MAGNETOACOUSTIC STUDY OF SUPERCONDUCTING TRANSITION IN Sr_2RuO_4

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Introduction

Sr_2RuO_4 is famous for its unusual intriguing spin-triplet electron coupling [1]. The basic properties of its superconducting transition can be understood in assumption of spin-triplet p-wave pairing, described by the spin S=1, S_z=0, and the orbital moment L_z=+1. In this case, one would expect the exponential temperature dependence of quasiparticle excitations. However, specific heat, thermal conductivity, nuclear quadruple resonance relaxation rate, and ultrasonic attenuation, all demonstrate power law temperature dependences [1]. This suggests the presence in the superconducting gap of either line nodes or narrowings. Their particular form constitutes a subject of arguments between different research groups. Some believe that the best explanation of experimental results can be achieved in assumption of vertical (perpendicular to planes of layers) nodes, others insist on assumption of horizontal (within the planes of layers) ones; there are also suggestions of point nodes. This work was set up in order to facilitate resolution of arguments.

Experiment and Results

Sr_2RuO_4 single crystal has been grown by the floating zone technique using URN-2-ZM installation [2]. Two opposite [100] surfaces of the crystal were polished with optical quality. Two 30 MHz transducers attached to these surfaces allowed investigation of longitudinal sound wave propagating in [100] direction in the frequency range 30-300 MHz. The experiment was performed in an 18 Tesla superconducting magnet at temperatures down to 0.4 K. The rather high zero field superconducting transition temperature of 1.25 K confirms a good quality of the Sr_2RuO_4 single crystals. Temperature dependence of ultrasound attenuation is consistent with the other report [3] (see Figure 1(a)). Figure 1 (b) shows the ultrasonic attenuation measured at temperature below T_c as a function of magnetic field. Theoretical curves based on several models from ref. [4] are presented in Figure 1 (b) also. It is seen that the best overall fit can be reached in assumption of the presence of vertical nodes with vertex corrections. However, as it is seen from the inset, at the low values of field the theory fails to reflect the almost linear magnetic field dependence of the experimental data.

Our results indicate that the most probable orientation of the nodes in the superconducting gap is the vertical one. However, the failure of the theory [4] to account for the almost linear dependence of the sound attenuation at low magnetic fields shows that the model needs to be improved.

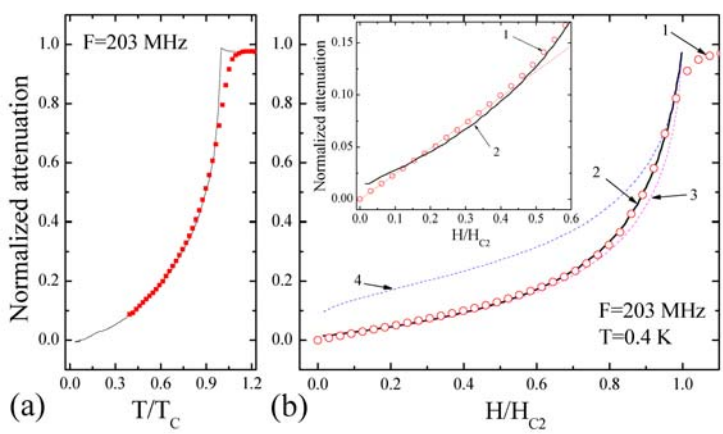

Fig. 1. (a) Temperature dependence of ultrasonic attenuation: this work (squares) and from Ref.[3] (line). (b) Ultrasonic attenuation *vs* magnetic field: measured (#1, red circles); and theoretically predicted [4] for the cases of the vertical nodes with vertexes (#2, black), the vertical nodes without vertexes (#3, magenta), and the horizontal nodes (#4, blue). Inset magnifies the low-field data; the straight line shows linearity of this part of the experimental curve.

Acknowledgements

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References

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