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Bottom-up superconducting and Josephson junction devices and qubits inside a Group-IV semiconductor

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The Nb/AlOx/Nb (or Al/AlOx/Al) Josephson junction (JJ) has become ubiquitous for superconducting (SC) applications such as magnetometers, voltage standards, logic, and qubits. But heterogeneous devices such as these can pose problems, especially for low-power or quantum applications, where losses in or at the interfaces of the various materials can limit device quality dramatically. Possible solutions include better materials, weak-link junctions, symmetry protection, or 3D cavity qubits. Here we consider another alternative: atomically-precise, hole-doped SC silicon (or germanium) JJ devices and qubits made entirely out of the same crystal [1]. Like the Si spin qubit, our super-semi JJ devices exist inside the "vacuum" of ultra-pure silicon, far away from any dirty interfaces. We predict the possibility of SC wires, JJs, and qubits, calculate their critical parameters, and find that most known SC qubits should be realizable. This approach could enable better devices, hybrid superconducting-spin qubit systems, and exotic SC circuits, as well as a new physical testbed for superconductivity.

[1] Yun-Pil Shim and Charles Tahan, arXiv:1309.0015.