Weyl Semimetals and the Interface: Surface State Transport Probed Via Weak Antilocalization in Ultrathin TaAs Films

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Topological semimetals hold promise for their use in low-powered electronics and spintronic devices [1-4] but these applications await targeted growth on conventional semiconducting substrates and the exploration of their properties in the ultrathin limit. Weak antilocalization (WAL) has been used extensively in the study of surface states in topological insulators and shows promise for the study of surface states in Weyl semimetals (WSMs). WAL is a quantum interference effect that results in an increase in a system's conductivity owing to the suppression of back-scattering from self-intersecting carrier paths. This quantum interference requires carriers maintain phase coherence over multiple scattering events. The length over which carriers maintain coherence is defined as the decoherence length. In an applied field, the WAL is destroyed when the magnetic length approaches the decoherence length, offering a natural insight into the localizing disorder length scales. Here we report on insights from WAL into the surface state and interface properties of the recently synthesized, single-crystal-like ultrathin films of Weyl semimetal TaAs(001) grown on GaAs(001) substrates [5-7].

Figure 1 shows atomic force microscopy and magnetoconductance for representative TaAs ultrathin films. AFM on a 10 nm thick TaAs film on GaAs reveals oriented, rod-like growth along $\vec{r}_n$ – the $(\bar{1}10)$ direction. At low temperatures, the magnetoconductance exhibits clear signatures of WAL. Intriguingly, we find that the number of apparent WAL conduction channels depends on the orientation of the applied current relative to the film topography as well as the number of GaAs/TaAs interfaces. We hypothesize that this unique anisotropic WAL stems from a topological and trivial state with different decoherence lengths localized at each interface.

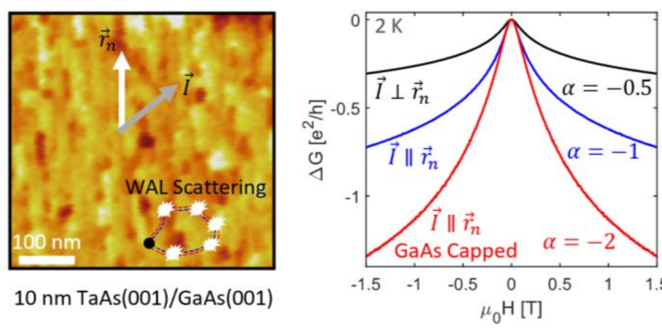

Figure 1: AFM (left) and magnetoconductance (right) for 10 nm TaAs(001) grown on GaAs(001). Rod-like features approximately 100 nm long and 20-40 nm wide are oriented along the $(\bar{1}10)$ direction. The vector $\vec{r}_n$ defines the orientation of the rods. The measured magnetoconductance We observe a magnetoconductance that depends on the orientation of the applied current relative to the film topography as well as the number of GaAs/TaAs interfaces.

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