Microwave Frequency Acoustic Resonators for Quantum Applications

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Principal Investigator(s): Andrew Cleland
Affiliation(s): Pritzker School of Molecular Engineering, University of Chicago

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Contact: anc@uchicago.edu

Primary CNF Tools Used: OEM Endeavour

Abstract:

We are exploring the low temperature mechanical performance of thin-film, oriented AlN deposited on silicon and sapphire substrates. We are using this material to make bulk acoustic wave and surface acoustic wave devices for quantum applications. These are ultimately for applications in quantum acoustics, to be measured using superconducting qubits as single phonon sources and detectors. The goal is to quantify loss in these devices at low temperatures and low phonon excitation powers.

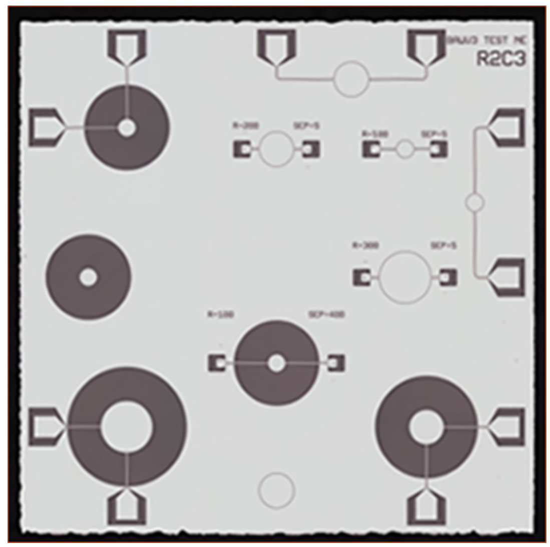

Figure 1: Image of set of bulk acoustic wave resonator structures; silver is aluminum metallization, darker areas are underlying AlN on silicon.

Summary of Research:

The oriented AlN films we are using are remotely grown by reactive sputter deposition at Cornell's CNF, targeting typically 300 nm thick oriented AlN films. These are then post-deposition patterned with thin-film aluminum at UChicago's PNF, where the patterned aluminum film defines either surface acoustic wave transducers or bulk wave acoustic resonators, with design frequencies in the microwave frequency band (1-10 GHz). At these frequencies, measured at mK temperatures on a dilution refrigerator, these systems will be in their mechanical ground states, so loss and performance can be measured at single phonon powers. The device patterns involve either using geometries with in-plane surface acoustic wave transducers as delay lines or SAW resonators, or using single-sided capacitively-coupled transducers to couple to thickness-mode bulk acoustic wave resonator modes. Devices are measured at low temperatures (10-100 mK) using either microwave frequency vector network analyzers or using superconducting qubits for quantum (single phonon) measurements.

We have demonstrated we can use the AlN films on double-side polished silicon wafers to make high quality factor (1-10 million Q) bulk acoustic wave resonators (BAWs) as measured using a vector network analyzer. We have also integrated similar design BAWs with superconducting qubits to perform measurements in the quantum limit; these experiments are still on-going, with no conclusive results to date.

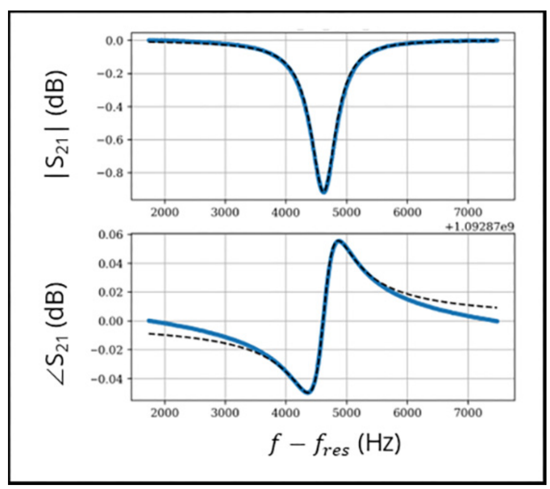

Figure 2: Vector network analyzer measurements of one bulk acoustic wave resonance, with a mechanical Q of about 2 million measured at about 3 GHz and a temperature of 3K.

Conclusions and Future Steps:

Work is still in progress. We may order additional films grown if and when we run out of the existing material.