

Surface Acoustic Wave Resonators for Measuring Superconductivity in 2D Materials

CNF Project Number: 3289-25

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Primary Source(s) of Research Funding: Moore Foundation

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Primary CNF Tools Used: Heidelberg MLA 150 Maskless Aligner, SC4500 Odd-Hour Evaporator, Zeiss Supra SEM

Abstract:

Surface acoustic wave devices can be used as a powerful probe for the electronic properties of 2D-materials [1,2]. Recently, surface acoustic wave resonators with high quality factors have emerged as an architecture with superior sensitivity over the traditional delay line geometry. By increasing the surface acoustic wave frequency, the quantum limit can be reached. In this regime the mean free path of conduction electrons exceeds the acoustic wavelength allowing for a k-space resolved measurement of the conductivity. In this project, we fabricated surface acoustic wave resonators on piezoelectric lithium niobate substrates and optimized the device geometry to increase their quality factor. We also pushed for smaller feature sizes to get closer to the quantum limit regime.

Summary of Research:

Resonators of different designs and fabrication parameters were fabricated using photolithography. To facilitate flexible and fast testing of different designs, the exposure was performed with a Heidelberg MLA150. The structures were then realized on the substrates using a Ti/Au deposition process through e-beam evaporation and subsequent lift-off. The resonators were characterized using a vector network analyzer. The best designs exhibited a quality factor of ~ 8000 , significantly improving on the designs previously used by our group (see Fig. 1). We additionally fabricated resonators that work at a resonance frequency of 1 GHz with feature sizes down to 1 micrometer.

Conclusions and Future Steps:

The improved design of the fabricated resonators allowed us to increase their sensitivity to the electronic properties of the materials we study with them. This enabled us to probe the transition between highly insulating and conducting states in graphene heterostructures and observe a superconducting transition in thin films of Nb.

In future work, we want to further improve the designs by using non-reflective transducers and will employ ebeam lithography to increase the resonance frequency up to several GHz in order to reach the quantum limit regime.

References:

- [1] Fang et al., PRL 130, 246201 (2023), Quantum Oscillations in Graphene Using Surface Acoustic Wave Resonators.
- [2] Song et al., PRL 136, 036301 (2026), Acoustoelectric Probing of Fractal Energy Spectra in Graphene/hBN Moire Superlattices.

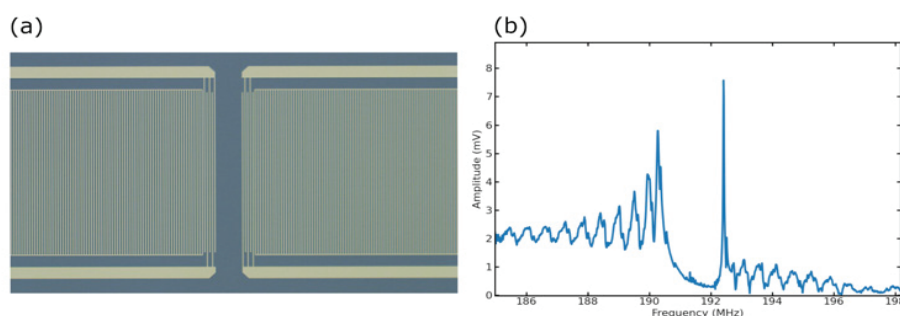


Figure 1: (a) Surface acoustic wave resonator on lithium niobate substrate. The resonator comprises a central cavity with interdigital transducers on either side that can be used for launching and sensing acoustic waves. Behind each transducer is an array of Bragg reflectors that confine the waves to the cavity. (b) Measured voltage at the sensing IDT as a function of frequency of a continuously applied RF voltage to the launcher IDT. The resonant mode at 192.5 MHz has a quality factor of ~ 8000 .

