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Phase diagram for $(Tl_{0.5}Pb_{0.5})(Ba_{0.2}Sr_{0.8})_2Ca_2Cu_3O_{8+\delta}$ (Tl-1223) polycrystalline sample with optimum oxygen content

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Abstract

The magnetic field–temperature phase diagram (*B–T*) of a optimally doped sample belong to $(Tl_{0.5}Pb_{0.5})$-$(Ba_{0.2}Sr_{0.8})_2Ca_2Cu_3O_{8+\delta}$ was studied thought resistivity and magnetization measurements. The phase diagram of this compound was built identifying four characteristic regions inside it. The thermally activated flux flow region (TAFF) followed both, the Yeshurum-Malozemoff and Tinkham's models. The magnetic field dependence of U_{eff} does scale with $B^{-0.5}$ signalising pinning mechanism similar to the ones found in Bi-2212.

1. Introduction

The magnetic field–temperature phase diagram (*B–T*) has an unusual richness of physical properties. It is well established the existence of an irreversibility line above which there exist a vortex-liquid state, with thermally activate or diffusive motion, of the vortex-lattice (VL). This effect leads to dissipation and its study is very important, from both, physical and technological point of view. The phase diagram and its vortex dynamics of high-T_c materials have been study in YBCO, Bi-2212 and recently in Hg-1223 systems. The Tl-1223 system has the second higher critical temperature (about 122 K) of the HTSCs, which strengthens the possibility of its use in technological applications.

In this work we extrapolate common studies on the vortex phase diagram of other HTSCs on a polycrystalline sample belong to the system $(Tl_{0.5}Pb_{0.5})$-$(Ba_{0.2}Sr_{0.8})_2Ca_2Cu_3O_{8+\delta}$ (Tl-1223) through resistivity and magnetization measurements. The theoretical analysis of the TAFF behaviour was performed using the Yeshurum-Malozemoff and Tinkham's models. Both models achieve a good fit of the experimental line. The $U_{eff}(B)$ dependence does not scale with the expected B^{-1} form signalising a more complicate pinning mechanism.

2. Experimental

The high-quality Tl-1223 polycrystalline sample was obtained as described by Ref. [5]. Four low-resistance electric contacts were attached to the sample using silver paint. Resistivity measurements in presence of external magnetic fields were made through the four-point method. Measurements of magnetization were made using a SQUID magnetometer (Quantum Design).

3. Results and discussion

In the inset of Fig. 1 it is shown the resistivity transitions for different applied magnetic field. The T_c for each curve was obtained from the maximum of the $d\rho/dT$ curve and it allowed to obtain the $B_{c2}(T)$ curve. The slope of $B_{c2}(T)$ near T_c is given by $dB_{c2}(T)/dT \sim -1.3$ T/K. The $T_c(0)$ was about 122 K. Following Ref. [6] we get $U_{eff} = -k_B d(\ln(\rho/\rho_0)/d(1/T) = U_0(T) - T dU_0(T)/dT$. In order to compared our experimental results we model the temperature dependent of U_0 according to the Yeshurum-Malozemoff (YM) model, $U_0(T,H) = U_0(0,H)(1 - T/T_c)^{3/2}$. Substituting U_0 in the

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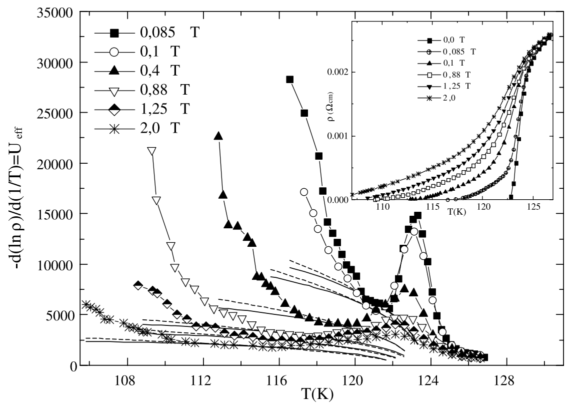

Fig. 1. Arrenius plot of the $R(T)$ curve for different applied fields.

expression for U_{eff} we arrive to: $U_{eff} = U_0(0,H)(1 - T/T_c)^{3/2}[1 + (3/2(T/T_c))/(1 - T/T_c))]$. On the other hand, in the Tinkham's model we have $U_0(T,H) = U_0(0,H)(1 - (T/T_c)^2)(1 - (T/T_c)^4)^{1/2}$. With a similar approach we have: $U_{eff} = -2U_0(0,H)(T/T_c)/(1 - (T/T_c)^4)^{1/2}T_c\{(1 - (T/T_c)^4) + (1 - (T/T_c)^2)(T/T_c)^2\}$.

In Fig. 1 we plot U_{eff} (T). The dashed line represents U_{eff} for the YM model and the solid line is the Tinkham's one. The two models fit the data very well in a narrow region (TAFF region), which decrease with the field. It should be point out that at high temperatures ($T/T_c > 0.5$) the Tinkham's model takes a limit form similar to the YM model. Similar analysis in YBCO epitaxial film [4] was made using Tinkham's theory while in Hg-1223 film [1] the YM model was used. Upon the temperature decreases, there is an abrupt increase for U_{eff} at a certain temperature identify as T^*. This effect is more abrupt for high-fields and it has been notified in Hg-1223 and other compounds [1,2]. For higher temperatures, the flux flow regime controls the dissipation mechanism. We identify T_{ff} (between T^* and T_c) as the temperature where flux flow arises [1].

The fit of $U_0(0,B) \sim 1/B^{\alpha}$ in the TAFF regime gave $\alpha \sim 0.484$ for YM and $\alpha \sim 0.473$ for the Tinkham's one. Similar experiment [1,2,4] shows $\alpha \sim 0.48$ for Bi-2212, $\alpha \sim 1.1$ for Hg-1223 and $\alpha \sim 1.28$ for YBCO. Our results are similar to the ones in the low field region of Bi-2212. It should be noted that in this field region the flux spacing line is smaller than the penetration length and, in particular for high-T_c materials like our case here, the pinning mechanism would be associated to collective effects. The U_{eff} magnitude is around 10^4 K higher than the one for Bi-2212 [2] and Hg-1223 and similar to the found in YBCO [4]. Thus our Tl-1223 (polycrystalline sample) showed high activation energy meaning a low anisotropy, as reported for compounds in Ref. [3].

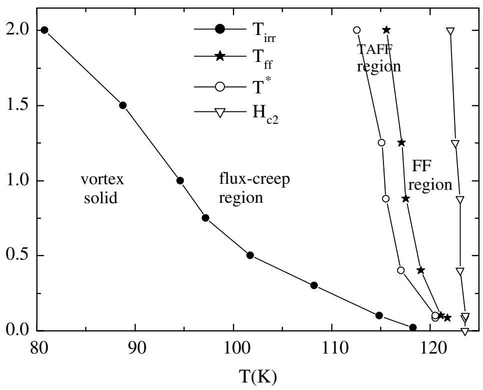

Fig. 2. Phase diagram for the Tl-1223.

The phase diagram of Tl-1223 polycrystalline is shown in Fig. 2. There is four regions well defined, the flux flow region (FF), the thermally activated flux flow region (TAFF), the flux-creep critical region and, finally, the vortex solid region. The irreversibility line (found through magnetizations measurements) separates the solid from the liquid phase. It should be noted that this diagram can be modify by the current as it has been noted by Zeldov et al. [4].

4. Conclusion

The phase diagram of polycrystalline Tl-1223 was built. In the TAFF region, the YM and Tinkham models can explain the data. More significantly, the magnetic filed dependence of the pinning energy in both models does not scale with B^{-1}. $U_{eff}(B)$ was proportional to $1/B^{0.5}$. The origin of this difference could be associated to different mechanism dissipation and it requires further study.

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