Piezoelectric RF SAW-based Energy Detectors

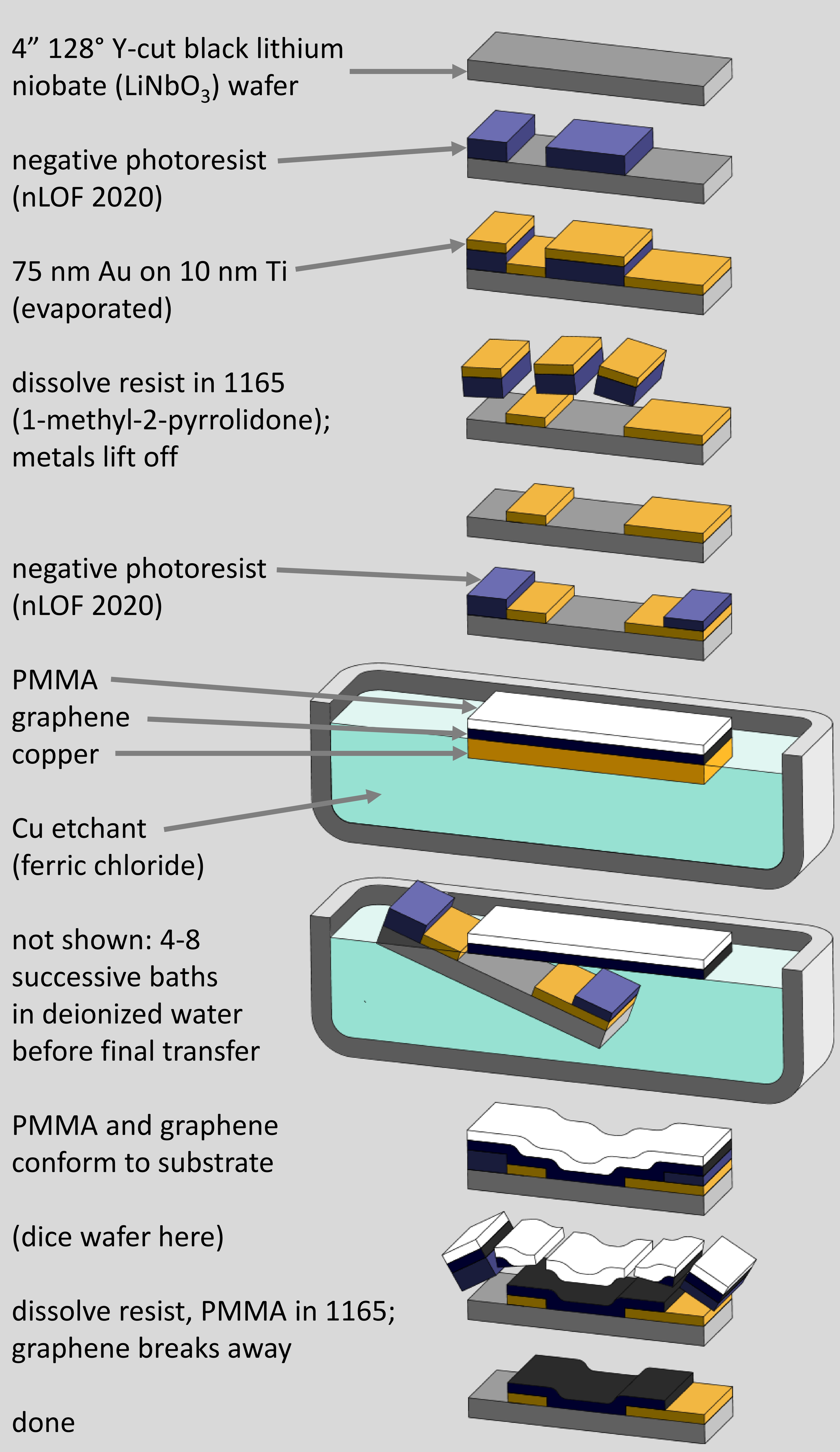
Daniel Teal · UT Austin · Cornell CNF REU
PI: Dr. Amit Lal · Mentor: Alex Ruyack · SonicMEMS Lab

Purpose

DARPA wants radio signal-powered sensors that draw no energy on standby. Traditional electronics are inefficient in this low power (2 µV at 50 Ω) regime.

Here, we build piezoelectric devices that rectify an input RF wave into measurable DC current – an alternative paradigm worth exploration.

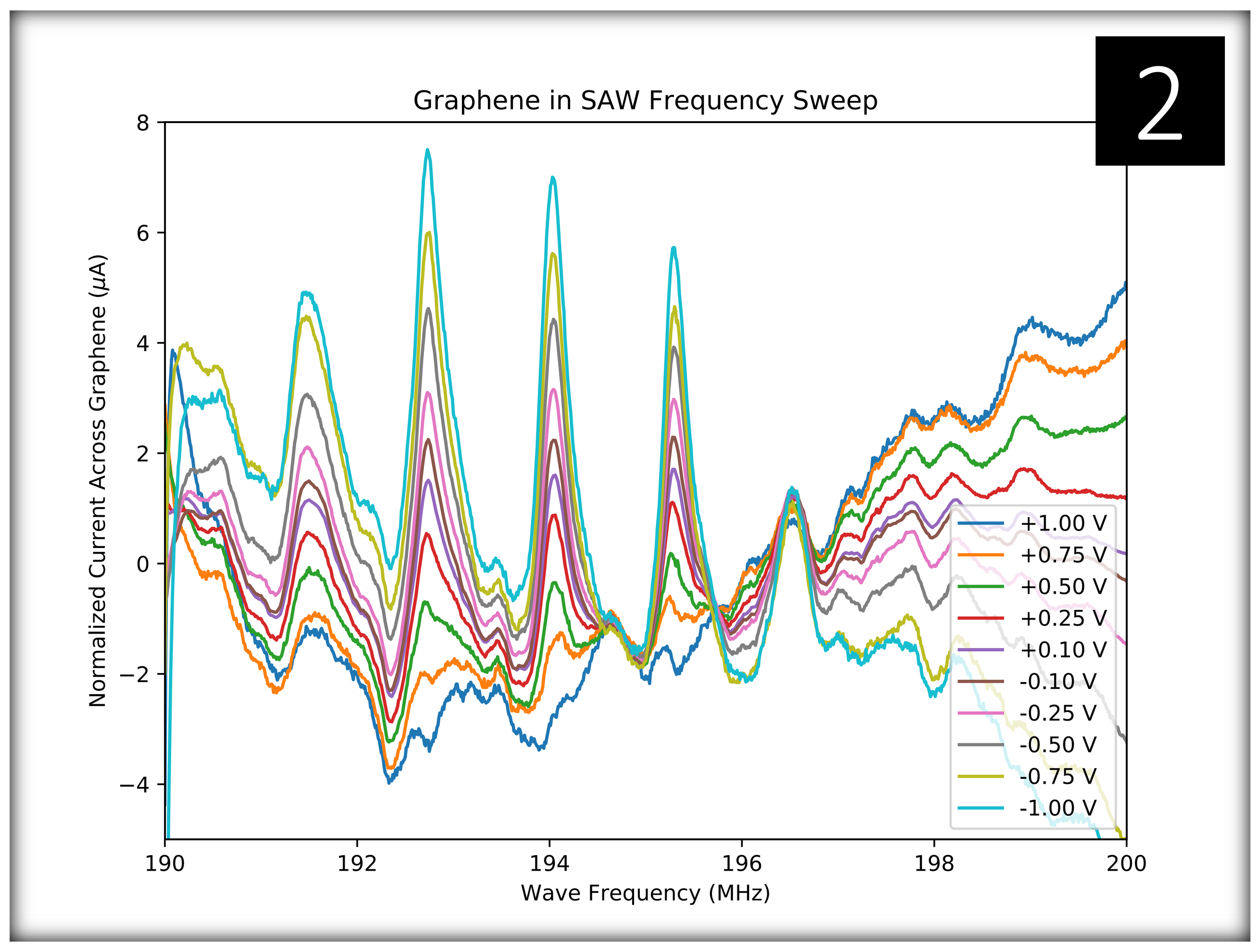
Fab Process

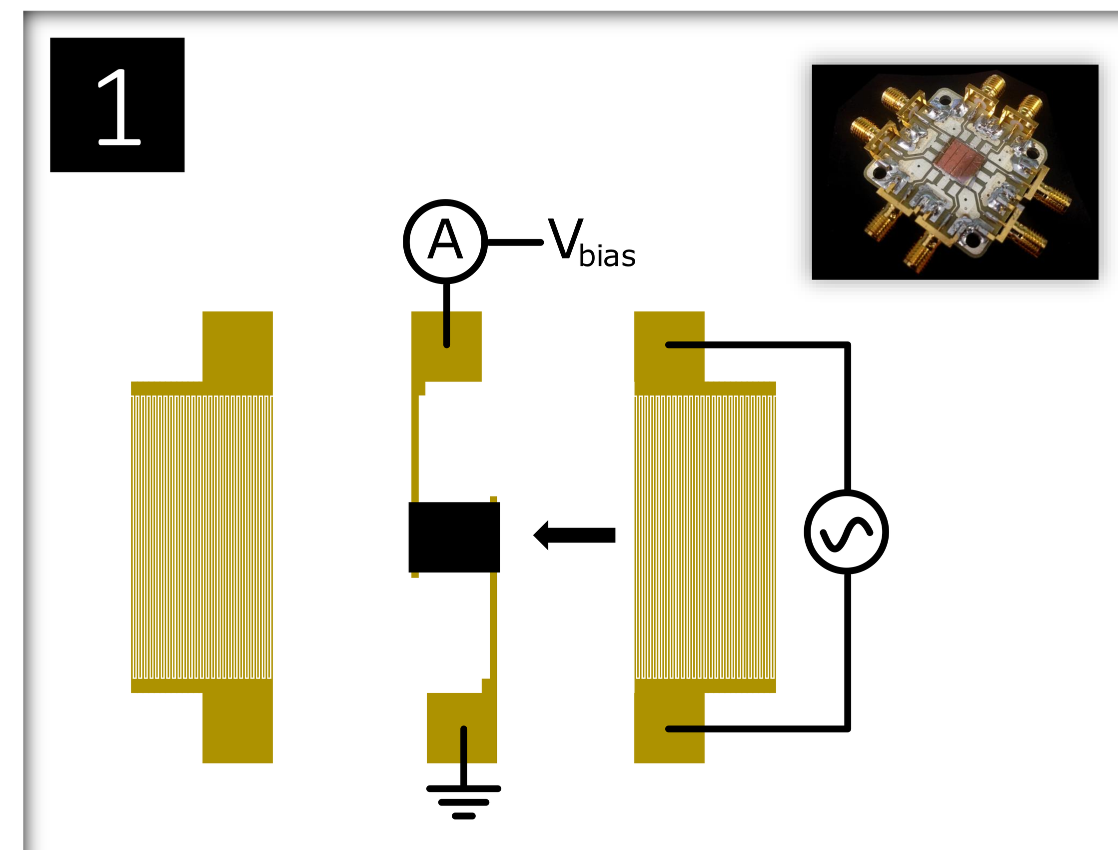


We use piezoelectric lithium niobate as a substrate, then evaporate 75 nm of gold (following 10 nm of Ti for adhesion) and pattern it using a previously applied liftoff mask for electrodes.

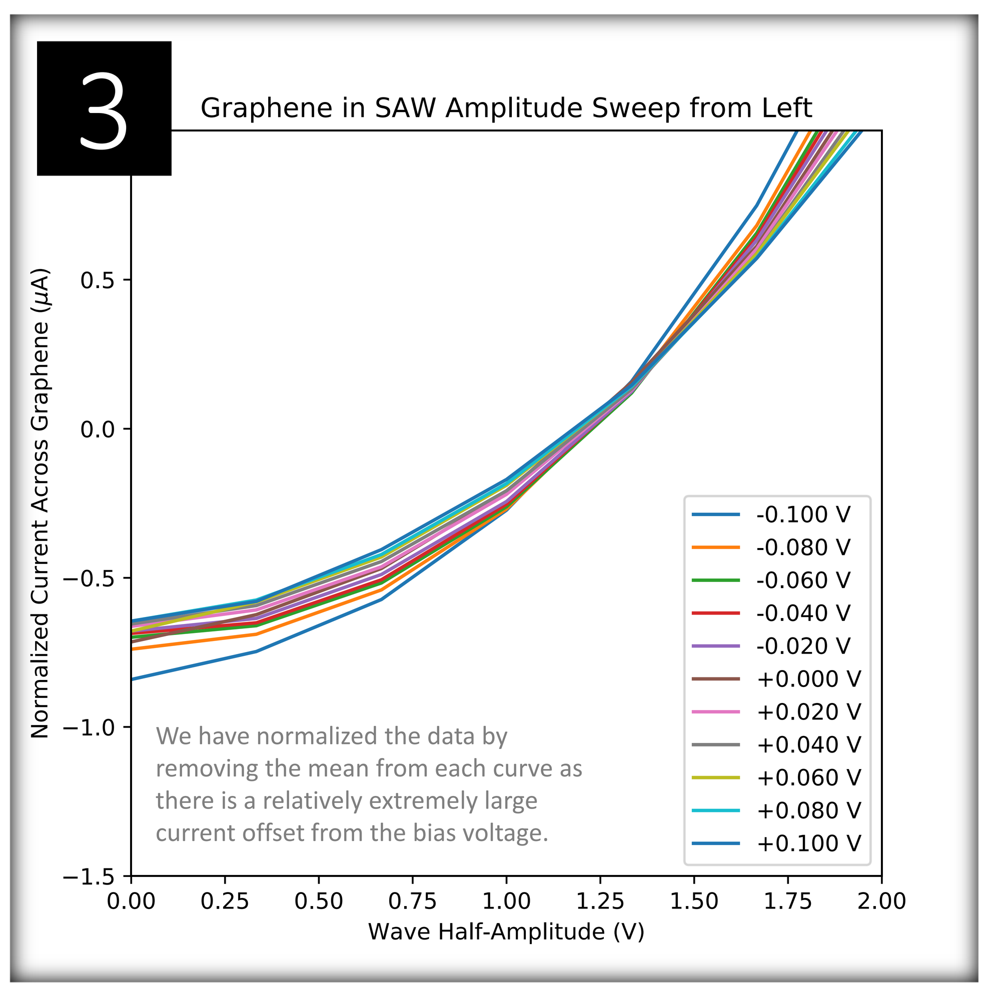
Next, a similar liftoff process[1] is used to pattern commercial CVD-grown monolayer graphene, which comes sandwiched between copper and PMMA. So far, minimum graphene feature size is approximately 100 µm.

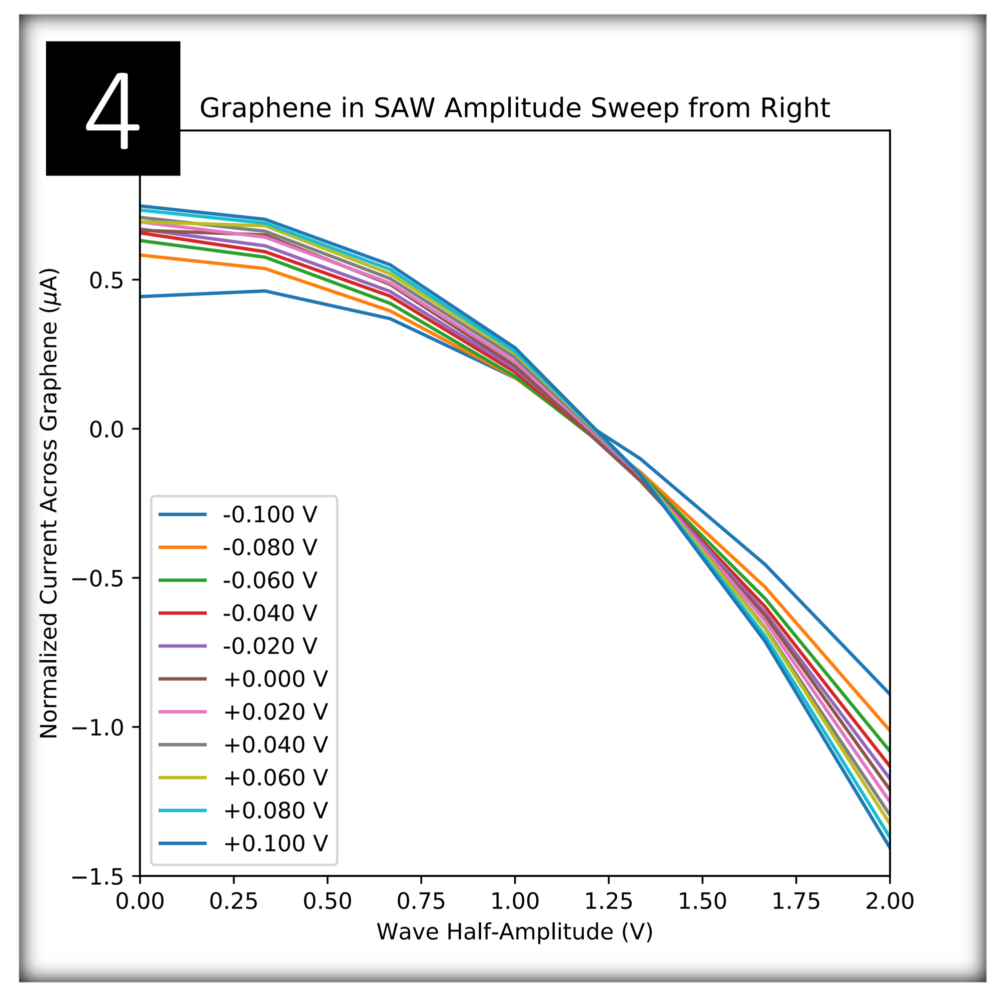
[1]: Kim et. al., *ACS-AMI*, 2017, DOI:10.1021/acsami.7b05790.

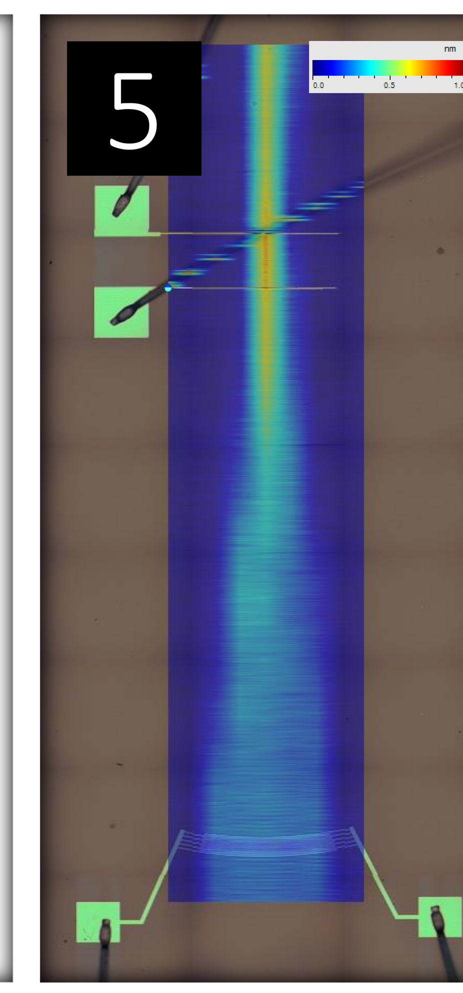




IDT fingers are 5 um wide, 5 um apart. We design for a 20 um wavelength at 200 MHz.
N.B.: graphene electrodes are thickened slightly in this picture for ease of viewing.







Experiments

(1) This is one test chip, in schematic and picture views. InterDigitated Transducers (IDTs) on a piezoelectric substrate are built on either side of a piece of graphene. A surface acoustic wave (SAW) is generated from one IDT at a time via the inverse piezoelectric effect. A bias voltage is placed across the graphene and the circuit current measured. We expect the SAW to push electrons through the graphene, creating additional current – the acoustoelectric effect.

(2) A SAW frequency sweep finds points with minimum IDT insertion loss.

(3) Fixing SAW frequency at a peak (192.73 MHz), we sweep SAW amplitude.

(4) We repeat (3) with the opposite IDT. As the SAW travels in the opposite direction, the current change, too, is inverted, suggesting this change is due to the acoustoelectric effect.

(5) A different device was built with a curved IDT. The SAW created by this IDT, as measured by a scanning vibrometer, focused, concentrating energy. This may prove useful later.

Conclusions & Future

This project demonstrates the acoustoelectric effect and focusing IDTs. Although the results presented here are not quite new[2], confirmation is nice.

Next, we hope to optimize SAW power transfer efficiency and use its generated current to actuate a NEMS switch.

[2]: Nash et. al., *APL*, 2013, DOI:10.1063/1.4822121.

Acknowledgements

National Science Foundation
National Nanotechnology Coordinated Infrastructure
Cornell NanoScale Science & Technology Facility
NSF grant no. ECCS-1542081

PI: Dr. Amit Lal
Mentors: Alex Ruyack & Benyamin Davaji, Nabil Shalabi
CNF REU Program Coordinators
CNF Staff, esp. Aaron, Jerry, Chris

Cornell University
Cornell NanoScale Science and Technology Facility
National Nanotechnology Coordinated Infrastructure