Magnetotransport properties of mesoscopically patterned narrow-gap semiconductors: localization and spin-orbit interaction effects

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The search for methods to create spin-polarized carrier populations in semiconductors, as part of a wider endeavor in spin electronics, has led to much present research in spin-dependent phenomena in semiconductors. Narrow-gap semiconductors, such as InSb and InAs, merit attention in this search, as they combine strong spin-orbit interaction with reasonably long electronic spin lifetimes and high electron mobilities. We will present experimental studies of electronic properties in mesoscopically structured narrow-gap semiconductor heterostructures, in which spin-orbit interaction is strong, leading to a variety of magnetotransport phenomena. Narrow-gap semiconductor quantum wells, featuring a high mobility besides the strong spin-orbit interaction, offer possibilities for spin manipulation in nanoscale geometries. We describe and demonstrate a method to create spin-polarized ballistic electrons through spin-orbit interaction in a two-dimensional electron system in an InSb/InAlSb heterostructure. The method utilizes intentional spin-flip scattering from a lithographic barrier towards spin manipulation. Furthermore, we investigate low-temperature magnetotransport properties of antidot lattices fabricated on InSb/InAlSb and InAs/AlGaSb heterostructures. In InSb/InAlSb, the magnetoresistance shows a strong localization peak at zero magnetic field as well as ballistic peaks due to the antidot lattice. The strength of the localization peak decreases exponentially, with a characteristic temperature of ~ 25 K, as the temperature increases from 0.4 K to 50 K. The exponential behavior and high characteristic temperature can be explained by classical scattering in chaotic systems. In InAs/AlGaSb heterostructures, the antidot lattice magnetoresistance shows a rich spectrum of behavior at low magnetic fields. Anti-localization appears at the lowest magnetic fields, superposed on the localization peak, in addition to several new low-field magnetotransport features. For both InSb/InAlSb and InAs/AlGaSb heterostructures, the localization and anti-localization behavior is interpreted in the light of the varied strength of spin-orbit interaction in the materials.

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