CALIFORNIA STATE SCIENCE FAIR
2014 PROJECT SUMMARY

Name(s)
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Project Number
S1825

Project Title
Time-Resolved Optical Study of the Surface States of the Topological Insulator Bi(2)Se(3)

Abstract

Objectives/Goals
The objective was to measure the spin lifetime of surface states on the topological insulator Bi2Se3 by a direct all-optical method.

Methods/Materials
A pump-probe femtosecond time-resolved optical study was performed on the surface of a (111)-oriented Bi2Se3 sample. The sample was cleaved in air at room temperature using the tape-method. The 828 nm pump was incident with controlled polarization states and varied with a photoelastic modulator. The second-harmonic (SH) frequency of the probe pulse at 414 nm generated at the surface was detected with a photomultiplier and lockin detection. The sample's in-plane orientation was set to obtain surface-specific signals due to spin-polarized states.

Results
An ultrarapid transient probe SH response was observed due to the pump. The signal sign changes when the helicity of the pump and the linear-polarization of the probe are reversed and provides a double-confirmation that the transient is due to spin-polarized surface carriers. The spin-lifetime is extracted from the data by curve-fitting with the measured pump-probe cross-correlation and model-fitting to be ~50 fs. A longer transient on the ~1 ps time-scale does not depend on the helicity of the pump and is due to field-screening. The change in field-screening in the ~1 hr after cleaving in air indicate that the surface Fermi level increases after cleaving.

Conclusions/Discussion
3-D Topological insulators, such as Bi2Se3 are a new class of materials in which surface electronic states are topologically protected from backscatter: the electrons moving in opposite directions have opposite spins and therefore backscatter requires spin-flipping. Here we have succeeded in unambiguously measuring the spin-lifetime of laser-excited carriers, but the lifetime is very short. This is likely due to the surface Fermi Level being in the bulk conduction band so that pump-induced spin-polarized surface holes are rapidly filled by bulk conduction electrons that scatter into the surface states. Observing a longer and protected spin-lifetime will require controlling the surface Fermi Level.

Summary Statement
Successful measurement of the spin-lifetime of laser-excited carriers in 3D Topological insulators, a new class of materials in which unique surface electronic states are topologically protected from backscatter.

Help Received
Used lab equipment at University of California Riverside.