8 Conclusions

Aspects of transport in both n- and p-type strained silicon-germanium heterostructures have been investigated, with a view to device applications as well as fundamentals of physics.

In a p-type device with a relatively high mobility, fundamentals of quantum transport have been investigated at millikelvin temperatures and it is shown that conventional theories do not account for the rate at which the quantum phase breaks. New theories are considered and the work is related to theories of the metal-insulator-transition in 2-dimensional systems. It is suggested that there at high sheet densities where the behaviour of the 2-dimensional hole gas is metallic the dephasing rate may saturate at a finite value as the temperature drops to zero. (Traditional theory predicts an infinite dephasing rate at zero temperature).

At a filling factor of ~1.6, a transition from the QHE state into an insulating phase is seen. The resistivity of this phase increases dramatically as the hole gas is depopulated. This transition has been observed in silicon MOSFETs and p-type silicon-germanium, but not in gated heterostructures. Again, it is related to the metal-insulator transition in 2-dimensional systems.

A contrasting p-type device has also been investigated. Here, the work stresses the issues commensurate with such small-scale devices where stray voltages can quickly destroy a whole batch. The device features a pseudomorphic $Si_{0.5}Ge_{0.5}$ alloy channel: there is a possibility that the channel has relaxed to some degree since it was grown, and if this were the case then the implications for electronics incorporating such structures is serious. The possibilities of lateral relaxation, oxide degradation or contamination are also considered.

A room temperature Hall scattering factor of 0.68±0.04 has been extracted by comparing the measured and calculated mobility at 282K, based on parameters found by fitting the mobility at 25K.

Traditional theories of the resistivity as a function of temperature in the ~1K regime are based on weak localization, interactions and screening. The temperature dependence of this device, however, is not satisfactorily explained in this manner, and a new functional form for the resistivity as a function of temperature has been proposed, but now needs theoretical justification.

A new method of mobility spectrum analysis has been applied to magnetoresistance data from an n-type device, at temperatures between 350mK and 294K. The results highlight both the strengths of mobility spectrum analysis and its shortcomings: in systems where transport takes place in both a quantum well and a dopant layer, two peaks are resolved. However, the peak shape (which should contain information regarding the energy dependence of the scattering time) owes more to the quality of the data than to scattering mechanisms.

It is also possible that the results in this particular device are invalidated at temperatures above 100K, due to conduction through the substrate.

Other mobility spectrum analysis methods are briefly reviewed. The common "mirror" peak artefact is investigated and an explanation is suggested. It is believed that whilst the program code used here could be refined slightly, significant improvement to the analysis is unlikely. It may be possible to apply the maximum entropy inversion method to find the energy dependence of the scattering time from the mobility as a function of sheet density or temperature.

Lastly, devices where both n-type and p-type conduction can be induced are investigated in terms of the physics of coupled carrier gases, and the possibilities of vertical CMOS integration. It is shown that carrier gases do not co-exist in this structure, and it is shown that the design of a silicon-germanium heterostructures which may support co-existing electron and hole gases is non-trivial and not necessarily possible.

These ideas are important not only to the growth of the next generation of silicon-germanium devices, but also to the ways in which they are characterized.

"I may add, as a mere conjecture, that under exceptional circumstances such as these there must occur a good many as yet uncharted phenomena having to do with the mysterious laws of electricity."

Hector Berlioz (1852) trans. Jacques Barzun.