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Carrier density-dependent mobility in semiconductor nanostructures

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Increasing material quality and carrier mobility of semiconductor nanostructures is crucial in many applications for coherent nanoelectronics and nanotechnology. A challenge in this respect is the inherent difficulty in performing four-terminal Hall effect measurements on nanostructures, including nanowires [1] and prompts efforts to extract mobility in other ways. In materials where mobility is independent of carrier density, field-effect measurements can be used [2]. However, this situation seldom occurs in nanostructures, where density-dependent scattering mechanisms give rise to a non-constant –and in some cases non-monotonic –relationship between carrier mobility and density. In this study, we investigate the non-monotonous electron mobility in InAs nanowires in a Hall bar geometry made using selective area growth [3,4]. We develop a method to accurately extract the gate voltage-dependent mobility from two-terminal field-effect transistor measurements and demonstrate an excellent match with the Hall mobility. Our method enables extracting similar information to a Hall effect measurement on two-terminal devices at zero magnetic field. Going beyond the conventional models which assume constant mobility –and significantly overestimate the true value - our approach further enables systematic investigation of the underlying scattering mechanisms that determine the mobility in a particular carrier density regime. For example, our devices exhibited an initial rise in mobility with increasing gate voltage, followed by a fall beyond the peak around Vtg = 0.5 V. The two behaviours may be attributed to screening of charged impurities and inter-subband scattering, respectively [5].

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