



# E-Scroll: A Rotational Haptic Ring Using Electrostatic Adhesion

Mia Onodera, Jung-Hwan Youn, Craig Shultz

University of Illinois Urbana-Champaign, IL, USA



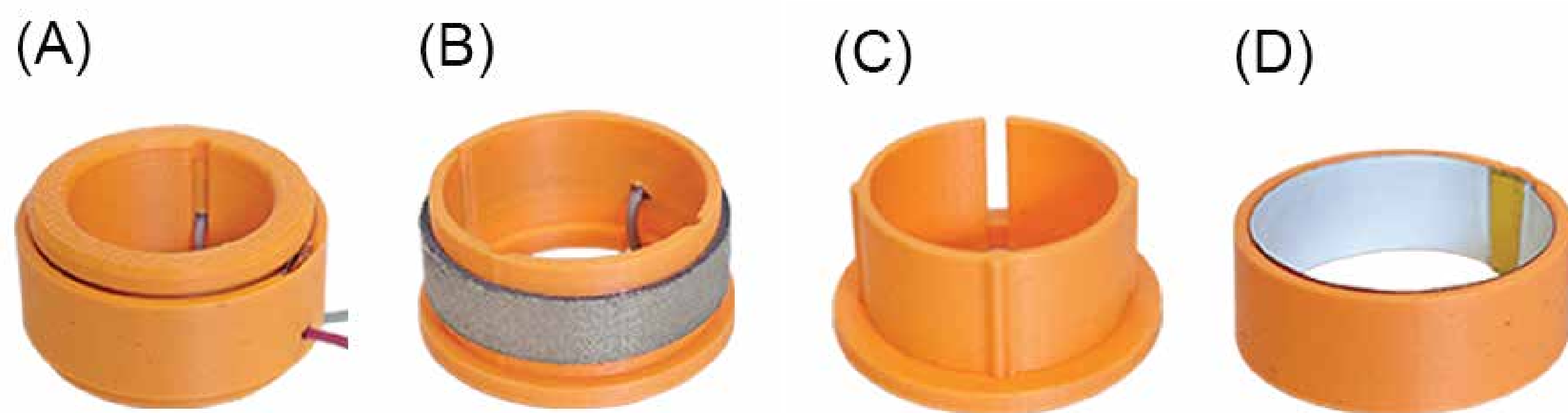
## Motivation

Wearable haptic devices primarily rely on **vibration**, limiting their ability to convey **continuous and directional information**. We use **electrostatic adhesion** in a finger-worn ring to modulate friction and render **continuous, directional rotational feedback** in a compact form factor.

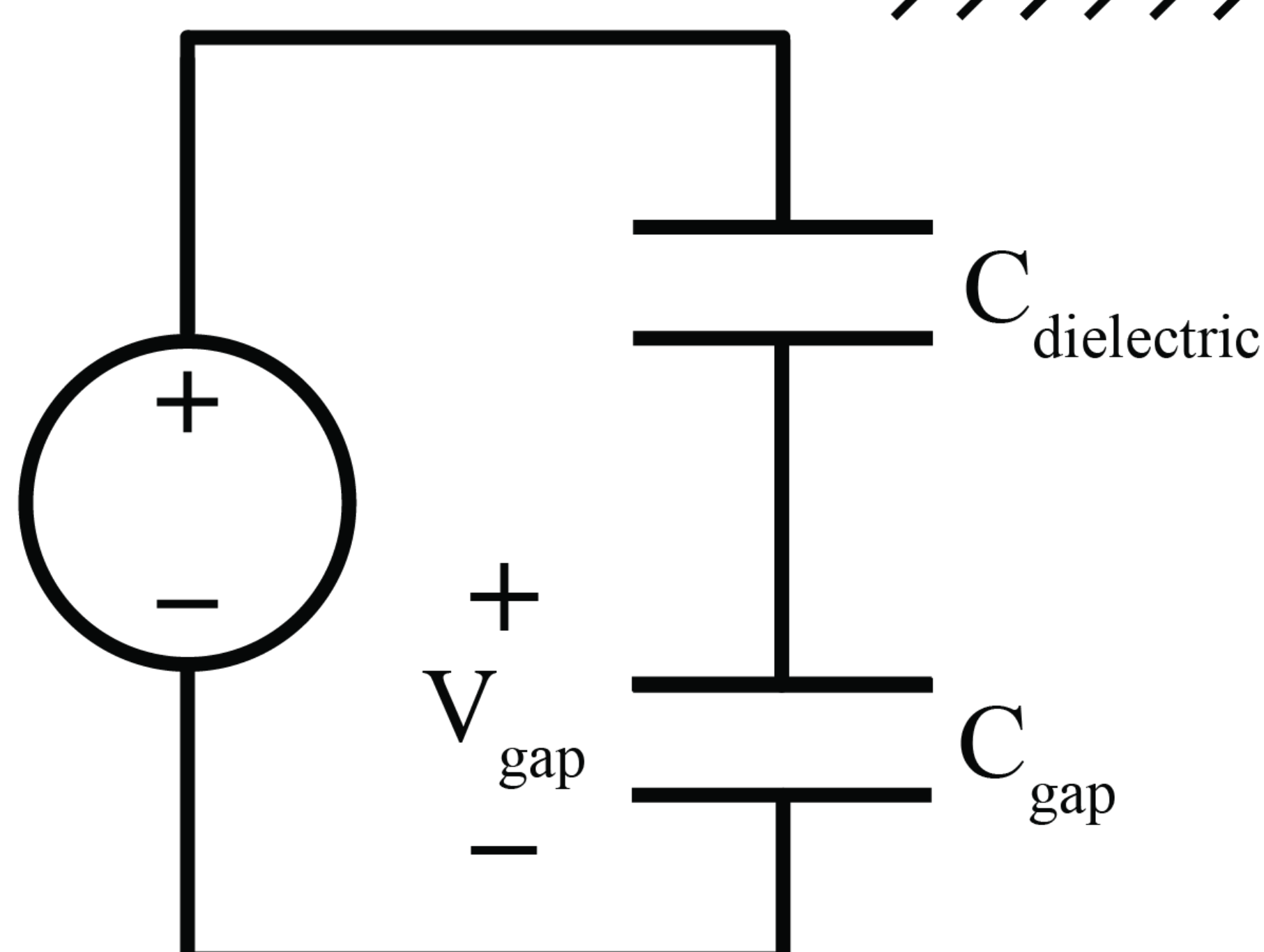
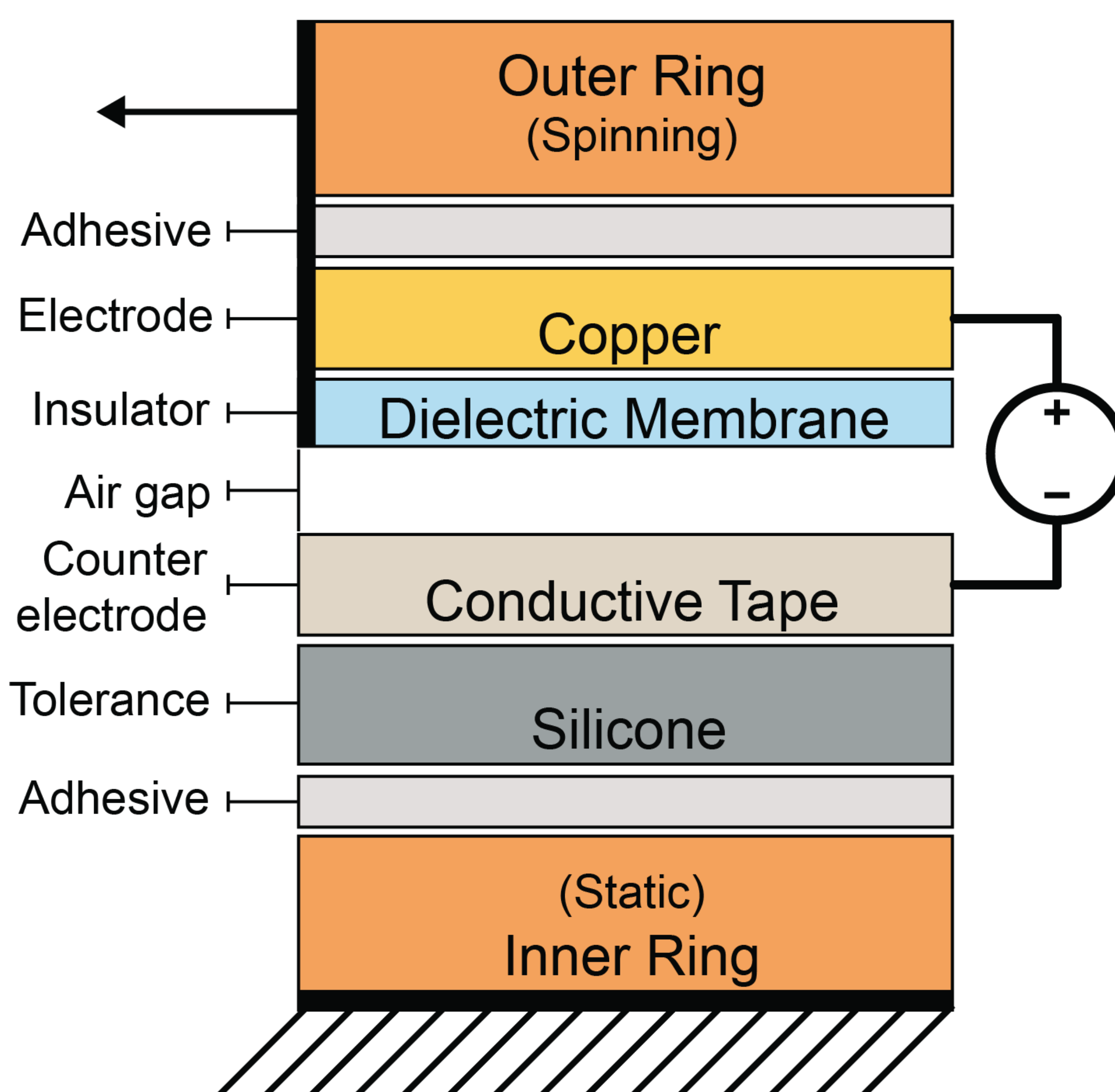


## E-Scroll

E-Scroll (A) consists of a stationary inner ring (B, C) and a rotating outer ring (D). A copper-dielectric electrode stack interfaces with a conductive counter-electrode to generate electrostatic adhesion, modulating friction during rotation.



The dielectric membrane is a thin (~19  $\mu\text{m}$ ) ceramic-filled epoxy composite with a dielectric constant of 21.

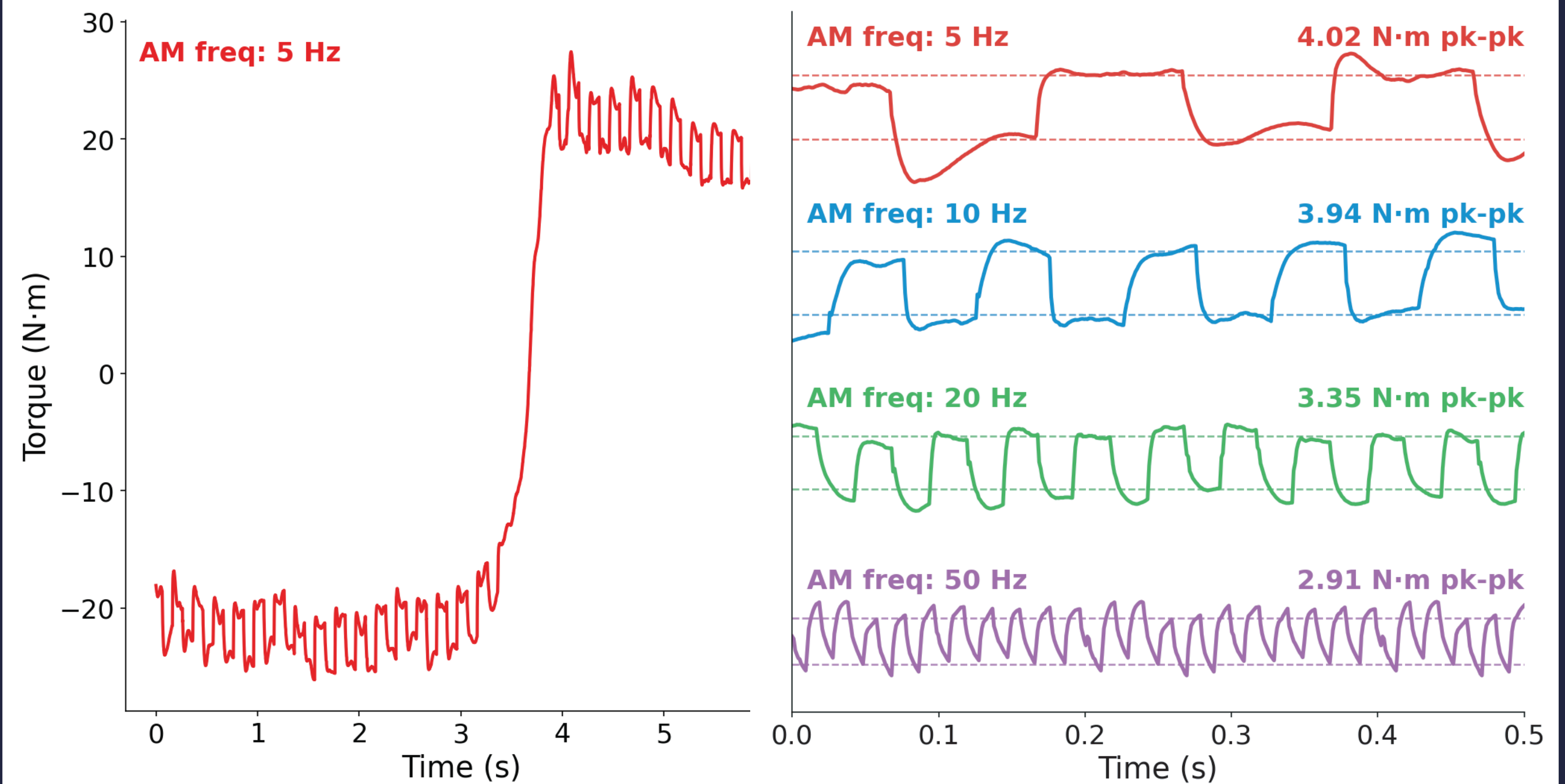


The interface behaves as two capacitors ( $C_{\text{dielectric}}$  and  $C_{\text{gap}}$ ) in series where:

$$F_e \propto V_{\text{gap}}$$

## Evaluation

Measured torque output under AM square-wave at 5-50 Hz using a 20kHz, 300Vpp carrier. pk-pk torque reflects adhesion strength.



### Method

- Ring rotated manually at ~0.2 Hz while AM frequency applied.
- Mean pk-pk torque calculated across all trials per AM frequency.

| AM Freq | pk-pk (N·m) | Baseline (N·m) | % of Baseline |
|---------|-------------|----------------|---------------|
| 5 Hz    | 4.02        | 19.9           | 20.2%         |
| 10 Hz   | 3.94        | 21.5           | 18.3%         |
| 20 Hz   | 3.35        | 20.8           | 16.1%         |
| 50 Hz   | 2.91        | 21.5           | 13.6%         |

### Results

- pk-pk torque modulation is 14–20% of baseline contact torque (2.91–4.02 N·m) across tested frequencies.
- Waveform transitions from square-wave (5Hz) to ramp (50Hz) suggesting contact cannot fully engage at higher frequencies.

## Future Work

### Hardware / Integration

- Integrate driving circuitry onto a compact PCB.
- Eliminate wiring on the rotating outer ring.

### Mechanical / Design

- Improve air gap uniformity and surface contact for increased adhesion force while maintaining smooth rotation.

### Interaction / Application

- Explore haptic rendering through waveform and modulation design.
- Integrate into XR systems for knob-like interaction.
- Evaluate perception of directional and continuous haptic feedback.

## Connect

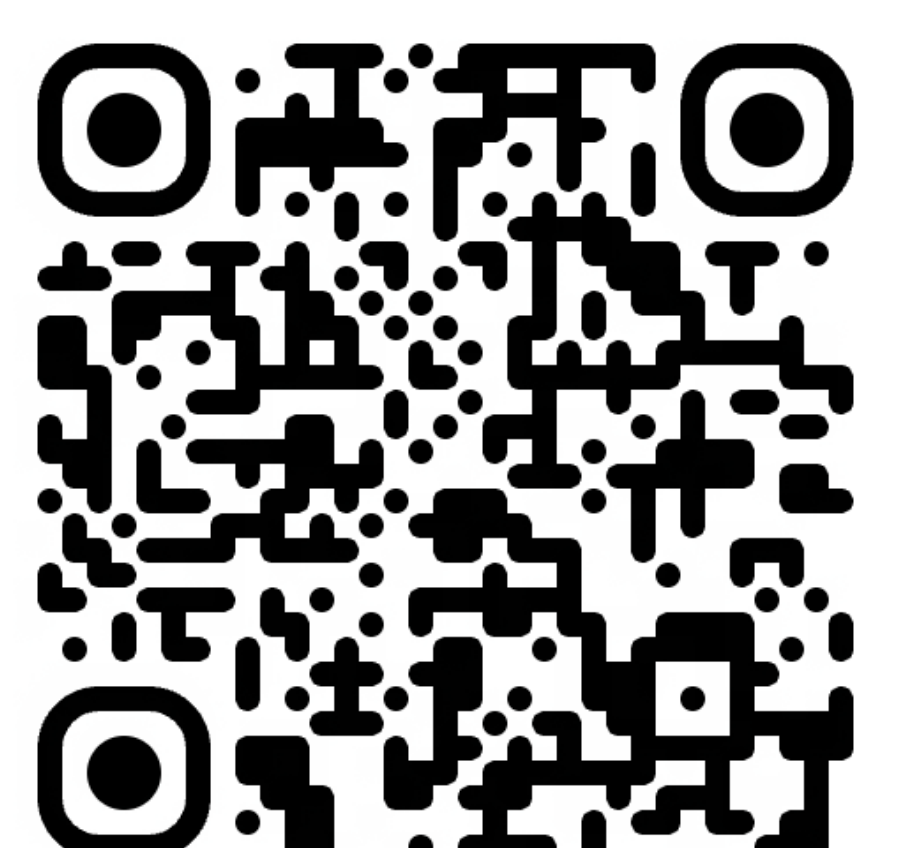
Mia Onodera

小野寺 海杏

M.S. Student in ECE @ UIUC

Would love to connect and learn more about your path in the field. Open to chatting after the conference!

Scan to Connect!



English / Japanese