ELECTRON-QUASIPARTICLE INTERACTION IN DyNi$_5$* ‡

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We have studied the electron-quasiparticle interaction in the hexagonal single crystal of antiferromagnetic DyNi$_5$ using the point-contact (PC) spectroscopy above and below T_N = 11.6 K. The observed maxima in low energy range up to $\approx$ 10 meV have the CEF origin (the excitations of $4f$ electrons from ground CEF level to higher excited levels). The broad maximum at about 18 meV is connected with phonons DyNi$_5$. The comparison of calculated CEF level scheme with experimental data is presented.

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1 Introduction

The intermetallic RNi$_5$ (R = rare earths) compounds crystallize in the simple hexagonal structure and have been the subject of detailed studies during the last years [1]. Their magnetic properties are predominantly determined by crystalline electric field (CEF) acting on R and exchange interactions. In this series the Ni atoms are nonmagnetic, although they are very close to the onset of Ni magnetism. The intermetallic compound DyNi$_5$ undergoes an antiferromagnetic ordering transition at T_N = 11.6 K [2]. However, till present all informations about CEF level scheme have been obtained indirectly from specific heat [2], magnetization and susceptibility [3], [4] in the paramagnetic state. Therefore, we have used the point-contact spectroscopy in order to study directly the electron-quasiparticle interaction in the hexagonal single crystal DyNi$_5$ above and below T_N.

Point-contact spectroscopy has been shown to be a very useful experimental method for direct study of the energy dependence of the interaction between conduction electrons and quasiparticle excitations in metals [5]. Small constrictions between the two metals show deviations from Ohm's law. For such clean metallic contacts, where both the inelastic l_i and elastic l_e mean free

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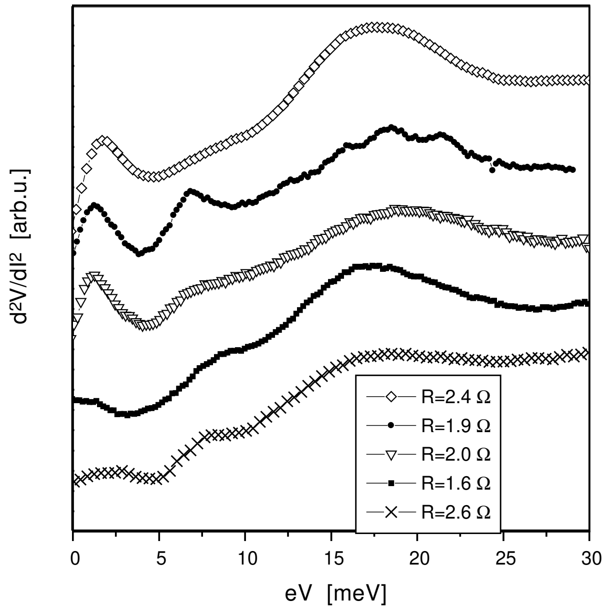

Fig.1. Characteristic PC spectra of $DyNi_5$ - Cu heterocontacts in ballistic regime at 4.2 K. Both axis are linear and starting from zero.

paths of the electrons are larger than the contact diameter d, the transport of electrons through the constriction is ballistic. The applied voltage accelerates electrons and thus it directly defines the energy scale for its scattering processes. Then the second derivative d^2V/dI^2 of PC $I - V$ characteristic is directly proportional to the spectral function for the interaction process under study. When both l_i, l_e are smaller than PC diameter d, then the temperature in PC region is locally increasing by Joule overheating with the applied voltage increasing [5].

2 Experimental

The PCs were made at liquid helium temperatures by touching a Cu needle to the electrochemically polished surface of the single crystal $DyNi_5$ sample. The single crystal of a good quality was grown by the vertical floating zone method in an image furnace. The derivatives dV/dI and d^2V/dI^2 of the $I - V$ characteristics were measured using standard PC technique [5] in the temperature range 1.5 K - 15 K.

3 Results and Discussion

In Fig. 1. the measured characteristic PC spectra (d^2V/dI^2 is directly proportional to the electron-quasiparticle interaction function) of the heterocontacts between $DyNi_5$ and Cu in ballistic regime are presented at 4.2 K in magnetically ordered state below T_N. We have observed the peak at 1.6 meV, the shoulder at $\approx$ 8 meV and the broad maximum at 18 meV. This structure is well

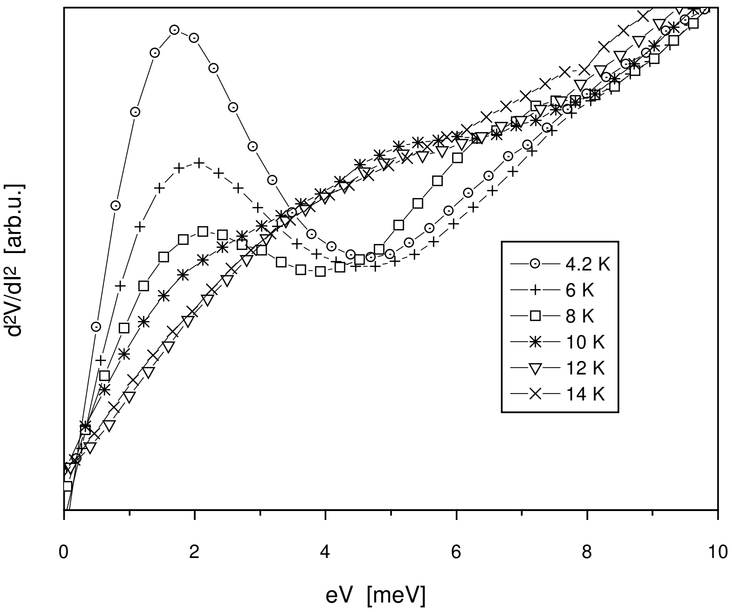

Fig.2. Temperature behaviour of the low energy part (below 10 meV) of PC spectrum of DyNi$_5$ - Cu heterocontact in ballistic regime. Both axis are linear and starting from zero.

reproducible. In order to distinguish between the phonon and CEF origin peaks we have measured the temperature dependence of the spectra for the same PC.

When temperature is increasing then the high energy part of PC spectra for $eV > 10$ meV (especially the maximum at 18 meV) does not change. The main changes are present in the energy range $eV < 10$ meV. Taking into account this fact and the previous results of PC spectroscopy obtained on RNi$_5$ (e.g. PrNi$_5$ [6]) this maximum has phonon origin. The contribution from Cu phonons lies too in this energy range. However, we have not seen the characteristic Cu phonons maximum at 30 meV. In Fig. 2. the characteristic temperature dependence of the low energy part ($eV < 10$ meV) of PC spectra of DyNi$_5$ - Cu heterocontact is presented. The peaks change their intensity and shift their position - finally one shoulder at about 3 meV remains above T_N only. This is the fingerprint of their CEF origin (the excitations of $4f$ electrons from ground CEF level to higher excited levels).

The observed CEF energies we can compare with the results of [2], [3] and [4]. The CEF with hexagonal symmetry splits the multiplet $^6H_{15/2}$ into 8 doublets as Dy^{+3} is a Kramer's ion. The eigenfunctions of the ground-state doublet contain the largest component with the minimal value of J_Z i.e. 1/2. In the ordered state, all levels are split by the exchange interactions. However, their splitting is small. The CEF energy level scheme closest to our results is the scheme given in [4] with overall CEF splitting 43 meV. Then the shoulder at about 3 meV in paramagnetic state could be identified as an allowed transitions from the ground CEF level to the second excited level (2.8 meV in [4]). The shift of peaks in magnetically ordered state is due to the splitting of CEF levels in molecular field. Therefore, two peaks at 1.6 meV and 8 meV observed below T_N could be again associated with the transition in CEF level scheme calculated in [4].

4 Conclusions

In conclusion, we have measured the electron-quasiparticle interaction function of $DyNi_5$ - Cu heterocontacts above and below T_N. The observed maxima in low energy range up to $\approx$ 10 meV have the CEF origin (the excitations of 4f electrons from ground CEF level to higher excited levels). The broad maximum at about 18 meV is connected with $DyNi_5$ phonons.

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