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POINT-CONTACT SPECTRA OF MeBe_{13} INTERMETALLICS**A NOWACK, D WOHLLEBEN***II Physikalisches Institut Universität Köln, 5000 Cologne 41, Fed Rep Germany*

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We have measured the differential resistance of point-contacts between Pt and the MeBe_{13} -compounds with $\text{Me} = \text{La}, \text{Ce}, \text{Yb}$ and U as function of bias U . The characteristics of Ce- and YbBe_{13} show an asymmetry which is typical for an f -instability, and so does UBe_{13} .

All the MeBe_{13} (cubic NaZn_{13} -structure) were single crystals except LaBe_{13} . The point-contacts were realized by the “needle-anvil”-method, by which a sharply etched Pt-wire was contacted with the freshly cleaved surface of the sample in liquid He. The dU/dI -characteristics were measured with a usual lock-in technique in a few hundred bias steps and stored in a computer. The d^2U/dI^2 -curves were calculated numerically out of these data. The voltage is always measured from the sample to the needle.

Fig. 1 shows the d^2U/dI^2 -characteristics of a contact between Pt and LaBe_{13} , which was studied as stable reference compound. One observes a maximum at 20 mV, the signal remains on a high level at higher voltages.

A typical dU/dI -characteristic of a CeBe_{13} -Pt contact is shown in fig. 2. With the exception of the asymmetry there are no further structures.

Fig. 3 shows the dU/dI and d^2U/dI^2 -characteristics of a YbBe_{13} -Pt contact and fig. 4 the behaviour of the small zero bias maximum (inside the larger minimum) of the dU/dI -curves in magnetic fields. The maximum decreases with increasing fields, at $B = 4 \text{ T}$ it has vanished completely (the other slight changes in the 4T-curve are due to a mechanical change of the contact, which became very unstable in higher magnetic fields).

The largest structures in the d^2U/dI^2 -charac-

Fig. 1 d^2U/dI^2 -characteristic of a LaBe_{13} -Pt contact

teristic are a peak at 2.7 mV at positive voltages and the corresponding one at -3.3 mV on the negative side (the asymmetry has its maximum here). A smaller peak lies around 6.2 mV. UBe_{13}

Fig. 2 dU/dI -characteristic of a CeBe_{13} -Pt contact

Fig. 3 dU/dI and d^2U/dI^2 -characteristics of a YbBe_{13} -Pt contact

shows, similar to Ce- and YbBe_{13} and other unstable Ce and Yb compounds, an asymmetry in the dU/dI -characteristic (fig. 5), additionally there is a minimum around zero bias

In the point-contact theory existing up to now [2,3], contacts are classified by the ratio of the mean free path l of the electrons to the radius a of the contact, which is regarded as a circular hole in

Fig. 4 Magnetic field dependence of dU/dI -characteristics near zero bias

Fig. 5 dU/dI -characteristic of a UBe_{13} -Pt contact

the elsewhere insulating interface between the two metals

Point-contact “spectroscopy” is possible when $l \gg a$ (Sharvin-limit). In this case any energy-dependent scattering process at energy E will cause structures in the characteristics at the corresponding voltage $eU = E$.

If electron-phonon interaction is the dominating scattering process, the d^2U/dI^2 (U)-characteristics should be correlated with the Eliashberg-function $\alpha^2F(\hbar\omega = eU)$ [2,3].

In the opposite case, $l \ll a$ (Maxwell-limit), no information about elementary scattering processes is expected because non-linearities in the characteristics should then be due to self-heating effects [3,4].

The radius of a contact made by the method described above cannot be determined directly. However, a can be estimated from the contact-resistance by aid of the Wexler-formula (3)

$$R = 4\rho l / 3\pi a^2 (1 + a/l)$$

$$(\rho = p_F / ne^2 l \text{ is the resistivity})$$

Using this formula for our contacts, we find that – La- and YbBe_{13} are in the Sharvin-limit at all voltages (the resistivity is lower than $1 \mu\Omega \text{ cm}$ at 1.6 K and of order $10 \mu\Omega \text{ cm}$ at 300 K [5,6]),

– CeBe_{13} starts with $l > a$ at zero bias, but might be driven into the Maxwell-limit by self-heating (i.e., if $l(U)$ varies as strong as $l(T)$). The resistivity is of order $5 \mu\Omega \text{ cm}$ at 1.6 K and increases up to above $60 \mu\Omega \text{ cm}$ [5],

– UBe_{13} should be in the Maxwell-limit at all

voltages (the resistivity is greater than $100 \mu\Omega\text{cm}$ at temperatures above 1 K [7])

It will be shown in another paper that there is no significant selfheating in contacts between materials with high resistivities even if $l \ll a$, as long as $v_F h / a k_B T \gg 1$, where T is the bath temperature [8]

Nevertheless, an explanation of the Ce- and YbBe_{13} -characteristics is quite involved and we shall not discuss them here

On the other hand, we can discuss the La- and YbBe_{13} -characteristics in the spectroscopic sense (Sharvin-limit)

From the temperature dependence of the resistivity of LaBe_{13} [5] we expect that the structures in the point-contact characteristic are due to scattering on phonons. No data are available for phonon energies of LaBe_{13} , but we can compare with data from inelastic neutron scattering on YbBe_{13} [9] and ThBe_{13} [10]. The phonons due to the oscillation of the lanthanide or actinide ion in these compounds have energies around 14.6 and 13.8 meV respectively, from which we can estimate 16.4 and 17.9 meV for La by the mass ratios. The maximum in the d^2U/dI^2 -characteristic at 20 meV might well indicate this phonon. On the other hand, MeBe_{13} may be viewed as a dilute Me alloy in a Be-matrix, we can expect therefore phonons up to voltages $eU = k\theta_D = 124 \text{ meV}$ ($\theta_D = 1440 \text{ K}$ for Be). In YbBe_{13} , indeed phonons up to energies of more than 100 meV were found by neutron scattering [9]. The high level of the d^2U/dI^2 -signal at high bias can be explained by this unusual structure of the phonon spectrum.

In YbBe_{13} a crystal-field (CEF)-spectrum of Yb^{3+} is well known to exist from neutron scattering [9,11] in addition to the phonon spectrum. It is surprising that neither the phonon nor the CEF-spectrum appears in the characteristics of YbBe_{13} .

We can give a simple explanation only for the small zero-bias maximum (inside the larger minimum) in the dU/dI -curves. YbBe_{13} orders antiferromagnetic at $T_N = 1.115 \text{ K}$ [12], at higher temperatures there are critical spin-fluctuations

introducing the order [9,11]. Scattering at these fluctuations and a suppression of them in magnetic fields might well explain the behaviour of the maximum.

With YbBe_{13} we have for the first time an f-unstable compound which allows point-contact experiments clearly in the spectroscopic region. The asymmetry, the most characteristic feature of other f-unstable compounds with higher resistivities is observed also here. This asymmetry was previously blamed on selfheating in connection with thermoelectric effects [13]. Apparently an isothermal explanation must be found at least for YbBe_{13} . A microscopic explanation of the characteristics of CeBe_{13} , YbBe_{13} and UBe_{13} will be given elsewhere.

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