Quantum confinement dependency of a 2DEG in Si:P delta-layers

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A δ-layer is a buried, high-density, doping profile in a semiconductor host which may give rise to the formation of a two-dimensional electron gas (2DEG) in the dopant layer [1]. Phosphorus δ-layers in silicon combined with scanning tunnelling microscope lithography have led to the fabrication of functional atomic scale devices, such as the single-atom transistor [2]. Much progress in the development of these atomic scale devices continue to today with the ultimate goal of developing future quantum computer devices [3, 4]. In order to realise a working quantum computer, engineered quantum states in a host material must be controlled, manipulated and read with atomic-scale precision.

Here we investigate quantum confinement effects induced by phosphorus delta layers in silicon, in particular the effect of reducing the thickness of the phosphorus dopant layer from 4.0 nm to the single atom layer limit using angle-resolved photoemission spectroscopy. The location of theoretically predicted, but experimentally undiscovered, quantum well states known as the Δ-manifold was revealed, validating density functional theory calculations [5] developed for describing these δ-layer systems. Moreover, the behaviour of the previously observed valley splitting between the most occupied Γ-states [6] is traced as the quantum confinement is varied. Verification of the Δ-manifold and insight into the valley splitting behaviour contributes to the development of accurate models describing the electronic behaviour of δ-layer derived devices.

References:
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