Ambipolar high-mobility transistors in undoped GaAs/AlGaAs quantum wells

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In an ambipolar device, electrons or holes can be populated on demand in the same conduction channel, with their different properties such as effective mass and spin-orbit coupling. In GaAs/AlGaAs heterostructures, standard modulation doped techniques cannot easily be used as the dopant determines the polarity of the carriers and precludes the formation of the other carrier type. Undoped heterostructures, where the two-dimensional (2D) gas is formed entirely by field effect [1], allow either electrons or holes to populate the channel dependent upon the polarity of the gate voltage, if both n-type and p-type ohmic contacts exist [2]. Unlike in graphene or in carbon nanotubes, there is a 1.5V voltage window between either electron or hole population, (primarily determined by the bandgap of GaAs, 1.52eV).

We have fabricated undoped ambipolar GaAs-based quantum well devices, with different well widths (L=10-25nm) with patterned Ti/Au back and front gates, using a flip-chip process [4, 5]. This method allows a large range of densities to be achieved, *e.g.* from 7×10^{9}cm^{-2} to 5×10^{11}cm^{-2} in a single device with single subband occupation, and without any parallel conduction of any kind. It also enables us to precisely control the wavefunction's position in the quantum well over a wide range, which we characterise by the variable α (Figure 1).

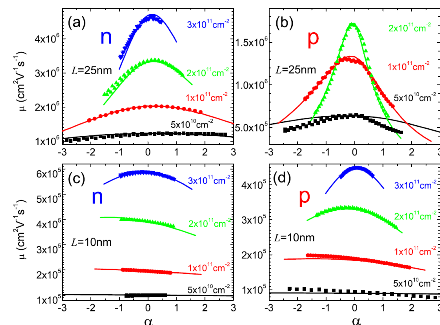

Figure 1: Electron/hole mobilities versus α for L=10nm and 25nm, where $\alpha = (\vec{E}_{front} - \vec{E}_{back})/|(\vec{E}_{front} + \vec{E}_{back})|$.

The change with α of the mobility (points) can be attributed to the relative change of interface roughness scattering from the two interfaces. We have modelled the mobility (solid lines) in the zero temperature limit within the Boltzmann transport formalism [3, 6], with numerically-solved wavefunctions, allowing us to independently characterise the two interfaces. As a growth optimisation tool, the information thus gained on the various scattering mechanisms present will help the development of very high mobility structures.

In conclusion, we have shown an excellent platform for creating high mobility two-dimensional electron (4.7×10^{6}cm^{2}V^{-1}s^{-1} at n=2×10^{11}cm^{-2}) and hole gases (1.8×10^{6} cm^{2}V^{-1}s^{-1} at p=2×10^{11}cm^{-2}), with considerable tunability which may assist the study of fractional quantum Hall states.

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