Single-Atom Control of Arsenic Incorporation in Silicon for Quantum Materials Fabrication

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Abstract

Semiconductor device manufacturing steadily approaches the ultimate limit of miniaturization – single-atom precision. Developing a scalable, atomically precise fabrication technique would afford tremendous scientific and technological opportunities. By providing novel engineered quantum materials and devices, scalable atomically precise fabrication will enable exploration of new areas of condensed matter physics and could facilitate the realization of universal solid-state quantum computers. Scanning tunnelling microscopy hydrogen resist lithography is the only fabrication technique capable of positioning individual dopant atoms at nearly exact lattice sites in silicon and germanium. Traditionally, this technique has used the precursor phosphine to precisely position phosphorus atoms. Using phosphorus-in-silicon, single and few atom donor devices are now routinely demonstrated, providing tantalizing glimpses into future quantum technologies. Recent studies suggest that the phosphine-silicon surface chemistry limits the single-atom fabrication yield. Arsine as a precursor to arsenic patterning offers an alternative and advantageous approach to atomically precise fabrication [1,2]. By using arsenic-in-silicon it is possible to improve the single-atom yield sufficiently to allow repeatable single atom fabrication, thus providing pathways to single-atom precision fabrication scale-up. In this talk we explore the single atom control of arsenic incorporation in silicon that can provide up to 100% yield, and discuss recent progress in fabrication of quantum materials using this approach.

References

[1] T.J.Z. Stock, *et al.*, arXiv:2311.05752 (2023)
[2] T.J.Z. Stock, *et al.*, ACS Nano 14, (2020) 3316

Figures

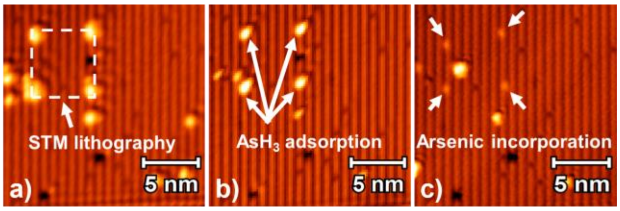

Figure 1: Single-atom arsenic pattering in Si(001) by scanning tunnelling microscopy hydrogen resist lithography: Step-wise fabrication of an artificial 2×2 single-atom arsenic lattice, imaged after: a) STM lithographic patterning of the hydrogen resist, b) room temperature adsorption of AsH_3 through the patterned adsorption windows, and c) thermal annealing for substitutional arsenic incorporation.