Variation of the Electronic Functionality of Self-Seeded Germanium Nanowires through Synthesis Determined Core-Shell Interface States

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Bottom up grown germanium nanowires may have an important role to play in future electronic devices. While the electrical properties of nanowires grown using a metallic seed as a catalyst have been extensively reported we study self-seeded nanowires in this thesis. Such wires are core-shell in nature and are grown without any intentional doping. Self-seeded nanowires have been previously proposed as an attractive alternative to conventionally grown wires due the alleviation of complications arising from unintentional doping from the metallic seed. The results in this thesis demonstrate that the electrical properties of the self-seeded, core-shell nanowire are dominated by doping from the interfaces states which is in turn dependent on the details of the nanowire growth.

We first examine the room-temperature electrical properties of two sets of wires grown under different growth conditions. A significant difference in electrical behaviour was seen. One batch showed a *p*-type gate response and memristive behaviour, while the other showed little or no gate effect, and low resistivity. It is proposed that the observed behaviour results from differences in the density of the charge traps located at the interface between the core and the shell of the nanowire, leading to a difference in the nanowire doping. The difference stems from a change in the structural and chemical properties of the shell which is caused by the altered growth conditions. A model is developed in this thesis to explain how the interface states lead to the observed memristive behaviour. In contrast a high density of surface states leads to the observed gate voltage invariance and low resistive response.

We then examine the change in resistivity with nanowire diameter. A non-monotonic relationship is seen. The resistivity falls by more than an order of magnitude as the diameter is lowered from 40 nm to 20 nm. Below this diameter a peak-like feature is measured at a diameter of approximately 14 nm. The results are modelled and two separate regimes are found. Above diameters of 20 nm the mobile holes in the wire are confined to an annular region close to the surface of the wire due to the electrostatic attraction of the electrons in the interface states. In this region we model the change in resistivity as resulting from the change in the carrier concentration arising from the difference in scaling between the surface of the wire and the volume of the annular region to which the mobile holes are confined. Below 20 nm diameters we model the mobility using the one-dimensional Kubo-Greenwood formula. Unlike previous applications of this formula to nanowires we take into account explicitly the effects of the aforementioned diameter dependent carrier concentration arising from the surface state doping. The peak-like feature is reproduced by the theory.

Finally we examine the temperature dependence of the nanowires. It is found that samples that show a gate effect have Efros-Shklovskii variable range hopping conduction due to the mobile holes hopping from one trapped electron to another. From this we extract the surface state density and find excellent agreement with previous results. The most highly conducting wires without a gate effect display a range of metallic and dirty-metal behaviours at different temperature ranges.