Arsenic delta-layers in germanium for quantum applications

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Recent years have seen the emergence of germanium as a platform for quantum computing applications. In addition to germanium's compatibility with conventional complimentary-metal-oxide-semiconductor (CMOS) technology, key material properties are enhanced compared to silicon. For example, the electron and hole mobilities are increased and the band gap is reduced which reduces switching voltage requirements. Much focus has been on hole-based quantum information applications, as germanium has the highest known hole mobility, and strong spin-orbit coupling of holes in the valence band which is advantageous for qubit control. Less studied are electron based approaches in germanium. Working towards electron based qubits, we study the fabrication of arsenic delta-layers in germanium using arsine as a precursor and investigate the compatibility of this material system with scanning tunnelling hydrogen resist lithography, a technique currently used for atomically precise phosphorus doping in silicon. Using a combined scanning tunnelling microscopy and density functional theory approach we identify and characterise arsine dissociation products on the germanium surface at room temperature, giving insight into the surface chemistry. By annealing the arsine dosed surface, we show arsenic incorporation into the germanium surface and good compatibility of the arsine-germanium system with a hydrogen resist. Increasing the arsine dose to full surface saturation, we study the formation of a highly arsenic doped surface layer. We cap this surface with germanium to form an arsenic delta-layer in germanium. Our results demonstrate the potential of this material system in the formation of a 2D electron gas, the fabrication of nano-scale electronic leads and atomically precise n-type doping of germanium.