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Decoherence in Josephson Qubits

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The Josephson junction can be thought of as an artificial atom, with energy levels determined by the circuit design parameters and bias. This system shows great promise for quantum computing, since it should be straightforward to scale to many-qubit circuits using standard integrated circuit technology. To date, however, device performance has been severely limited by coupling of the qubit to spurious materials defects. Here I discuss a recent breakthrough which has enabled striking improvements in phase qubit coherence and visibility, and which has deep implications for other Josephson qubits. I present a model of qubit decoherence induced by two-level defect states, and describe an intimate connection between intrinsic (low-temperature and low-power) dielectric loss and qubit performance: coupling to individual defects in the tunnel barrier of the Josephson junction results in a loss of visibility of coherent qubit oscillations, while coupling to a continuum of defects in the wiring dielectric leads to energy relaxation from the qubit $|1>$ to the $|0>$ state. Optimization of the phase qubit proceeds along two lines. The first approach involves a novel circuit architecture which promotes statistical avoidance of resonant defects, and leads to dramatic enhancements in qubit visibility and measurement fidelity. The second approach is to explore novel high-Q dielectrics for qubit circuits. Recent improvements in materials have led to a factor of 30 increase in qubit coherence time. I describe progress in the development of novel epitaxial dielectrics grown on epitaxial refractory metal underlayers for qubit applications. These results open the door to the realization of many-qubit algorithms in superconducting circuits.