Longitudinal and transverse voltages have been measured on Bi-based superconductors in zero external magnetic fields. In close vicinity of the superconducting transition nonzero transverse voltage has been observed while far away from $T_c$, both above and below no such voltage has been detected. The value of the transverse resistivity depends on the value of the transport current. Several models have been discussed taking into account also the penetration of self field due to the applied transport current. It seems that observed results can be explained using the Kosterlitz-Thouless model as a result of an unpairing of vortex-antivortex pairs created below $T_KT$ due to fluctuations. At $T_KT$ free vortices and antivortices are created and can contribute to a dissipation of energy. Their movement should also be responsible for the observed nonzero transverse voltage.

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1. Introduction

High $T_c$ superconductors represent an interesting group of substances for both theoretical and experimental investigations. A lot of new phenomena has been observed for the first time on these materials. For practical applications the most important properties of interest are those belonging to the group of dynamic properties, i.e. physical effects in electric field. From the point of view of fundamental research the well characterized single crystalline samples are asked for. But one should have in mind that polycrystalline ceramic materials rather than single crystals will be the main components of superconducting devices. It is thus necessary to study the properties of such polycrystalline systems as well. In this paper we deal with transport properties of highly textured Bi-based (2223) polycrystalline bulk superconductors in zero magnetic field. The temperature dependence of longitudinal and transversal resistivity has been studied in close vicinity of the transition temperature.

2. Experimental

Two different methods of transport measurement have been used. For the sample in the form of thin stripe standard six point contact method was used with contacts for the measurement of longitudinal and transverse voltage, respectively. The misalignment of transverse contacts was corrected for by measuring the transverse voltage in the regime where no Hall voltage should appear i.e. well above transition temperature where the sample was in the normal state.

Several samples were measured by the van der Pauw method [1]. In this case the samples were either in the form of a square or disk with the contacts equally spaced on the perimeter of the sample. The thickness of the samples was in all cases below 250 $\mu$m. The dependence of the observed nonzero transverse voltage on the current was also measured by both methods. The reason for using standard six point method as a supplement to the van der Pauw method was to verify if the non-homogeneous current distribution in the latter method is not responsible for the observed effect. The results for all type of the samples...
and methods were qualitatively the same. Results of the van der Pauw measurement are shown in Figs. 1 and 2 for the samples of disk shape of 15mm diameter with thickness of the disk 120µm. From this graph one can clearly see that in the close vicinity of the $T_c$ nonzero transverse voltage appears which is absent both well bellow and above $T_c$. One can also see the non symmetric shape of the transverse voltage peak. As to the current dependence of the resistance peak its height increases with the increasing current passed through the sample. The current not exceeding 50 mA was used in all measurement. For such currents we did not observe any heating effects. This conclusion has been confirmed by two facts: no change of the measured voltage was detected upon varying the equilibration time (i.e. the period between switching-on the current and measuring the voltage) and no shift was seen in the temperature where longitudinal voltage vents effectively to zero value.

3. Discussion

Glazman proposed a model for the explanation of the observed effect. Magnetic field produced by the current going through sample can penetrate into the sample in the form of vortices of different sign. This sign is determined by different direction of magnetic field on the opposite sides of the sample resulting in vortices penetration from one side and antivortices penetration from the opposite one. Vortices and antivortices move in opposite direction under the influence of Lorentz force and can annihilate if the attractive interaction between them overcomes the Lorentz force. This means that the path of vortex and antivortex will be distorted and transverse voltage appears according to the Josephson relation. With increasing current the Lorentz force is stronger and the probability of annihilation decreases i.e. for high enough current the trajectories of vortices and antivortices are not influenced by their interaction. They can therefore move perpendicularly to the edges until they reach the opposite side of the sample.

According to this theory the transverse voltage value should increase for low transport current and again decrease for high enough current. We have changed the transport current by two orders of magnitude in our experiments and did not observe any decrease of transverse voltage. Similar effect was observed by Francavilla et al. on thin sputtered YBaCuO films of unknown thickness using currents up to 180 mA. Moreover the calculated magnetic field on the surface of our sample is in the range of units of $\mu$T. At such small magnetic fields the concentration of vortices and antivortices is probably too small to initiate the observable voltage.

In the following we will propose another explanation of the above mentioned effect. Since Bi based materials are strongly anisotropic their electrical behavior should reflect the two-dimensional-like nature. Near the percolation transition when the phase of the wave function becomes coherent along a privileged path in the sample and weak links among grains become irrelevant, the behavior should be similar to that occurring at Kosterlitz-Thoules temperature $T_{KT}$. Bellow $T_{KT}$ vortex-antivortex pairs are thermally activated. At $T_{KT}$ these pairs spontaneously dissociate into free vortices. These free vortices and antivortices can move under the influence of external fields and cause in this way dissipation of the energy above $T_{KT}$. There are two possibilities how to determine $T_{KT}$. First one, most simple, is to determine this temperature as that at which the resistance of the sample reaches zero value at zero magnetic field. It is commonly believed that the beginning of the dissipation is connected with the creation of free vortices and with their movement. According to the Coulomb gas model there are no free vortices present below $T_{KT}$ and no flux-flow resistance. However free vortices should, according to this model, be generated below $T_{KT}$ provided a finite current is imposed across the superconducting sample. The Coulomb gas model prediction for the flux-flow resistance generated below $T_{KT}$ in this way is equivalent to a nonlinear I-V characteristic of the form $V = I^{\alpha(T)}$. Precisely at $T_{KT}$ the prediction for the exponent is $\alpha = 3$ which was confirmed by many of experiments. The exponent $\alpha(T)$ for our measurement is shown in Fig. 3. One can see that the value
\[ \alpha = 3 \] corresponds to the temperature 104 K i.e. \[ T_{KT} = 104 \text{ K} \]. This value roughly coincides with the temperature where resistance in zero magnetic field effectively reaches zero (see Fig. 1). It is shown in Fig. 2 that the nonzero transverse resistance starts at the same temperature. Set of free vortices and antivortices created above \( T_{KT} \) is forced to move by Lorentz and Magnus forces and dissipation can start and according to the Josephson relation the nonzero transverse resistance appears. This suggestion is also supported by sudden increase of the resistivity from the side of low temperatures.

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Figure captions

Fig.1: Temperature dependence of longitudinal resistance \( R_{xx} \) for different current in zero external magnetic field

Fig.2: Temperature dependence of transverse resistance \( R_{xy} \) for different current in zero external magnetic field

Fig.3: Temperature dependence of the exponent \( \alpha \) for nonlinear I-V characteristics \( (V = I^\alpha) \)
