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Published in:
Physica C: Superconductivity

DOI:
10.1016/0921-4534(91)91434-6

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
1991

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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ANISOTROPY OF UPPER CRITICAL FIELD NEAR $T_C$ AND MAGNETIC GAP OF SUPERCONDUCTING UR$_2$Si$_2$ SINGLE CRYSTAL.

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Studying thermal conductivity and STM spectra in the normal and magnetic phase of superconducting UR$_2$Si$_2$ single crystal, we found, that the magnetic gap, partially opened on the Fermi surface below Neel temperature $T_N = 17.5\, K$, is strongly anisotropic: gapped states mainly correspond to tetragonal $ab$ plane.

At present, strongly correlated superconducting electron systems, including HTSC and heavy fermion superconductors are intensively investigated. The main purpose of our work was to study anisotropy of the magnetic gap in the superconducting UR$_2$Si$_2$ single crystal at $T>T_c$ from temperature dependences of thermal conductivity and STM spectra to compare their character with symmetry properties of the upper critical field $H_{c2}$ near $T_c$.

The measurements were performed on a single crystal about $1\times1\times5\, mm^3$, oriented along $c$-axis, $T_c = 1.16\, K$. Temperature dependence of thermal conductivity, electrical resistivity and Seebeck coefficient of UR$_2$Si$_2$ single crystal along the $c$-axis are shown in Fig.1. Assuming that below $T_N$, $k= AT + BT^3 + A_0 \exp(-\Delta/T)$, the $k$ values being determined by electron, phonon and magnon contributions respectively and neglecting the change in electron part $k_e$ ($k_e < (1/10)k$, see insert on Fig.1), then extrapolating $k=AT+BT^3$ dependence from $T=T_N$ to $T=0$ and subtracting these values from experimental data, we may estimate magnetic gap along $c$-axis $\Delta = 54\, K$.

Fig.2 presents typical anisotropy of dynamical conductivity, $d\sigma/dV$ at $T=2\, K$. For tip direction along $ab$ plane a strong anomaly in $d\sigma/dV$ near zero bias.

Fig.1 Temperature dependences of thermal conductivity, resistivity and Seebeck coefficient along $c$-axis for UR$_2$Si$_2$ single crystal. Insert shows the upper limit of electron part $k_e$. 

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voltage due to gap in the DOS is observed. Depending on tip position and separation between tip and surface, the value of the gap varies up to 20 meV. For tunneling spectra along tetragonal axis only a small asymmetric feature near \( V=0 \) in the \( dI/dV \) curves was seen (Fig.2, insert).

In URu$_2$Si$_2$, below \( T_n \) spin waves with moment transfer and polarization vector along ordered moment $^2$ coexist with gapping of at least half of FS, obtained from heat capacity $^3$. Discrepancy between gap value, estimated from heat transport along c-axis \( \Delta \approx 54K \) and from heat capacity (\( \Delta \approx 150K \)) may originate from the strong anisotropy of magnetic gap. While for magnetic excitations along c-axis only a spin wave gap of 1.8 meV is formed$^2$, calculations of FS in ab plane show gapping of spectrum in A-directions and relatively high DOS in B-points$^4$ (see left insert on Fig.2). Our results are in a qualitative agreement with this FS picture: for c-axis only a relatively small feature in \( dI/dV \) characteristics near \( V=0 \) is seen, but along ab-plane strong anomalies in \( dI/dV \), corresponding to gap at Fermi level up to 20 meV are observed.

Anisotropy of the \( H_{c2}(T) \) studied at the same crystal$^1$, did not reveal 4-fold symmetry in the basal plane, possibly due to the small mean free path. Nevertheless, strong reduction of the \( H_{c2} \) in the c-direction in comparison with ab-plane$^1$ may also reflect symmetry of FS: for \( H II \) electrons are rotating in the ab-plane and crossing regions of gapped DOS, while for \( H II \) ab-plane the probability of such intersections is much less.

Fig. 2 Dynamic conductivity \( dI/dV \) along ab-plane for various tip-sample distances (solid lines) and along c-axis (dashed-dotted lines) at \( T=2K \). Left insert demonstrates calculated in FS picture in the ab-plane.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge to I.M.Shmytko, J.G. Rodrigo for help in experiment, and to M.A.Lopez de la Torre for discussions. The work in MSU was supported by grant N.11/12 from GKNT and in UAM-by grant MAT-88*0716 from Plan Nacional de Materials.

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