Advances in electron transport in InSb/Al\textsubscript{x}In\textsubscript{1-x}Sb quantum wells

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Narrow-gap indium antimonide (InSb) based heterostructures are of increasing interest for use in quantum transport devices. InSb exhibits the lowest electron effective mass ($m^* = 0.014 m_e$) and highest reported room-temperature electron mobility ($\mu = 78,000 \text{ cm}^2/\text{Vs}$) of any compound semiconductor, as well as a strong spin-orbit interaction and large Landé $g$-factor ($g \approx 50$). These properties have gained attention for use in spintronics and quantum information control, as well as the possibility of the realisation of Majorana Fermions in a system where potentially advanced planar fabrication can be exploited.

We report on advances in electronic transport measurement and corresponding modelling of high mobility InSb/Al\textsubscript{x}In\textsubscript{1-x}Sb quantum well heterostructures, demonstrating the critical scattering mechanisms across a range of samples [1]. Through the use of Differential Interference Contrast DIC (Nomarski) optical imaging we have observed characteristic surface roughness [2], and we present evidence for the effects of these on magnetoresistance measurements. Using a Monte Carlo model combined with Drude transport modelling, and modified 2D Landauer-Büttiker tunnelling calculations [3], we show that transport in these structures can be successfully described using a potential barrier model for grain boundaries, where these effective Schottky like barriers are inferred to pin at $\mu \approx 78\%$ of the mid gap value. We further expand on this model using an analytic approximation to accurately predict the low temperature mobility behaviour. Using a modified transport model combined with this potential barrier scheme we can successfully describe measured mobilities across a wide range of samples and demonstrate that there is the potential for vast improvements in this material system given correct buffer redesign and significant defect reduction.

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\textbf{Fig. 1:} a) Magnetoresistance measurements as a function of temperature showing local minima associated with proposed scattering mechanisms (surface feature related scattering and background impurity scattering). Inset) Corresponding longitudinal $R_{xx}$ resistance against $B$-field. b) Carrier density ($n_{2D}$) vs mobility for a series of samples with increased doping (filled squares), with 3 regions shown. Lines show transport model fit with limiting contributions labelled [2].