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A SIMPLE PROCESS FOR THE FABRICATION OF PARALLEL-PLATE ELECTROSTATIC MEMS RESONATORS BY GOLD THERMOCOMPRESSION BONDING

W32-d

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Novelty / Progress Claim:

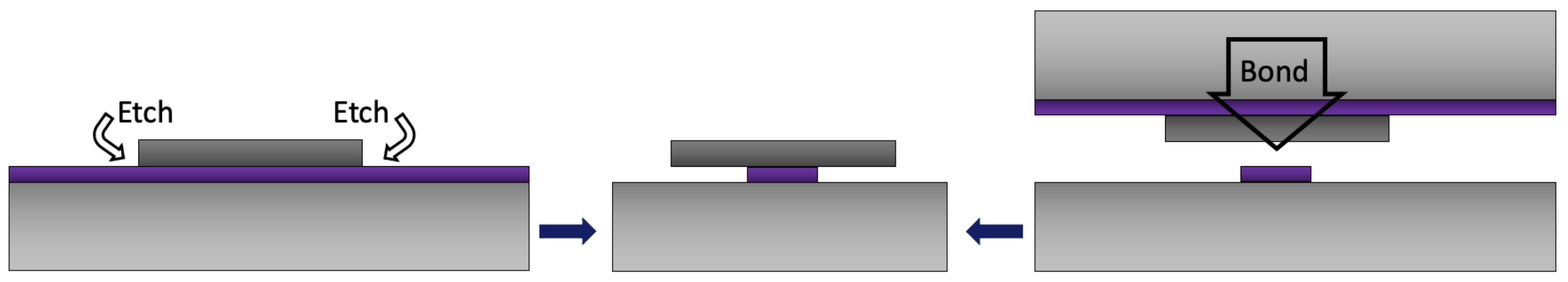
We use gold **thermocompression bonding to fabricate electrostatic MEMS** with the following advantages/characteristics:

- The process is simple and short
- It is suited to the fabrication of flexural mechanical resonators with electrostatic actuation and capacitive detection
- **Mechanical and electrical connections of the free-standing structure are realized in a single step**
- **A sealing joint protects the structure during the wet etching release step**
- **The gap of the parallel-plate capacitor can be easily controlled ⇒ squeeze-film damping is reduced by fabricating devices with increasing gaps**

State of the art: 2 routes to electrostatic MEMS

1. **Surface micromachining**
using a sacrificial layer

2. **Transfer methods**
e.g. wafer bonding, micro-masonry



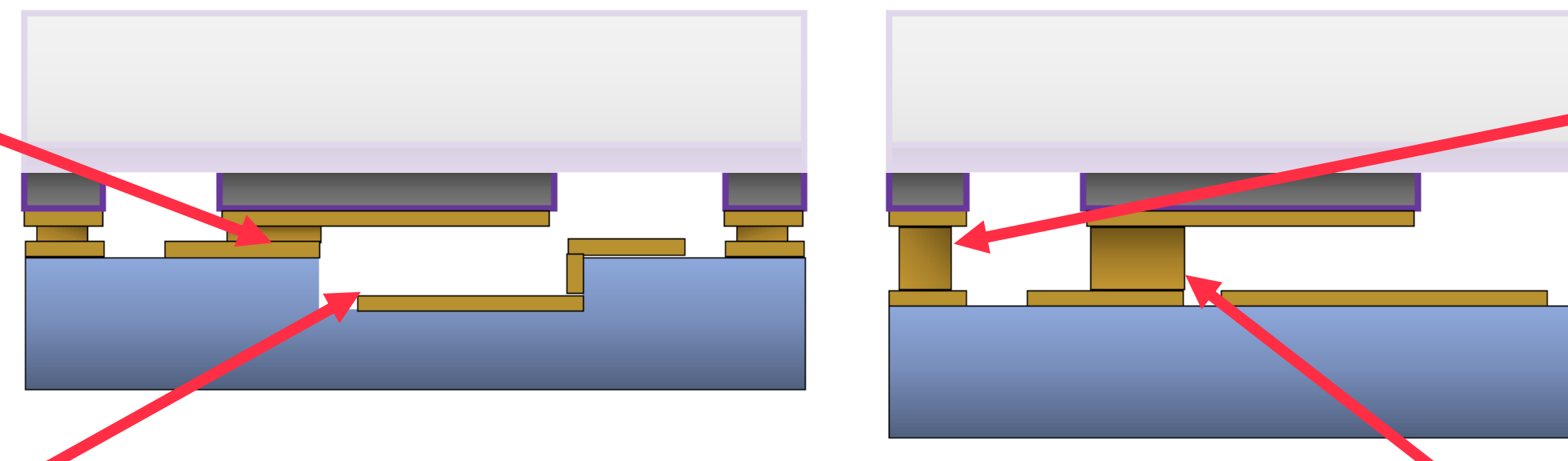
✗ Prone to stiction

✗ Difficult electrode integration

Our approach

Gold-gold thermocompression bonding is widely used in MEMS packaging
Proposition: use thermocompression bonding to fabricate electrostatic MEMS

2 gap configurations



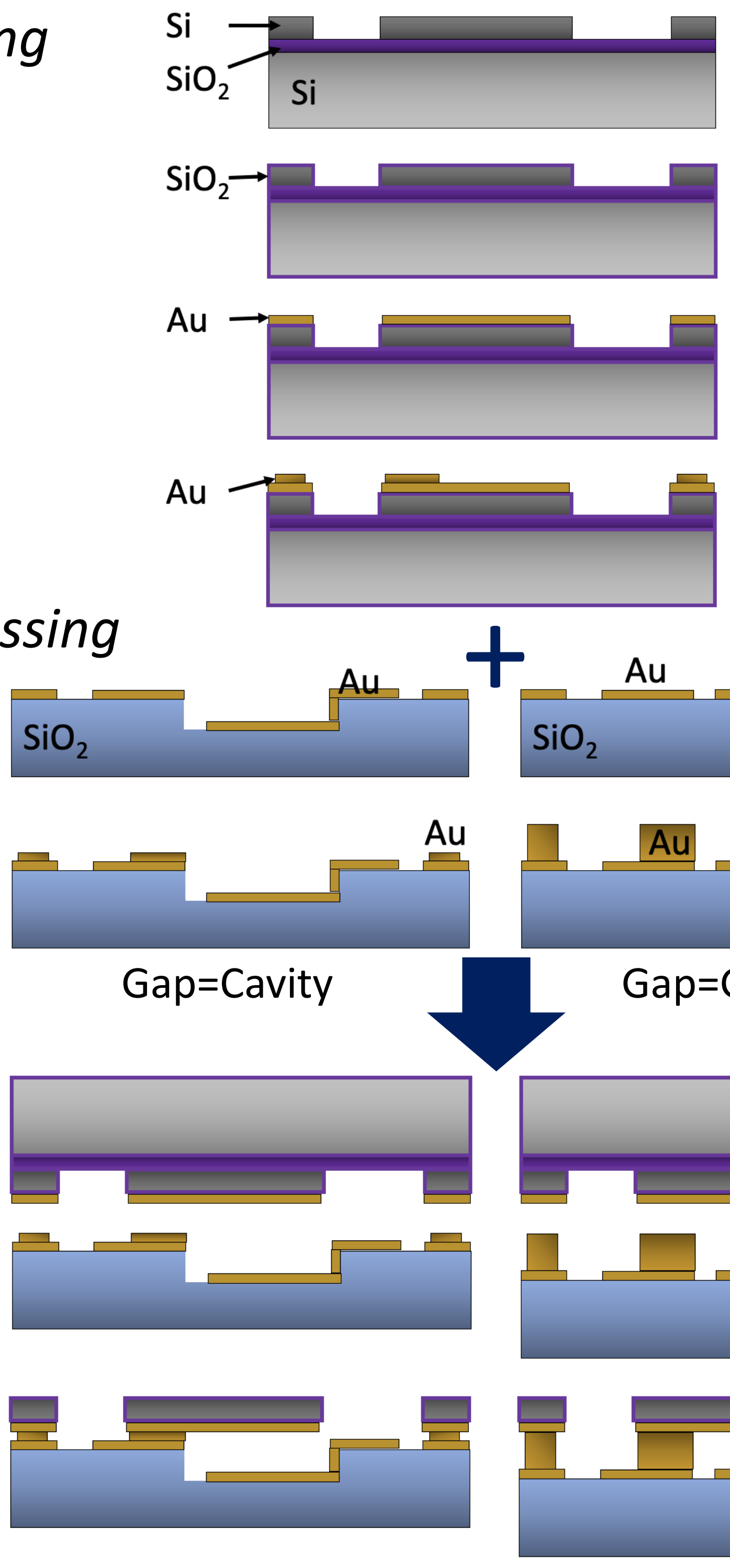
Electrode connection provided by the bond

Joints to protect the structure during wet etching

Electrostatic gap set by the cavity

Gap set by the gold bond

Fabrication process



1. Device processing

Etch the structure in top SOI layer

Oxidize the structure for protection

Pattern metal electrode

Electroplate metal joint

2. Substrate processing

Etch cavity / Pattern metal

Pattern metal electrode

Electroplate metal joint

Electroplate metal joint

Gap=Cavity

Gap=Gold bond

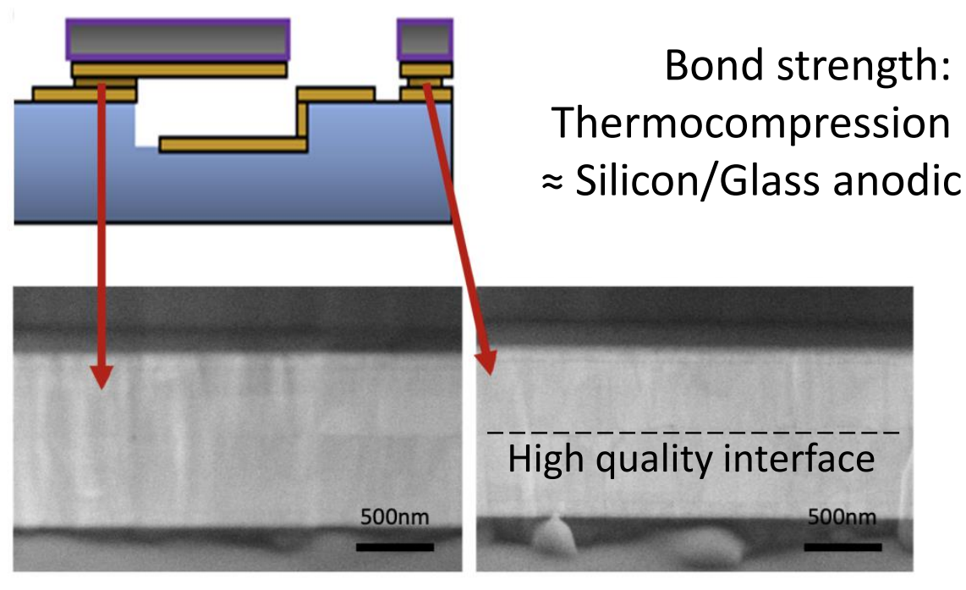
3. Bonding

Align wafers & perform thermocompression bonding (40KgF/350°C/ 10min)

4. Release

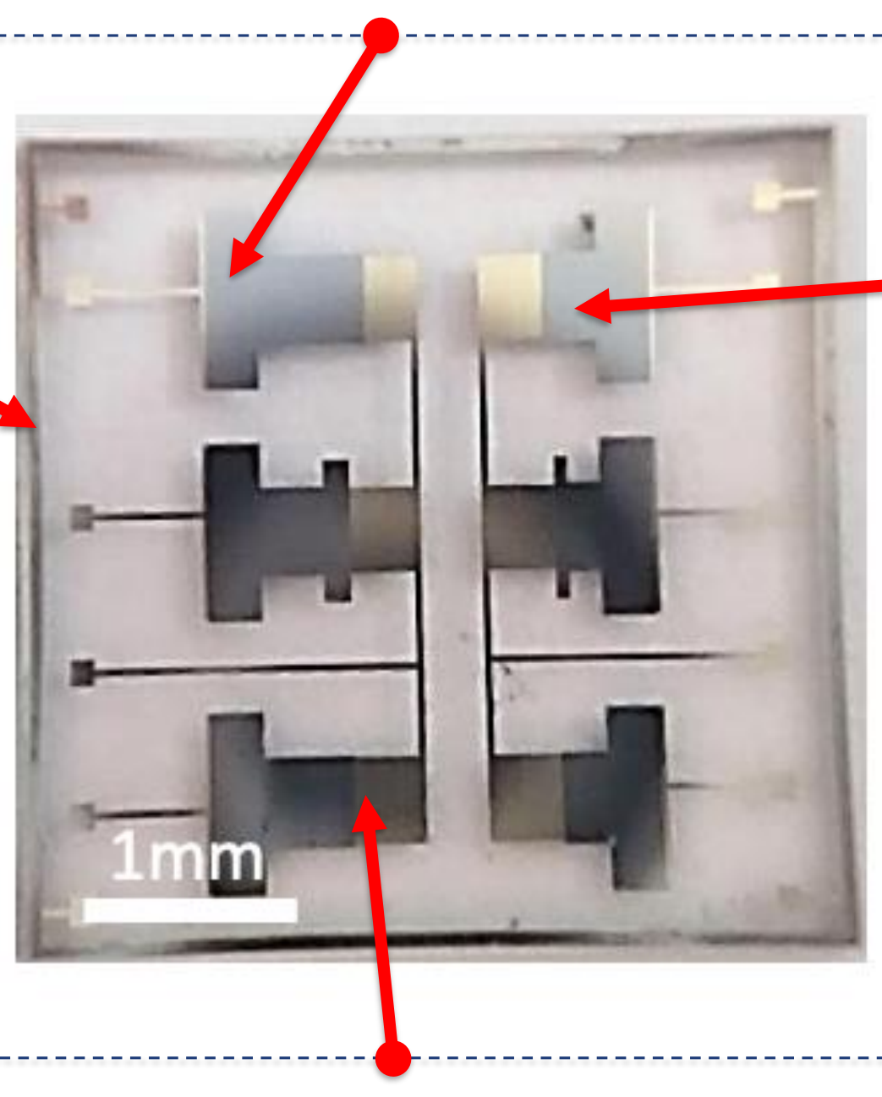
Wet etching (TMAH/BHF)

Fabricated devices

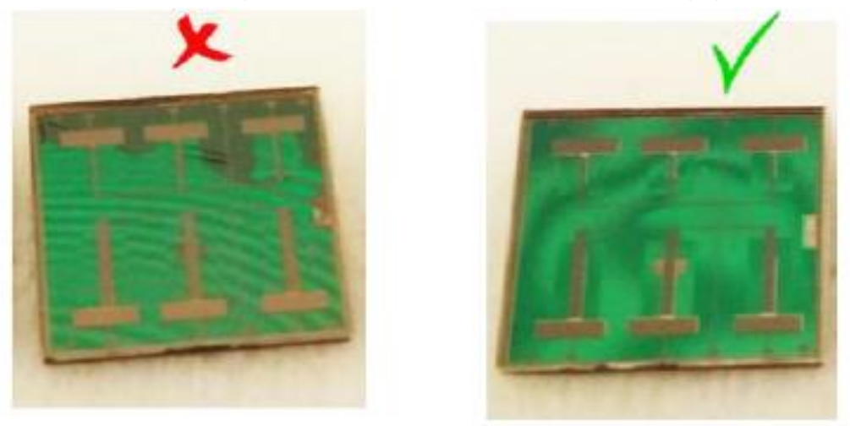


Bond strength:
Thermocompression bond
≈ Silicon/Glass anodic bond

Mechanical and electrical connections



Protective joint

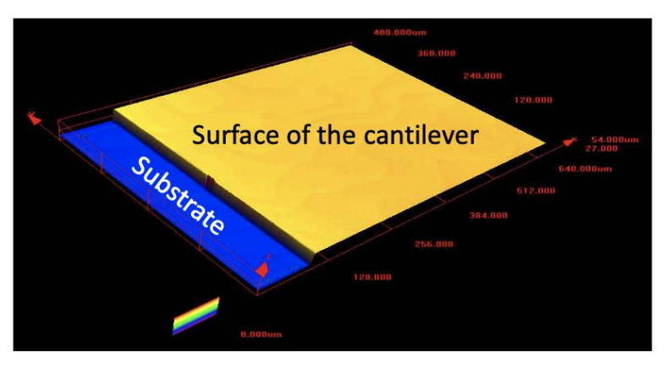


Defective joint ⇒ Device failure

Working joint ⇒ Working device

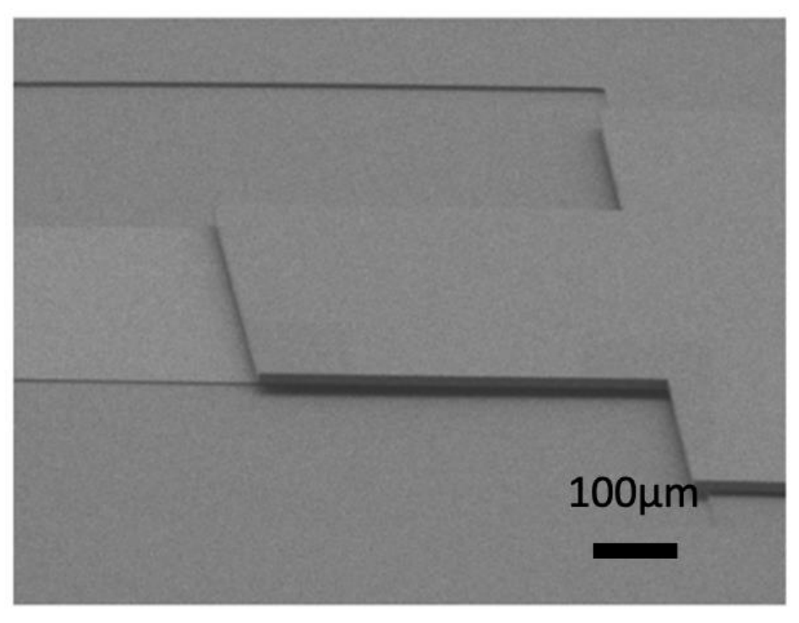
Cantilevers

Length=250-500µm/Width=500µm/Thickness=5µm



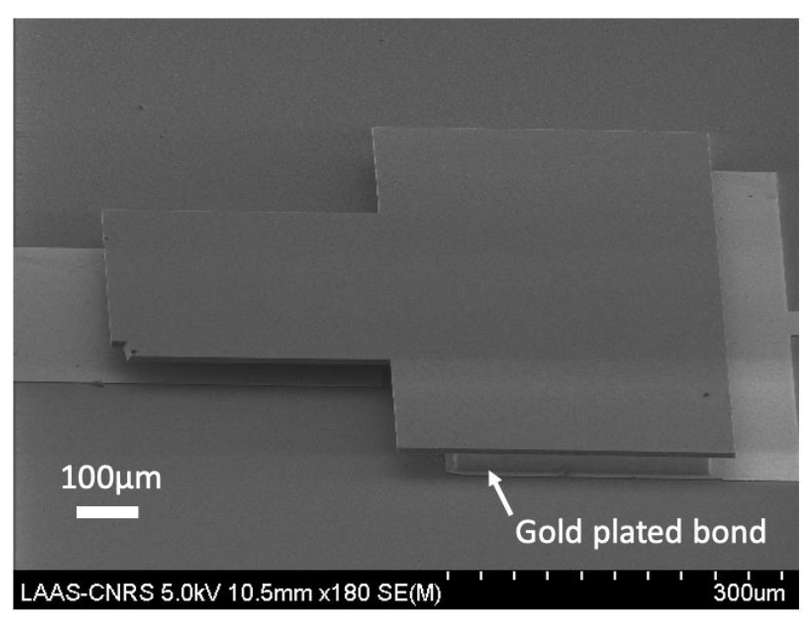
Cantilever surface is parallel to the substrate ⇒ pressure evenly distributed during bonding

Electrostatic gap



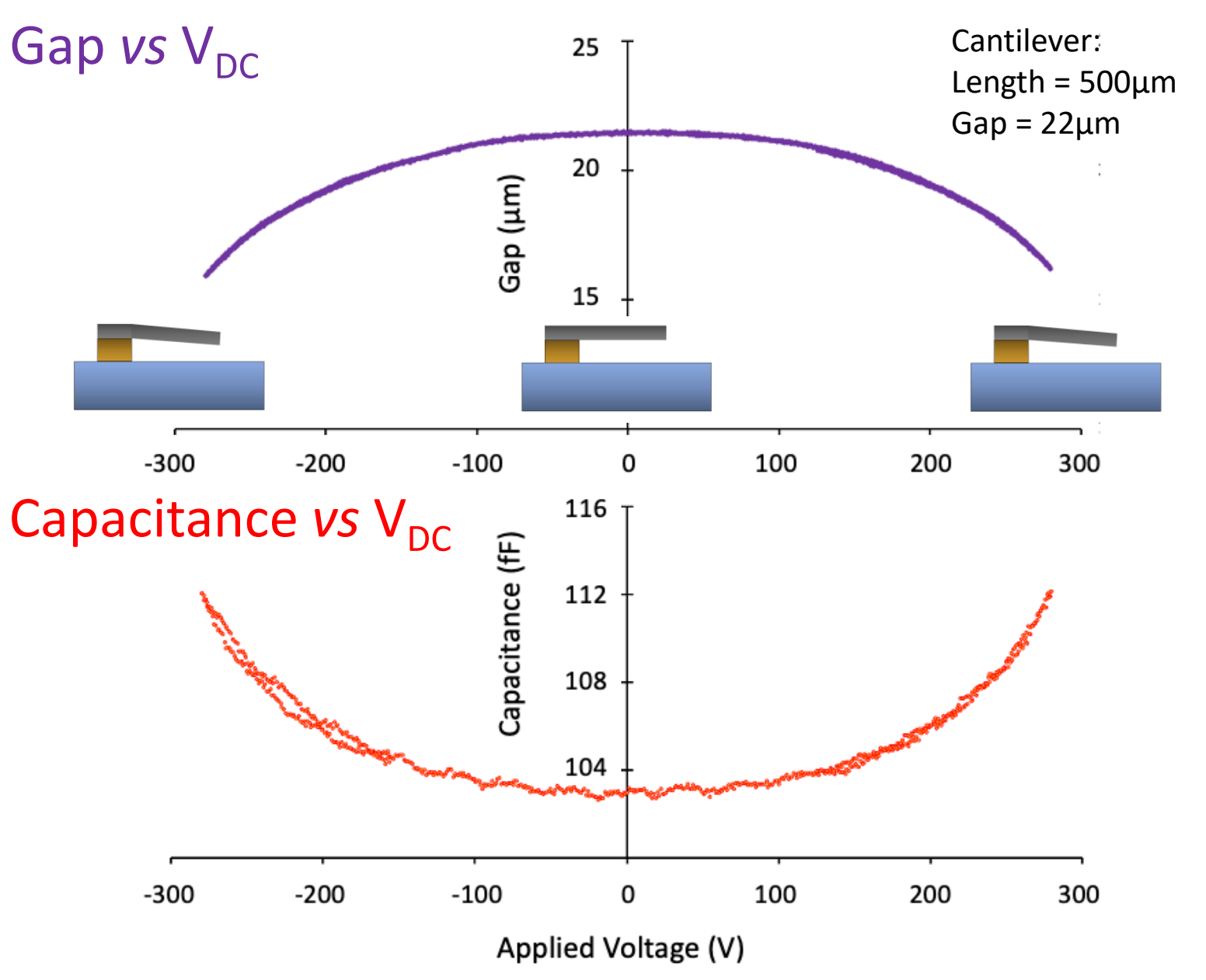
Gap set by the gold bond
From 10µm to 25µm

Gap set by the etched cavity
From 3µm to 9µm



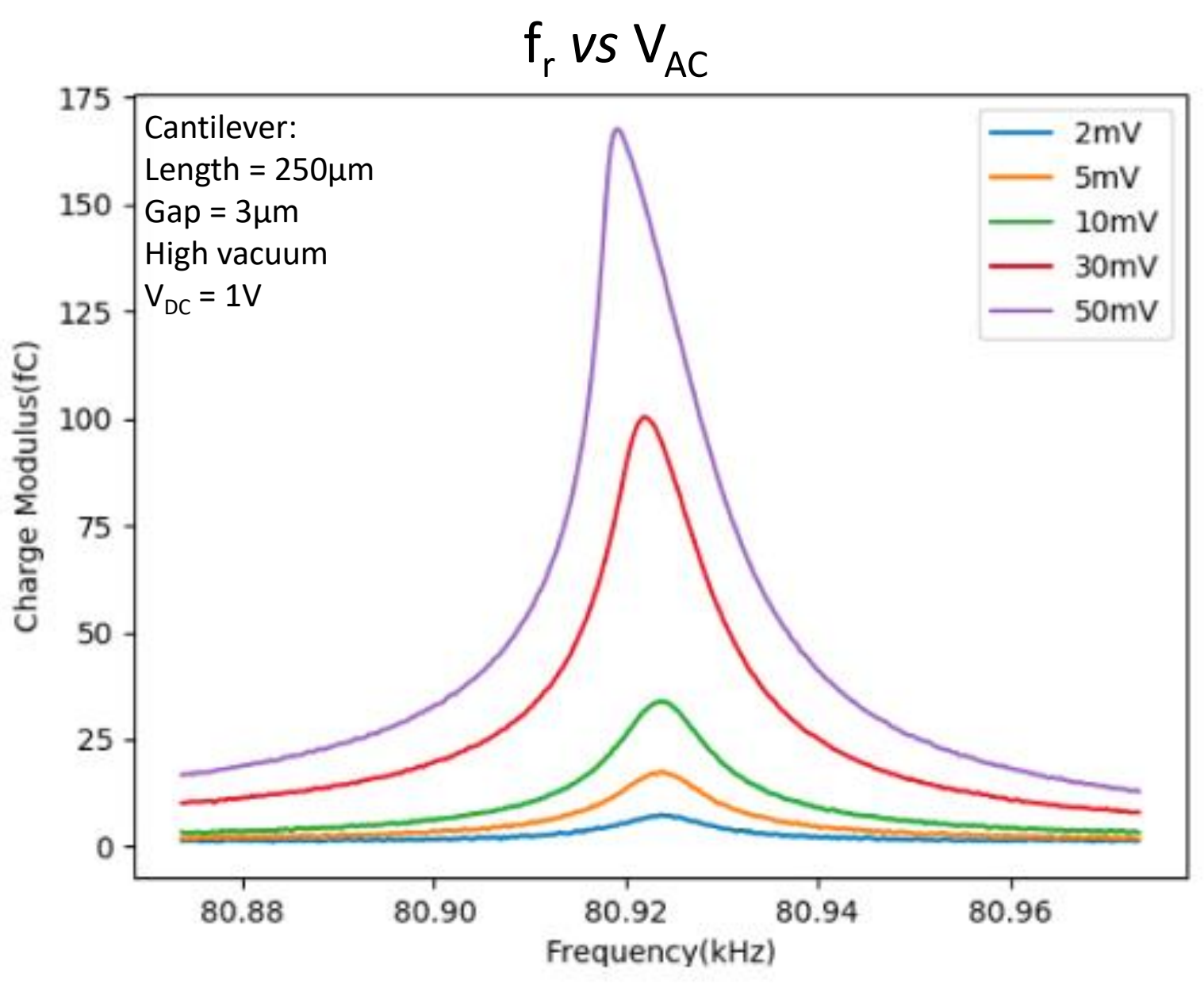
Characterizations

Static mode

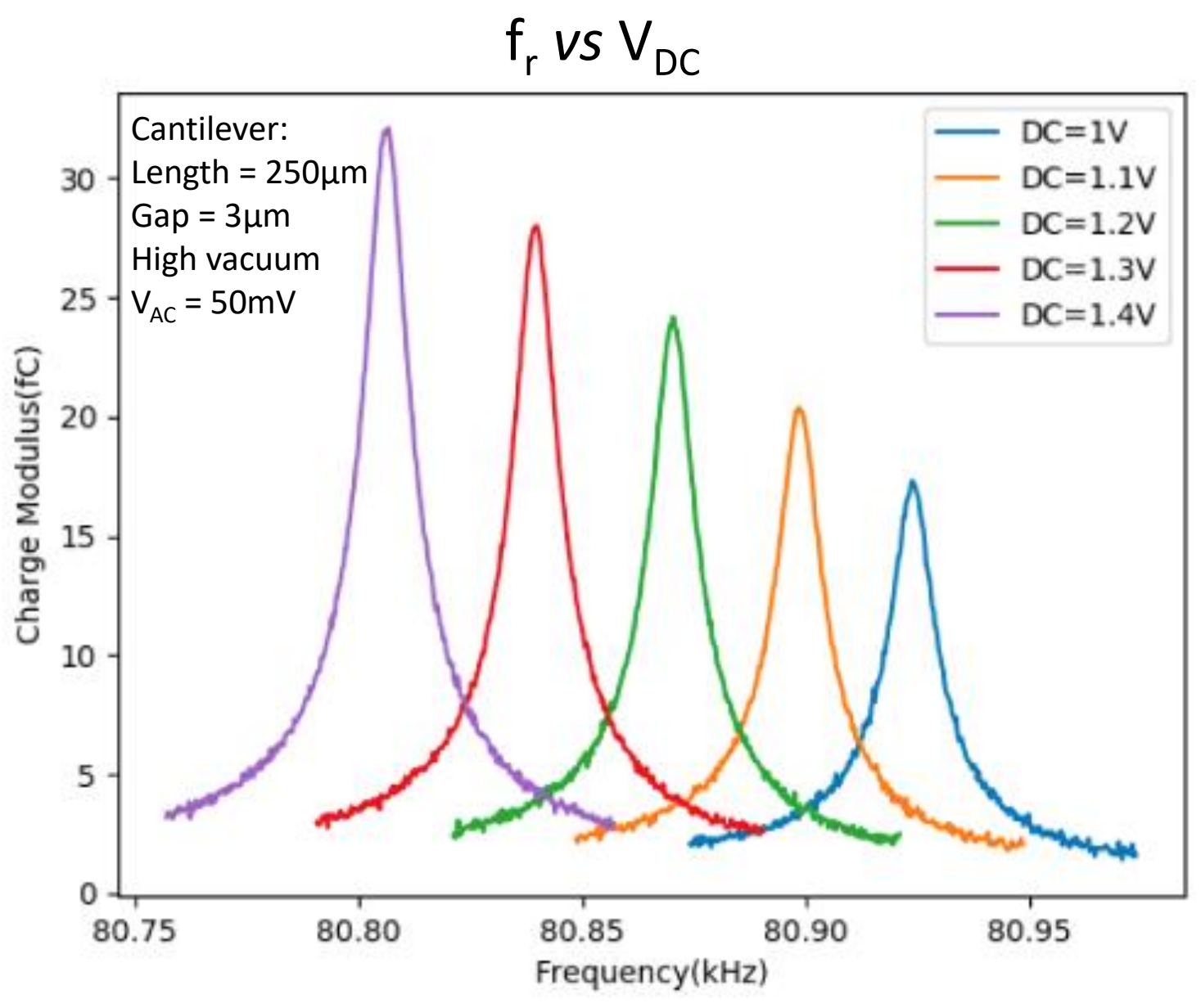


✓ Quadratic dependance of the gap and capacitance with applied voltage

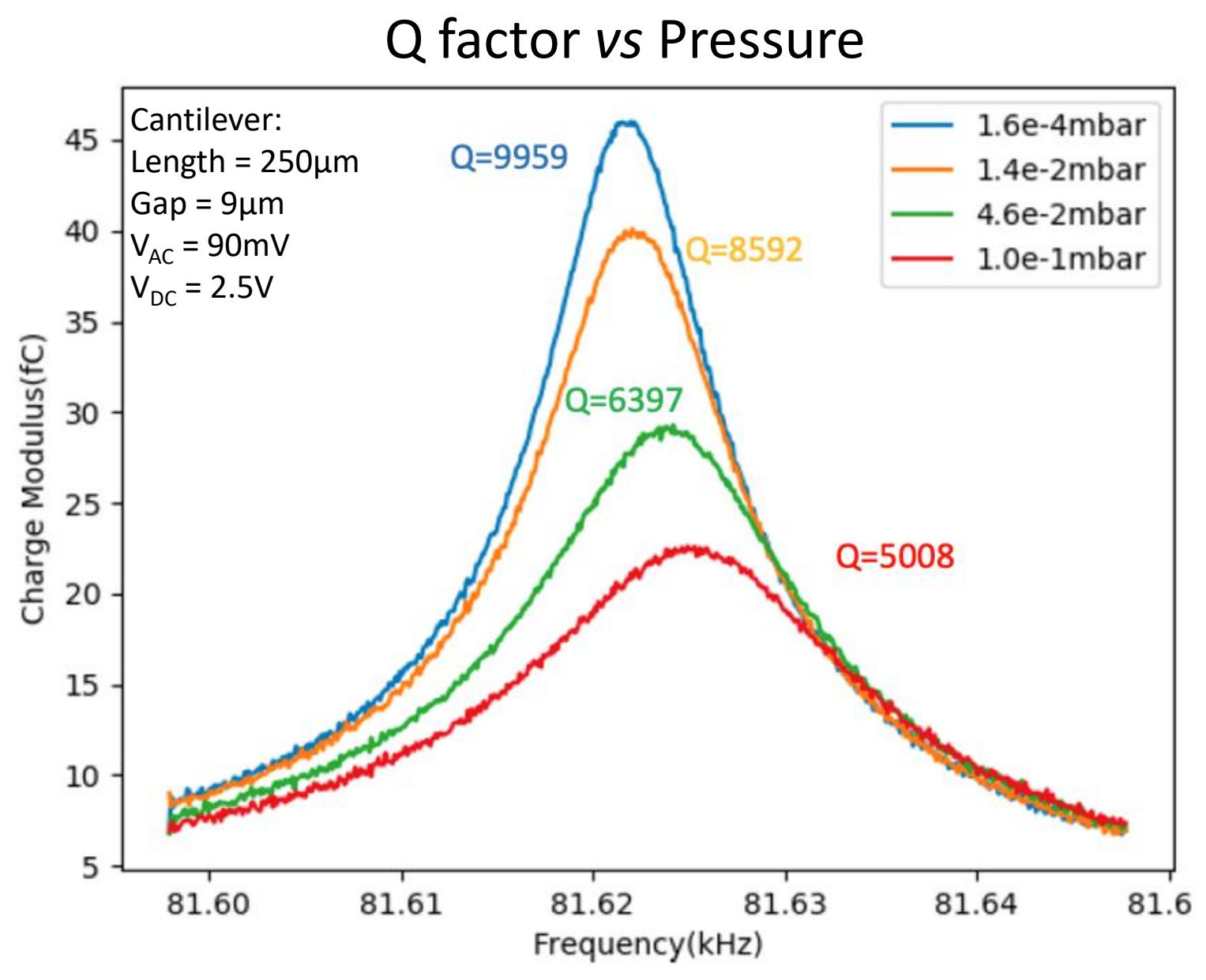
Dynamic mode



✓ Non-linear response regime at resonance is obtained with high AC voltage



✓ Spring softening effect is observed with increasing DC voltage



✓ Q factor drops with increasing pressure due to molecular and squeeze-film damping

<u>Conclusions:</u>
- Gold thermocompression bonding provides mechanical and electrical connections for electrostatic MEMS in a single step
- Fabricated structures behave as theoretically predicted with limited mechanical dissipation due to the gold anchor
- Squeeze-film damping is reduced with thicker thermocompression bonds: critically damped vibrations for 3µm gap in air ⇒ Q = 45 for 25µm gap

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