Influence of surface states on quantum and transport lifetimes in high-quality undoped heterostructures

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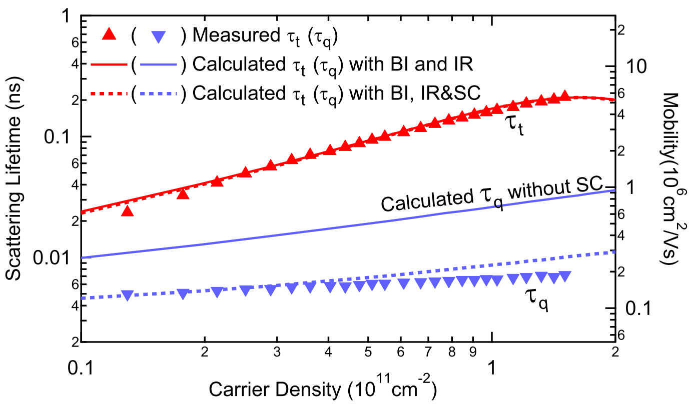
While extremely high mobility 2D systems have been realized in modulation-doped heterostructures, remote ionized impurities, which can act as an additional source of disorder causing both Coulomb scattering and long-range fluctuation of the potential landscape, are ineluctably introduced to the system[1]. Therefore, the presence of these ionized impurities is the predominant factor limiting the transport and stability of shallow modulation-doped heterostructures[2, 3]. Undoped heterostructures, on the other hand, are expected to have fewer ionized impurities owing to the absence of intentional doping, which makes shallow undoped hereostructures more desirable than modulation-doped ones for nanostructures with fine lithographic configurations. However, there still exists unavoidable surface charge, which may affect the carriers in a manner similarly to remote ionized impurity scattering, adding unwanted disorder to undoped devices. We present a comparison between experimental and theoretical values of transport τ_t and quantum τ_q scattering lifetimes in high-quality undoped AlGaAs/GaAs heterostructures. We obtain excellent agreement between the experimental and modeled scattering times using three scattering processes: background impurity (BI) scattering, interface roughness (IR) scattering, and remote ionized impurity scattering from surface charge (SC). We show that despite the high mobility ($\mu_{peak} = 5.6 \times 10^6 cm^2V^{-1}s^{-1}$), the quantum lifetime τ_q is significantly reduced by small-angle scattering from remote surface charge. We further show that in shallow undoped heterostructures scattering from surface charge will be a limiting factor for both transport and quantum lifetimes.



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