Magnetotransport of the Dirac Semimetals Na_3Bi and Cd_3As_2

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Ultrahigh Mobility and Giant Magnetoresistance in Dirac Semimetals

We have investigated high-field transport in the two Dirac semimetals Na_3Bi and Cd_3As_2. In the Dirac semimetal, the bulk Dirac nodes are protected against gap formation by crystalline symmetry and time-reversal symmetry (TRS). An applied magnetic field is predicted to break TRS and split each Dirac node into Weyl nodes with opposite chirality, resulting in novel transport features. We have uncovered several anomalies in the magnetotransport properties of both Dirac semimetals. In related research, we have also investigated the dichalcogenide WTe_2 which has matched electron and hole pockets. At 4 K, the observed magnetoresistance (MR) is exceptionally large. In pulsed fields (60 T), the MR ratio attains values exceeding 10^5 without evidence of saturation.

Experiments

Hall and MR measurements on both Na_3Bi and Cd_3As_2 were performed in the 33 Tesla DC magnet at selected tilt angles of the field **H**. Using the pulsed field facilities at Los Alamos, we extended measurements in Cd_3As_2 to 65 T. In addition, the MR in WTe_2 was measured in pulsed fields to show the absence of saturation up to 65 T.

Results and Conclusions

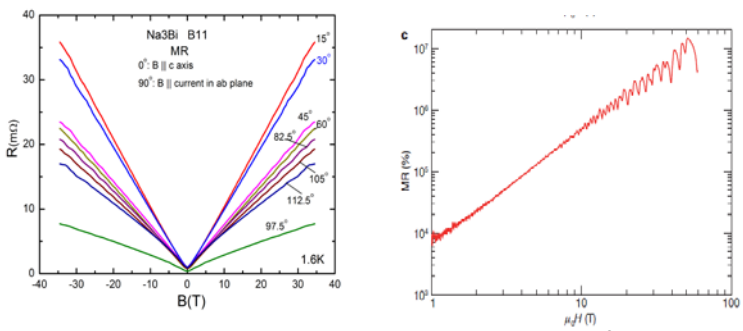

Figure 1 (Left panel) Striking *H*-linear MR observed in Na_3Bi.[2] (Right panel) Non-saturating MR in WTe_2.[3]

1) A surprising result in the Dirac semimetal Cd_3As_2 is the observation[1] that its mobility can reach values as high as 9 million cm^2/Vs in zero field (nearly comparable to MBE grown GaAs heterostructures). In applied **H**, the mobility is rapidly degraded, resulting in either an *H*-linear MR or H^2 MR in ultrahigh-mobility samples. The high-field experiments confirmed the MR behavior. We were also able to reach the quantum limit (last Landau level) in a field of 40 Tesla.
2) In the Dirac semimetal Na_3Bi, we observed[2] a striking *H*-linear MR that extends up to 34 T. We also found that the Hall angle shows a step-function profile vs. *H*, which supports our inference that, in Dirac semimetal, the Dirac electrons are protected against backscattering in zero *H*. A finite *H* kills the protection presumably by breaking TRS.
3) In WTe_2, we showed[3] using pulsed fields that the giant MR ratio (~2,000 at 15 T) extends to values as high as 200,000 in pulsed fields up to 65 T (Fig. 1). Unlike in pure Bi or graphite, the MR shows no signs of saturation at large *H*.

Acknowledgements

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References

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[3] Mazhar N. Ali, *et al.* "Large Magnetoresistance in WTe_2," *Nature* **514**, 205 (2014). doi:10.1038/nature13763