Spatially resolved transport spectroscopy of few donor clusters in silicon

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Electrons bound to dopant-based quantum dots in silicon represent a formidable platform for multi-qubit quantum technologies and analogue quantum simulators [1, 2]. Building a better understanding of these engineered quantum states properties is therefore paramount, for which the atomic-scale resolution of low-temperature scanning tunnelling microscopy (STM) is highly relevant as it gives a direct access to these wave functions [3, 4]. Here, we present spatially-resolved spectroscopy of dopant-based atomic-scale devices in silicon towards the fabrication and local spectroscopy of artificial quantum matter.

We first characterise individual As donors using spatially resolved magneto-transport spectroscopy and observe clear signatures of the Zeeman splitting of the ground state at 2 K, thereby providing experimental access to the spin degree of freedom as well as an absolute calibration of the electronic temperature and lever arm parameter [5]. We then perform local spectroscopy on few dopant-quantum dots (1P, 2P, and 3P) engineered with the atomic precision placement of scanning tunneling lithography [6]. The spectra are explained through a capacitive transport model to infer the number of dopants per quantum dot and charging energies [5]. We finally present local spectroscopy results on controllable dopant devices that include in-plane source and gate electrodes where the filling factor can be independently tuned, resulting in highly stable Coulomb blockade oscillations and a dense excitation spectrum. These results demonstrate the viability of dopant-based quantum dots in silicon embedded in a low-temperature STM as a platform for the exploration of strongly correlated states in Fermi-Hubbard analogue quantum simulators, with the STM tip as local spectral function probe.

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