Helical State in Ge/Si Core/Shell Nanowire

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A helical state, exhibiting spin momentum locking, is predicted to emerge in 1D ballistic semiconductor nanowires (NWs) possessing strong Rashba spin-orbit interaction under an appropriate applied external magnetic field. Such a helical state is a key ingredient for the realization of Majorona zero modes, and has application for spin filtering, and Cooper pair splitters. A distinct experimental signature of the helical state is a re-entrant conductance gap feature at the $2e^2/h$ conductance plateau as different portions of the band dispersion are probed. Recently the helical state has been experimentally detected in the lowest subband of InAs and InSb NWs [2]. Hole systems offer several potential advantages for spintronics and quantum information processing application, having an effective spin of $\boldsymbol{J} = 3/2$, momentum and spin are strongly coupled, enabling pure electric spin manipulation. Additionally, hole spin lifetimes can be significantly prolonged in the presence of confinement.

Here, we report the experimental measurement of helical hole states in a quantum point contact formed in a Ge/Si core/shell NW. Owing to a large valance band offset ~ 0.5 eV between Ge and Si, holes are naturally accumulated in the Ge core and strongly confined by the interface with the Si shell [3]. The dopant-free growth leads to the high mobility with mean-free-path up to ~500 nm. In addition, both Ge and Si lack nuclear spin which through hyperfine coupling is the typical leading contributor to the limit of spin coherence times for III-IV based qubit devices. More importantly, a strong dipole-coupled Rashba type SOI is predicted in Ge/Si NWs as a result of the quasi-degeneracy in its low energy valence bands [4], as such Ge/Si NWs are a promising material system to investigate helical hole states. The helical hole state is detected as a re-entrant conductance feature on conductance plateaus observed at integer multiples of $2e^2/h$. The helical spin-gap feature is confirmed by both magnetic field dependence and angular dependence, from which we can also extract a strong spin-orbit energy E_{so} = 2.8 meV and large Landé g-factor of 4.7. They show good agreement with previous theoretical predictions and our previous weak anti-localization measurements.

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