Superconducting Resonator Circuits

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Principal Investigator: Michel H. Devoret
User: Markus Brink

Affiliation: Applied Physics Dept., Yale University
Primary Funding: NSF
Contact: michel.devoret@yale.edu, markus.brink@yale.edu
Web Site: www.eng.yale.edu/qlab/

Abstract

With the promise of applications in quantum computing, solid state electronic circuits with quantum mechanical properties have been proposed, developed, and investigated in recent years. The aim of our work is to replace the Josephson tunnel junction in such circuits by devices in which carbon nanotubes play the role of the tunnel barrier.

Summary of Research

Our research focuses on electrical circuits whose macroscopic behavior exhibits quantum mechanical properties. All these circuits are made of superconducting material and involve one or more Josephson tunnel junctions. Examples include solid-state qubits [1] and quantum-limited amplifiers, with applications in quantum computation. Several recent experiments showed that carbon nanotubes (CNTs) can support a proximity-induced supercurrent [2, 3], and we are planning to incorporate CNTs into our quantum circuits.

Given the unique properties of CNTs [4], such CNT quantum circuits are attractive from multiple points of view, for example: (i) CNTs have large inductances [5], making them interesting circuit elements, (ii) the non-linear current-phase relationship between a proximity-induced supercurrent in the CNT and the difference of superconducting phase between its metal contacts allows CNTs to act like Josephson junctions [3], and (iii) given their small diameter (of a few nanometers) CNTs are an ideal interface to the molecular world [3].

To meet some specific challenges in making CNT devices, we have recently started using the CNF with its extensive nanofabrication capabilities. Our fabrication protocol starts by exposing local, chip-level, and global alignment marks on a 4-inch Si wafer. These marks are etched into the substrate so that they survive the high furnace temperatures during CNT growth. Catalyst for CNT growth is deposited at small islands on the substrate in a lift-off process. Our CNTs are grown by chemical vapor deposition in Paul McEuen’s lab at Cornell. Following growth, we image the CNTs by atomic force microscopy and design contact electrodes for each CNT device. We have made CNT devices with good contacts, and we have developed the process to incorporate them into quantum circuit geometries.

References