Superconducting transition in quasi-one-dimensional sulfide $A_xV_6S_8$ (A=In,Tl) under magnetic field

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Abstract

Superconducting phase transitions of quasi-one-dimensional compound have been studied by the measurement of AC magnetic susceptibility χ'. The χ' of powdered sample decreased stepwise, which was characterized by two transition temperatures T_{C1} and T_{C2}. The T_{C1} is considered to be the transition within the grains, and T_{C2} is the inter-grain transition. Under the magnetic field, T_{C2} shifted to the lower temperature. The magnetic field dependence of T_{C2} is presented.

Key words: Superconducting transition; Nb_3Te_4 type structure; Quasi-one-dimensional structure; Inter-grain transition

$A_xV_6S_8$ which belongs to Nb_3Te_4 type structure (space group $P6_3$) has a quasi-one-dimensional structure with the V-V zigzag chains running along the c-axis[1]. Superconductivity of $A_xV_6S_8$(A=In,Tl) was found in resistivity measurements by Bensch *et al.* [2]. Recently, we have confirmed the superconductivity in these sulfides by the measurements of χ', and have newly observed the superconductivity in KV_6S_8, RbV_6S_8 and CsV_6S_8 [3]. The χ' of the powdered samples showed stepwise decrease characterized by two transition temperatures T_{C1} and T_{C2} [4]. The higher transition temperature T_{C1} is considered to be the intra-grain transition temperature, and T_{C2} corresponds to the inter-grain transition temperature. In the present study, we have investigated the behavior of T_{C2} by applying the external magnetic field.

The procedures of sample preparations are described in Ref. 3. The powdered sample consists of small rod-like single crystals with 10∼30 μm in length and 2∼6 μm in diameter. The sample was packed in a copper cylinder with 5 mm in height and 3 mm in diameter with the pressure of 1700 MPa for 3 min. in order to make adequate contact between grains, and then a cap was screwed into the cylinder. The sample cell was thermally connected to the mixing chamber of a dilution refrigerator. The 16 Hz-AC-magnetic susceptibility was measured employing a SQUID as a null detector, and AC magnetic field produced by primary coil was $\sim 10^{-6}$ T. A permalloy case was attached outer the saddle magnet for external field so that the residual DC field at sample position was reduced to $\sim 10^{-7}$ T.

Fig. 1 shows the temperature variations of χ' of sintered InV_6S_8 observed at 10^{-7} T, 2×10^{-3} T, 5×10^{-3} T and 10^{-2} T. The χ' decreased quite sharply at 3.5 K, and the transition temperature was not influenced by the magnetic field. In the next stage, the same sintered InV_6S_8 sample was crushed into powders and packed by pressing. Fig. 2 shows the temperature variations of χ'. The powdered sample showed two steps, and the step at higher temperature was not influenced by the application of external field. On the other hand, the inflection point which is denoted as T_{C2} shifted to the lower temperature as the increase of magnetic field.

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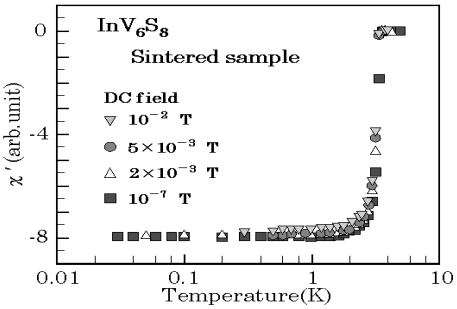

Fig. 1. Temperature variations of χ' for sintered InV_6S_8 under various magnetic fields.

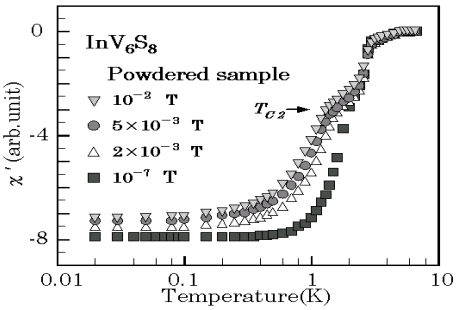

Fig. 2. Temperature variations of χ' for powdered InV_6S_8 under various magnetic fields.

The temperature variations of χ' are explained by following consideration. As the temperature decreases, the energy of Josephson coupling between grains becomes to exceed the thermal energy, and thus the inter-grain superconducting transition would occur at T_{C2}. Above T_{C2}, the AC magnetic field produced by primary coil penetrates the surface of each grains even at zero external field. Below T_{C2}, the penetration volume becomes negligibly small since the shielding current flows the surface of the packed sample. Fig. 3 shows the temperature dependence of χ' of powdered $In_{0.71}V_6S_8$ under various magnetic fields. The values of χ' were not varied for the zero field cooling and the field cooling measurements in all samples.

The similar intra-grain and inter-grain superconducting transitions have been reported for high T_C ceramic superconductor (YBCO) and $BaPb_{1-x}Bi_xO_3$ (BPBO) [5-7]. According to Ref. 7, the magnetic field dependence of T_{C2} is represented as follows,

$$H = H_0(1 - T_{C2}/T_0)^n \qquad (1)$$

where H is applied magnetic field, H_0 is constant and T_0 is the inter-grain transition temperature at H=0. The values of n, T_0 and H_0 are respectively 0.5, 56 K and 5×10^{-2} T for YBCO, and are respectively 1.5, 7.65 K and 0.3 T for BPBO [7]. Fig. 4 shows the magnetic field dependence of T_{C2}/T_0 for InV_6S_8 and $In_{0.71}V_6S_8$. The obtained values of n, T_0 and H_0 are

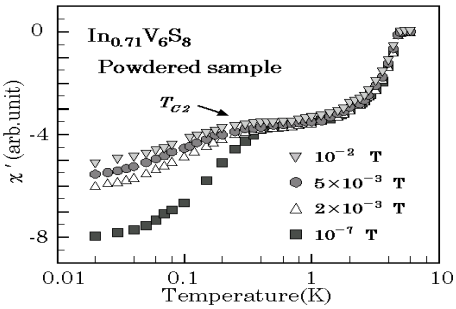

Fig. 3. Temperature variations of χ' for powdered $In_{0.71}V_6S_8$ under various magnetic fields.

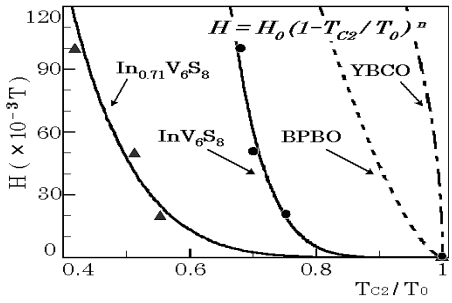

Fig. 4. Magnetic field dependence of inter-grain transition temperatures for InV_6S_8 and $In_{0.71}V_6S_8$.

respectively 6.1, 1.97 K and 9.1 T for InV_6S_8 and are respectively 5.8, 0.37 K and 0.26 T for $In_{0.71}V_6S_8$. The shape of H-T_{C2} curve shown in Fig. 4 is concave upward similar to BPBO. However, the value of n is large compared with BPBO, and the shift of T_{C2} is remarkable at low magnetic field. In order to analyze more precisely the effect of magnetic field on T_{C2}, it is necessary to investigate the effect in other AV_6S_8 samples.

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