High-Field Study of Superconducting Thallium Doped Lead Telluride ($Pb_{1-x}Tl_xTe$)

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Introduction

PbTe is a narrow-band gap semiconductor. Pb vacancies and/or Tl doping place the Fermi level in the valence band, yielding a degenerate semiconductor with low carrier densities. For Tl concentrations above a critical value x_c~0.3%, the material superconducts, with a maximum transition temperature of 1.5K, unusually high given the low carrier density. This critical concentration coincides with the appearance of anomalous normal state transport properties that were previously interpreted as evidence for a novel charge Kondo effect associated with charge fluctuations of the Tl impurities [1, 2]. Our Magnet Lab proposal was aimed at obtaining a better understanding of the evolution of the Fermi surface of $Pb_{1-x}Tl_xTe$ through the threshold Tl concentration, in order to provide a much better basis for interpreting the doping effect of Tl-impurities in PbTe, and perhaps the anomalous normal state properties, too.

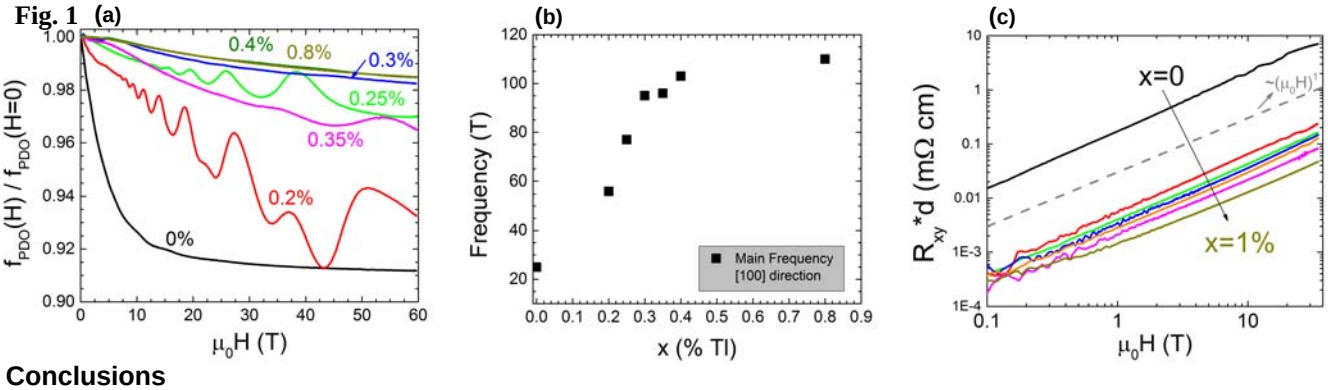
Experimental

We performed measurements of frequency shift in a proximity detector oscillator (PDO) for samples of $Pb_{1-x}Tl_xTe$ with Tl concentrations ranging from x=0 to x=1%. These measurements were performed at the Pulsed Facility, in a 65T magnet. Additionally, we performed full angle dependence measurement for two samples with compositions above and below the critical concentration of x_c=0.3%, obtaining a complete study of the Fermi surface for such compositions. Furthermore, we performed measurements of magnetoresistance and Hall Effect in the DC facility, using a 35T magnet.

Results and Discussion

For all the compositions studied we were able to observe Shubnikov-de Haas (SdH) oscillations, and to determine the area of the Fermi surface and the effective mass of carriers in the [100] direction. Our results are consistent with a single band picture, as we observe a single frequency in the SdH oscillations along this direction (Fig. 1(a)). This frequency, coming from carriers in the L pockets, increases rapidly with Tl concentration, and then saturates for compositions above the critical concentration of x_c=0.3%, as shown in Fig. 1(b). A single band picture is also supported by Hall measurements taken in the DC facility, shown in Fig. 1(c), which reveal a Hall signal that is linear for fields up to 35T, with possible non-linearities for the lower Tl concentrations, related to deviations from the weak field limit regime (i.e., proximity to the quantum limit).

Fig. 1



Conclusions

SdH and Hall measurements reveal the existence of only one type of carriers for compositions across the critical x_c=0.3% value, with Fermi level pinning above this concentration.

Acknowledgements

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References

[1] Matsushita, Y., *et al*., Phys. Rev. Lett. **94**, 157002 (2005).
[2] Dzero, M., *et al*., Phys. Rev. Lett. **94**, 157003 (2005).