Materials Origins of Decoherence in Superconducting Qubits

March 31, 2009 (HP21). In a recent review article in *IEEE Trans. Appl. Supercond*., R. McDermott describes critical materials issues that limit the performance of quantum bits ("qubits") based on superconducting integrated circuits incorporating Josephson junctions [1]. The title of the article is "Materials Origins of Decoherence in Superconducting Qubits". We like to bring it to the attention of our readers.

Superconducting qubits can be viewed as "artificial atoms", with energy level spacings that can be tuned over a broad range by appropriate variation of the circuit design parameters and bias. In contrast to Nature-given atoms or nuclear spins, superconducting qubits can be made to interact strongly with one another simply by connecting the circuits with wires and linear circuit elements such as capacitors or inductors. The micrograph of a phase qubit circuit, is shown in Figure 5(a) as an example. In principle, then, it should be straightforward to scale up to circuits comprising many qubits, once the single qubit circuits have achieved high-fidelity operation. Recent breakthroughs in the field include quantum state tomography of coupled qubits [2] and investigations of the coherent interaction between qubits with cavity photon states [3-4]. However, superconducting quantum circuits also couple strongly to spurious sources of dissipation and dephasing in the environment, and these act to destroy the quantum coherence of the qubit state. Work over the last several years has shown that a dominant source of decoherence in superconducting qubits is microscopic two-level state (TLS) defects in the amorphous materials that are used to implement the qubit circuit. There has been considerable progress in understanding the underlying physics that governs qubit dissipation and decoherence, and already this increased understanding has been leveraged to develop novel materials and novel circuit designs with improved coherence times [5]. An example is shown in Figure 5(b), where replacing SiO_2 by SiN_x as the wiring dielectric alone results in enhancement of qubit relaxation time by a factor of 20. It is expected that the continued development of qubit materials will yield significant improvements in qubit coherence and fidelity, and thus facilitate realization of scalable quantum information processing with superconducting circuits.

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[2] M. Steffen *et al*., *Science* **313**, 1423 (2006).
[3] A. Wallraff *et al*., *Nature* **431**, 162 (2004).
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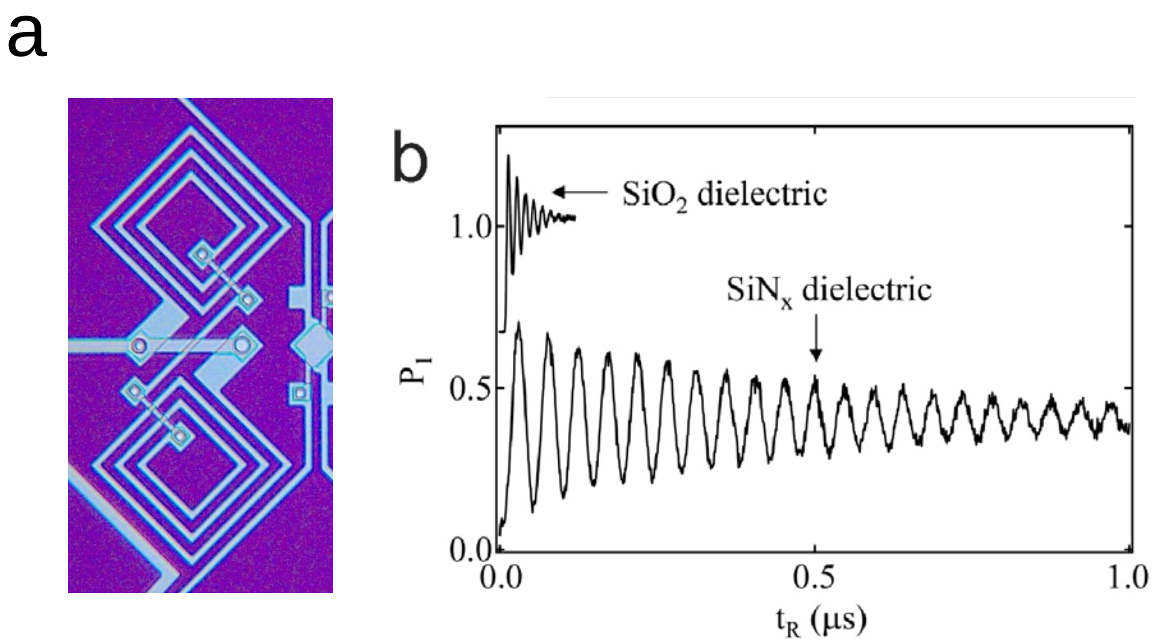

Fig. 1. (a) Micrograph of Josephson phase qubit circuit. (b) Rabi oscillations for phase qubit circuits incorporating PECVD-grown SiO_2 and SiN_x wiring dielectrics. The factor 20 improvement in loss tangent for the SiN_x compared to the SiO_2 yields a factor 20 enhancement in qubit energy relaxation time. Reprinted figure with permission from [5]. Copyright 2005 by the American Physical Society.