Electron Paramagnetic Resonance Characterization of Cr-doped Bi_2Se_3 Topological Insulators

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Introduction

A topological insulator (TI) is an emerging material with new states of quantum matter [1]. The bulk interior has an insulating energy band gap while the sample boundary exhibits a gapless edge or surface states, providing quantum-Hall-like behavior with quantized conductance of charge and spin in the absence of a magnetic field [2,3]. These surface states are helical edge states, which interconnect spin and momentum of the carriers. Introducing magnetic impurities on the surface or bulk of the topological insulators has been proven to be a successful way to open a gap in the Dirac-cone-like dispersion spectrum of the surface states. We have synthesized Cr-doped Bi_2Se_3 thin films with a thickness of 6 quintuple layers (QLs) grown on lattice-matched InP (111) substrates by molecular beam epitaxy (MBE). We report an Electron Paramagnetic Resonance (EPR) characterization with both continuous-wave and pulsed techniques.

Experimental

Thin film samples are prepared using molecular beam epitaxy (MBE) at UCLA. High field EPR measurements at 240 GHz were done on home-built super-heterodyne instrument at the National High Field Magnetic Laboratory, Tallahassee, FL.

Results and Discussion

Figure 1 shows the temperature dependence of EPR spectrum of a 10% Cr-doped Bi_2Se_3 sample at 240 GHz. The spectrum at 100 K contains three even spaced peaks, and as the temperature is lowered the right two peaks get smaller. Those observations confirm the S = 3/2 spin state of Cr as indicated by our earlier studies with SQUID. Below 5 K, the center peak disappeared first, which is not very unusual and interesting. We are continuing to investigate this phenomenon.

In order to probe the spin dynamics of doped Cr in TI, spin relaxation times (T_1 and T_2) were measured by pulsed EPR. Spin echo was observed up to ~10 K. As shown in **Figure 2**, at the low temperature regime, T_2 shows a sharp decrease at ~4.3 K which indicates a phase transition. Considering our transport measurements, the phase transition should be ferromagnetic to paramagnetic. T_1 stays relatively constant up to 5 K, implying that above phase transition does not influence spin-lattice relaxation a lot at studied temperatures.

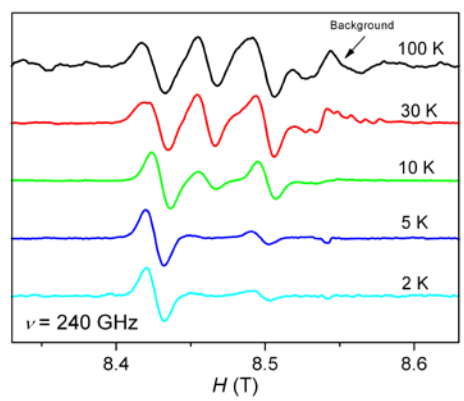

Figure 1. Cw-EPR spectra of Cr-Bi_2Se_3.

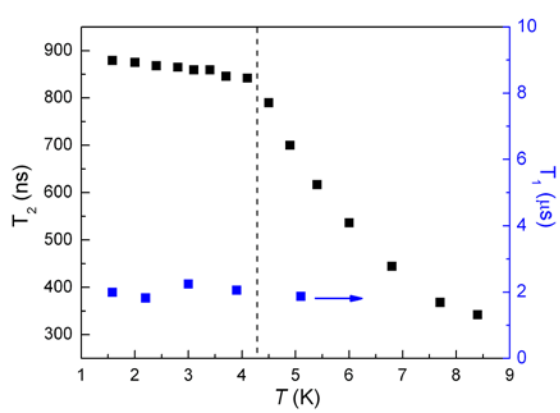

Figure 2. T_1 and T_2 of Cr-Bi_2Se_3.

Conclusions

We have successfully observed the EPR signals and studied the spin relaxation in a Cr-doped TI sample, which has not been reported in literature. EPR has been proved as a promising technique to study the TIs. We are undertaking more detailed work on this project.

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References

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