has been observed for the heterocontacts between two metals due to the difference in the effective electron masses [6].

In this work, we have studied the asymmetries of the PC dV/dI dependencies as a function of the applied voltage for heterocontacts between NdCu and Cu in ballistic and thermal regimes in order to determine its origin and to compare with measurements of the thermopower $S(T)$ and the electrical resistivity $\rho(T)$ on bulk NdCu.

2 Experimental

The PCs were made at liquid helium temperatures by touching a Cu needle to the polished surface of NdCu polycrystalline sample. The derivatives dV/dI and of d^2V/dI^2 the $I-V$ characteristics were measured using the standard PC technique [1].

3 Results and discussion

The characteristic asymmetric part $dV^{as}/dI(V) = [dV/dI(+V) - dV/dI(-V)]/2$ for NdCu - Cu heterocontacts in ballistic regime at 1.5 K [1] is shown in Fig.1.(a). The $+/-$ sign at V marks the polarity on the compound. A negative asymmetrical part dV^{as}/dI has been observed in the whole range of applied voltages. It decreases smoothly with increasing applied voltage and its magnitude varies up to -0.25 % (of the $dV/dI(V = 0 \text{ mV})$ value) at 20 mV. The curve at 1.5 K has small upturn at about 5 mV with a tendency to saturation. When temperature is increasing dV^{as}/dI behaves similar with smaller magnitude (-0.5 % at 20 mV for 15 K).

The characteristic asymmetric part $dV^{as}/dI(V)$ for NdCu - Cu heterocontacts at 1.5 K in thermal regime is presented in Fig.1.(b). Again a negative magnitude of dV^{as}/dI within the whole range of applied voltages is observed. However, the magnitudes are about twice smaller than in the case of ballistic regime (-0.5 % at 20 mV) without a tendency to saturation. Moreover, with increasing temperature a shoulder appears which shifts to lower voltages. Because of the overheating of the PC, the asymmetric part $dV^{as}/dI(V)$ has to be proportional to the difference $\triangle S(T_{PC})$ [4] between the bulk thermopower of NdCu and Cu at the local PC temperature T_{PC} with a scaling factor proportional to the value of the Lorenz function $L(T)$.

In Fig.2.(a) the symmetric part $dV^{s}/dI(V) = [dV/dI(+V) + dV/dI(-V)]/2$ for NdCu - Cu heterocontacts in ballistic regime at 1.5 K is presented. The symmetric part dV^{s}/dI is increasing with a main shoulder about 6 meV associated with the scattering processes of conduction electrons by CEF excitations [1]. With increasing temperature the shoulder is smearing out. The behaviour of $dV^{s}/dI(V)$ in thermal regime at 1.5 K is shown in Fig.2.(b). The symmetric part is proportional to the bulk electrical resistivity $dV^{s}/dI(V) \approx \rho(T)$ [4] with the same scaling factor as for $dV^{as}/dI(V)$.

For comparison, we have plotted in Fig.1.(c) the thermopower $S(T)$ [8] and in Fig.2.(c) the electrical resistivity $\rho(T)$ [7] of bulk NdCu. Unfortunately, the $S(T)$ data are measured only in the temperature interval 77 - 300 K. However, in this temperature range due to the dominating diffusive term of the thermopower we could expect the validity of Wiedemann-Franz law and a value of $L(T)$ close to L_0. Thus it is possible to estimate [4] for an applied voltage V = 20 mV the temperature of PC region at least 70 K which is very close to the starting point of bulk

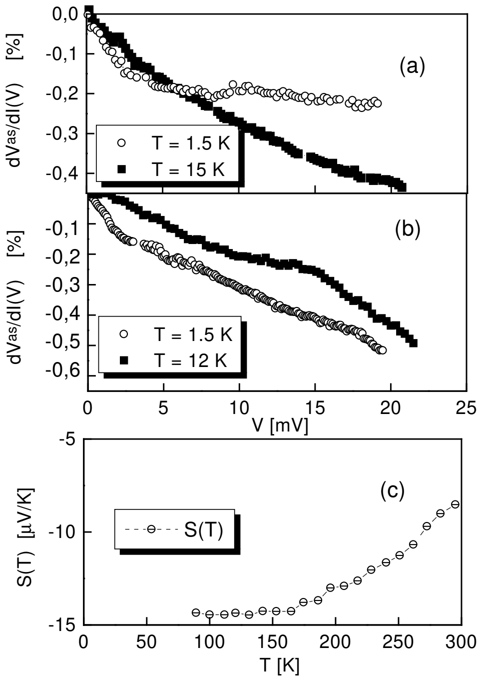

Fig.1. The asymmetric part $dV^{as}/dI(V)$ for PC NdCu - Cu at 1.5 K in (a) ballistic regime and (b) thermal regime. The temperature dependence (c) of the thermopower $S(T)$ [8] of bulk NdCu

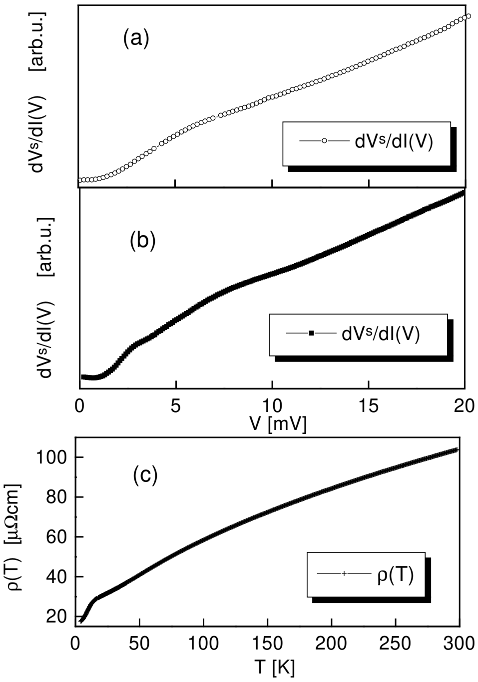

Fig.2. The symmetric part $dV^s/dI(V)$ for PC NdCu - Cu at 1.5 K in (a) ballistic regime and (b) in thermal regime. The temperature dependence (c) of the electrical resistivity $\rho(T)$ [7] of bulk NdCu

measurements. From the comparison of the magnitudes of $\triangle S$ at 77 K and dV^{as}/dI we could conclude that the model is in a qualitative agreement with the experiment and a negative low temperature behaviour of $S(T)$ for NdCu similar to dV^{as}/dI is expected. With respect to the symmetric part, from the comparison of the dV^{as}/dI and $\rho(T)$ we could estimate a value of the Lorenz function $L \sim \mathrm{L}_0$ at T_N.

The negative values of dV^{as}/dI in ballistic regime could not be explained by the difference in the effective electron masses [6], because this effect leads to a positive asymmetry. If we suppose that the low temperature behaviour of $S(T)$ for NdCu is similar to that of dV^{as}/dI, and taking into account the dominating drag term of thermopower at low temperatures then the observed behaviour could be explained by quasiparticle drag effects [3].

4 Conclusions

In conclusion, we have found that thermoelectric effects play an important role in the dV/dI asymmetry of PCs between NdCu and Cu. The asymmetry in ballistic regime could be interpreted in terms of the quasiparticle drag model, while in thermal regime the heating effects are dominating ones. Moreover, these experiments have shown the possibility of providing a valuable information about the electronic transport properties of this compound by using point-contact spectroscopy technique.

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References

[1] M.Reiffers, J.Garcia Soldevilla, J.C.Gomez Sal, J.I.Espeso, J.A.Blanco, E.Bystrenova: *Czech. J. Phys.* **46** (1996) 2097

[2] J.Garcia Soldevilla, J.I.Espeso, J.A.Blanco, J.C.Gomez Sal, P.Galez, D.Paccard, J.Rodrigez-Carvajal, B.Ouladdiaf: *Physica* **B234-236** (1997) 758

[3] Yu.G. Naidyuk: *Fiz.Nizk.Temp.* **18** (1992) 470

[4] B.I. Verkin, I.K. Janson, I.O. Kulik, O.I. Shklyarevski, A.A. Lysykh, Yu.G. Naidyuk: *Solid St. Comm.* **30** (1979) 215

[5] A. Nowack, J. Klug: *Fiz.Nizk.Temp.* **18** (1992) 534

[6] Yu.G. Naidyuk, M. Reiffers, A.N. Omelyanchouk, I.K. Janson, A.G.M. Jansen, P. Wyder, D. Gignoux, D. Schmitt: *Physica* **B194-196** (1994) 1321

[7] J.Garcia Soldevilla, J.I. Espeso, J. Rodriguez-Fernandez, J.C. Gomez Sal, J.A. Blanco, P. Galez, D. Paccard: *J. Magn. Magn. Mat.* **157-158** (1996) 624

[8] J. Fontcuberta, M. Reiffers, A.N. Omelyanchouk, I.K. Janson, A.G.M. Jansen, P. Wyder, D. Gignoux, D. Schmitt: *J. Appl. Phys.* **81** (1997) 3887