Name(s)

Nikita Salunke

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Project Title

Effect of Epitaxial Compression on Structural & Electrical Transport Properties of 3D Topological Dirac Semimetal Cd3As2

Abstract

Objectives

Three-dimensional topological Dirac semimetals (3D-TDSM) have been increasingly studied in the areas of materials science and condensed matter physics due to their unusual three-dimensional linear electronic band dispersion and non-trivial band topology. Devising a method to tune the band dispersion of 3D-TDSMs could revolutionize the field of electronics. This study aimed to determine if an epitaxial compression could alter the electronic transport properties of Cd3As2, a 3D-TDSM.

Methods

In the study, Cd3As2 thin films were grown on (In(x)Ga(1-x))Sb buffer layers deposited on a GaAs substrate. Specifically, since the Cd3As2 lattice parameter lies between that of GaSb and InSb, the concentration of indium and galium in the buffer layer were varied to induce an epitaxial compression in the Cd3As2 thin film during growth. The following four indium concentrations were each deposited onto its GaAs substrate: 0.76 In (lattice match), 0.74 In (0.195% lattice mismatch), 0.70 In (0.483% lattice mismatch), and 0.66 In (0.661% lattice mismatch).

X-ray diffraction readings were used to determine the lattice parameter of the films and assure the crystal/film quality. Additionally, atomic force microscopy served to confirm the surface morphology of the expitaxially compressed Cd3As2 thin films. Further, X-ray diffraction readings confirmed that Cd3As2 can be epitaxially strained up to a 0.661% lattice mismatch via a reciprocal lattice space map.

In order to study the low temperature electrical transport properties of the Cd3As2 thin film, physical property measurements were taken on the DynaCool machine. Specifically, Hall Bars were prepared on the thin films in the clean room and were then placed in the DynaCool to determine the sheet resistance, mobility, and sheet density of the epitaxially compressed thin films at variable temperatures.

Results

The study found that the heteroepitaxial films exhibited differing electrical transport with the lattice match thin film having the highest mobility. The change in mobility, sheet resistance, and sheet density of the heteroepitaxial films suggests that the band dispersion of Cd3As2 had changed.

Conclusions

Thus, the study confirmed that an epitaxial strain can be induced in Cd3As2 thin films and that this expitaxial strain may yield an altered band structure through growing the thin film on variable (In(x)Ga(1-x))Sb buffers. Collectively, this study demonstrated that epitaxial compression can be used successfully to alter the electronic transport properties of 3D-TDSM thin films.

Summary Statement

This study shows that an epitaxial compression can be used to alter the electronic transport properties of Cd3As2, a three-dimensional topological Dirac semimetal.

Help Received

This research is conducted at University of California, Santa Barbara Materials Research Lab under the guidance of Doctoral Student Manik Goyal.