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POINT-CONTACT SPECTRA OF $MeBe_{13}$ INTERMETALLICS

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We have measured the differential resistance of point-contacts between Pt and the $MeBe_{13}$-compounds with Me = La,Ce,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 $B = 4$ 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-characteristic 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}

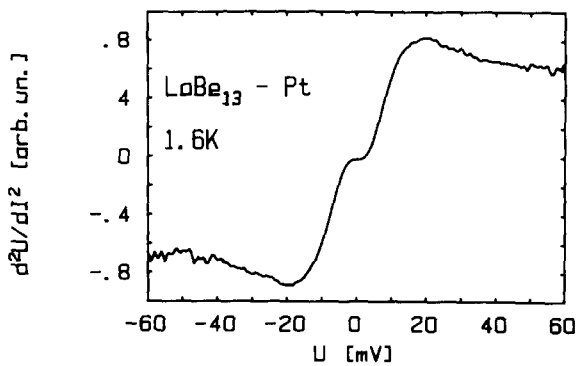

Fig 1 d^2U/dI^2-characteristic of a $LaBe_{13}$–Pt contact

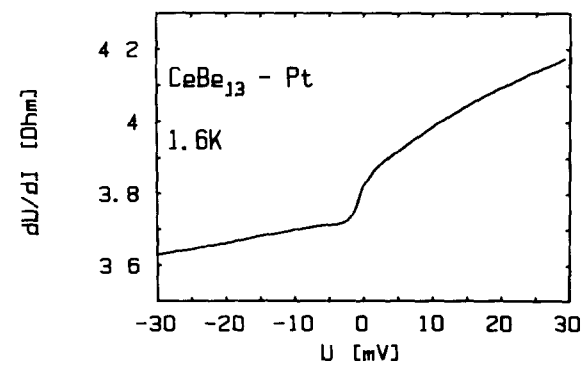

Fig 2 dU/dI-characteristic of a $CeBe_{13}$–Pt contact

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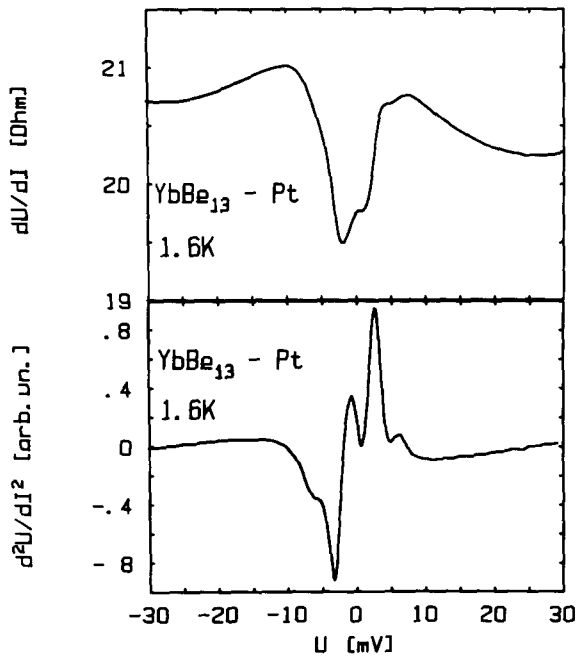

Fig 3 dU/dI and d^2U/dI^2-characteristics of a $YbBe_{13}$–Pt contact

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

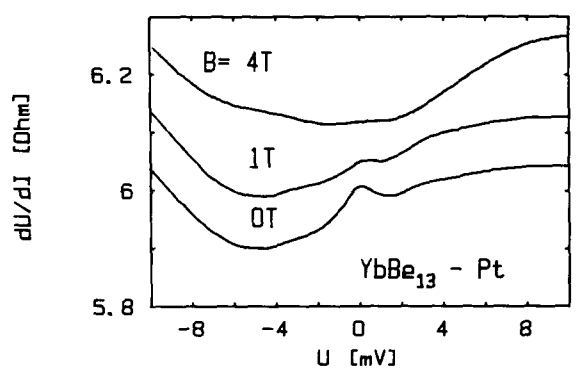

Fig 4 Magnetic field dependence of dU/dI-characteristics near zero bias

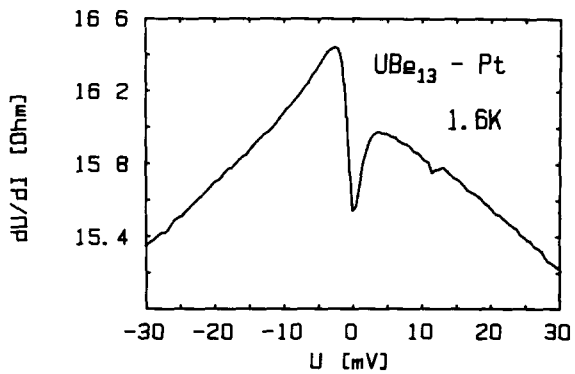

Fig 5 dU/dI-characteristic of an UBe_{13}–Pt contact

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)

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

($\rho = p_F/ne^2l$ 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 μΩ cm at 1 6 K and of order 10 μΩ 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 μΩ cm at 1 6 K and increases up to above 60 μΩ cm [5],
- UBe_{13} should be in the Maxwell-limit at all

voltages (the resistivity is greater than 100 μΩcm 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 $v_F h/ak_B T \gg 1$, where T is the bath temperature [8]

Nevertheless, an explanation of the Ce- and UBe_{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 $eU = k\theta_D = 124$ meV ($\theta_D = 1440$ 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 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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