Superconducting Materials and Process Exploration for Quantum Devices

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The performance of quantum devices strongly depends on the quality of materials and interfaces between them, controlling which at every fabrication step is crucial. The parameter space for superconductor synthesis is typically very large and scales up rapidly with more complex material systems, for example when going from binary to ternary or quaternary alloy superconductors. As a result, understanding the fundamental underpinnings of growth and fabrication processes needed to fine tune the application-specific superconductor performance becomes increasingly important. To address this problem a cluster deposition and characterization system was designed and recently launched at the Berkeley Lab's Molecular Foundry user facility, that includes multiple nanofabrication tools (deposition, oxidation, ion milling), a characterization suite (XPS, ellipsometry, FTIR, OES) and automated robotic system — all combined in an integrated vacuum system. This new capability enables synthesis and characterization of materials at every fabrication step, as well as their integration into quantum devices in a single vacuum cycle, preserving pristine interfaces between various device layers. By using the synthesis - characterization - machine learning loop we can efficiently tune material properties and accelerate new materials discovery. For example, we have optimized multiple superconducting systems towards their integration into all-nitride Josephson junctions, or to improve phonon management in superconducting sensors. In this presentation I will discuss this new user accessible capability and the wide range of ongoing and future applications of it.