



# **A simple process for the fabrication of parallel-plate electrostatic MEMS resonators by gold thermocompression bonding**

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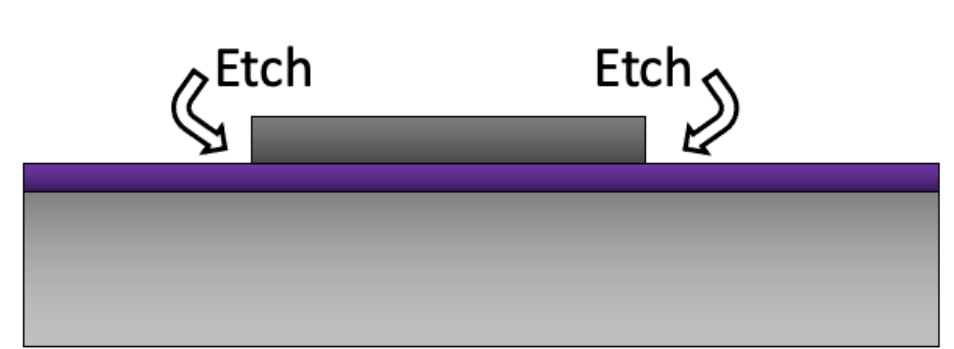
## Novelty / Progress Claim:

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  $\Rightarrow$  squeeze-film damping is reduced by fabricating devices with increasing gaps

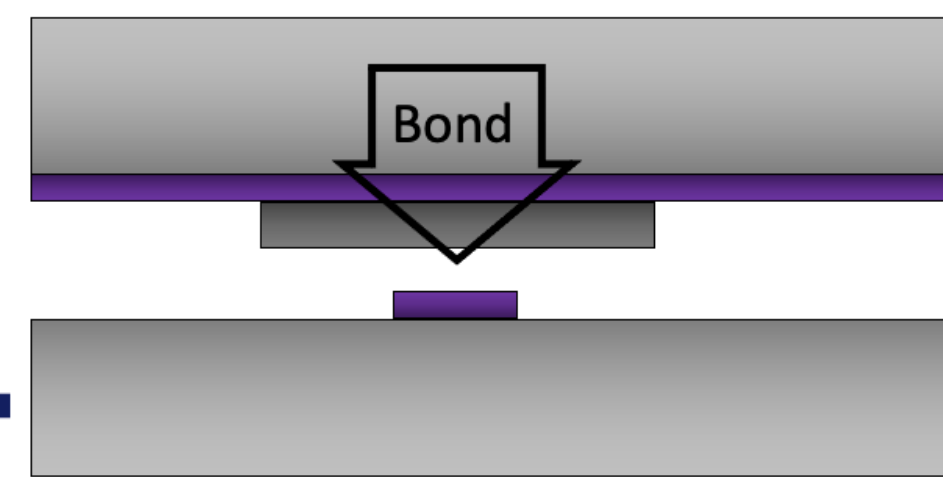
## State of the art: 2 routes to electrostatic MEMS

### 1. Surface micromachining using a sacrificial layer



X Prone to stiction

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

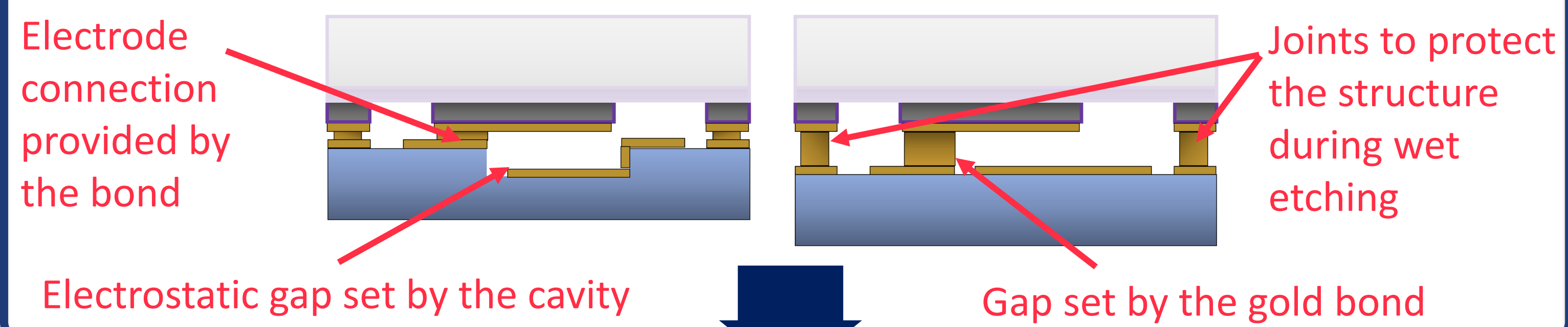


X Difficult electrode integration

## Our approach

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

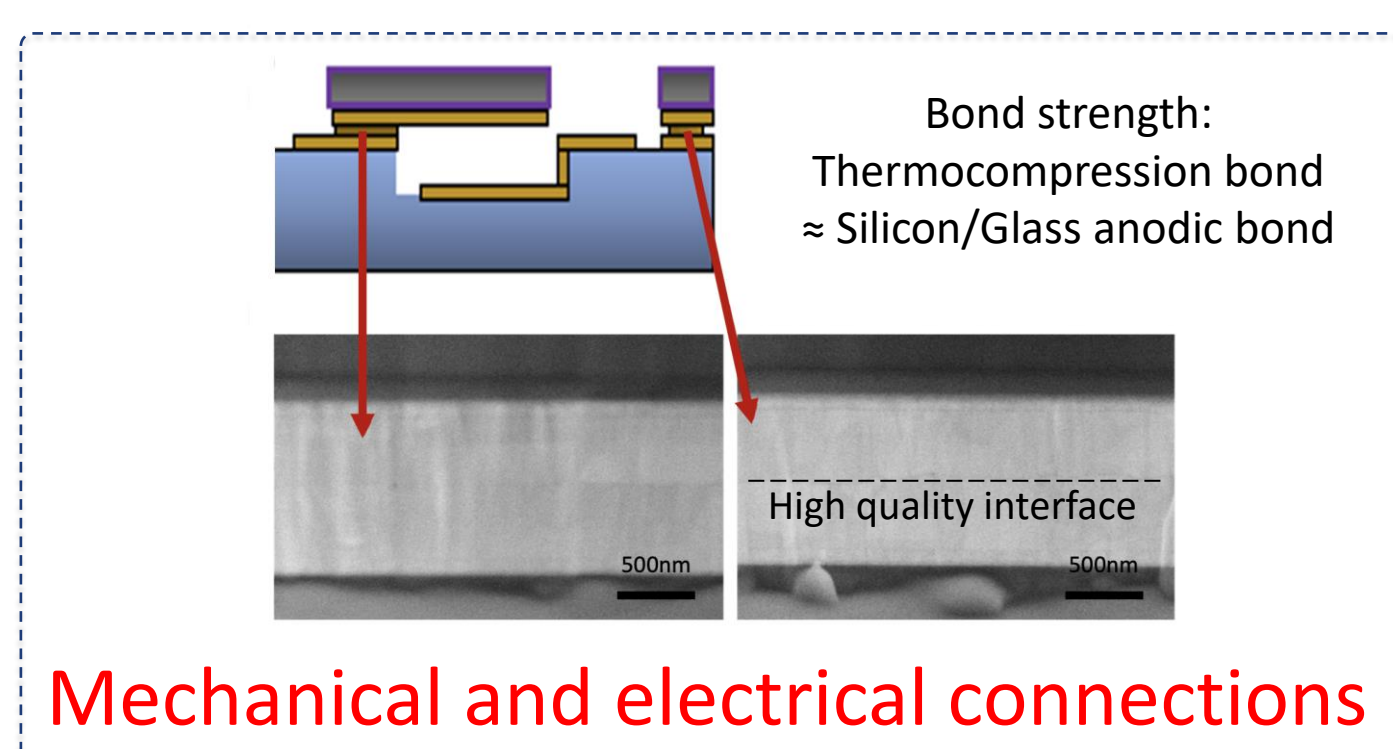
### 2 gap configurations



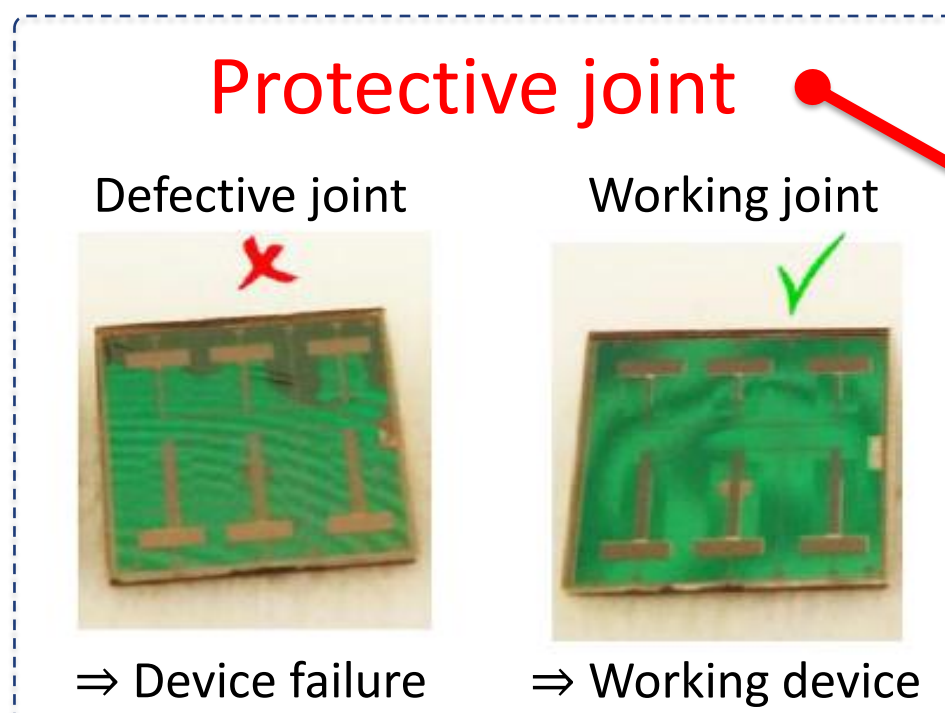
Electrostatic gap set by the cavity

Gap set by the gold bond

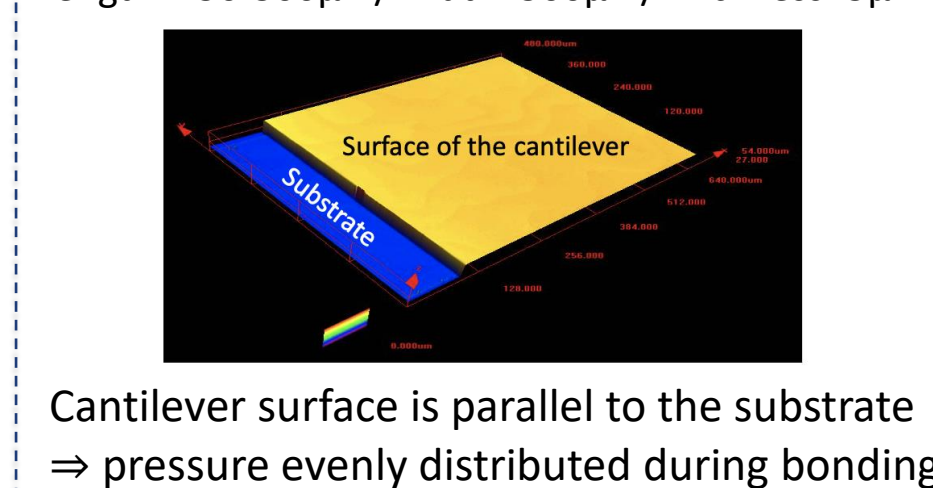
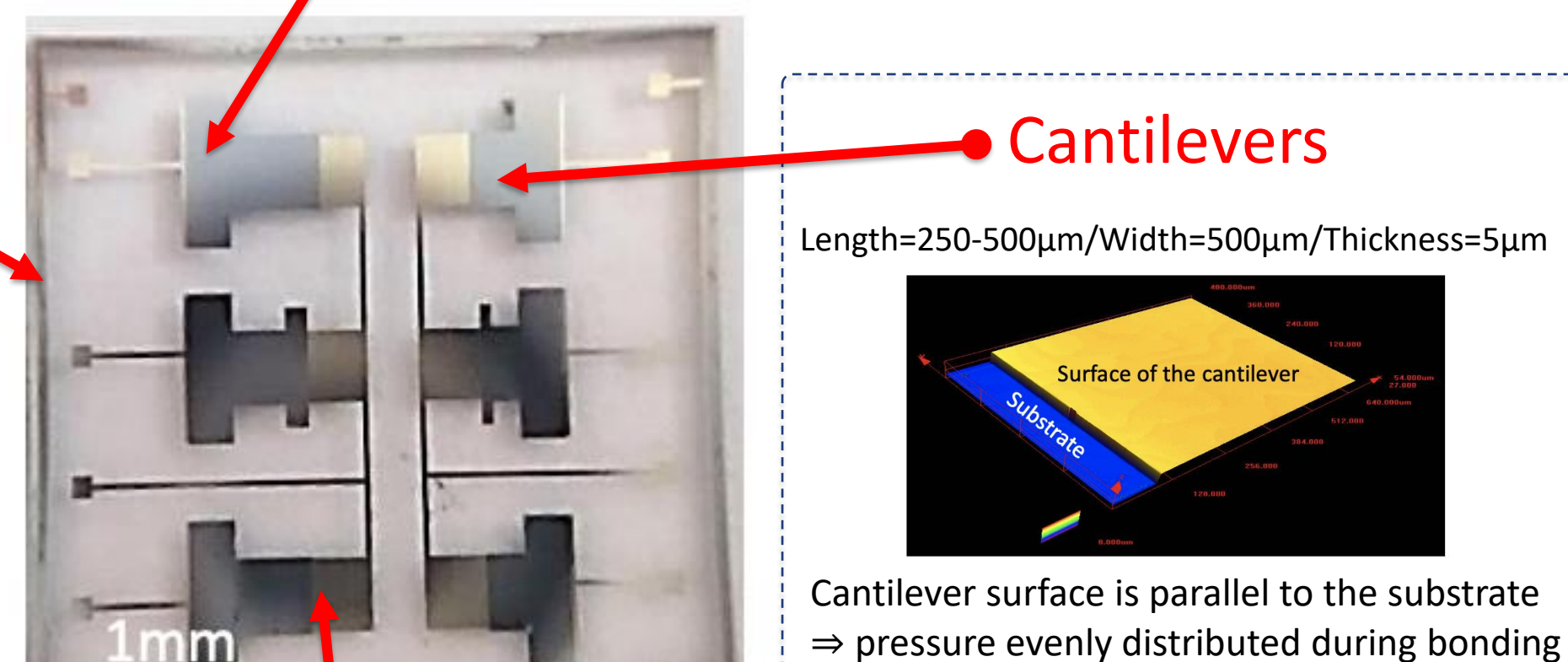
## Fabricated devices



Mechanical and electrical connections



$\Rightarrow$  Device failure  $\Rightarrow$  Working device

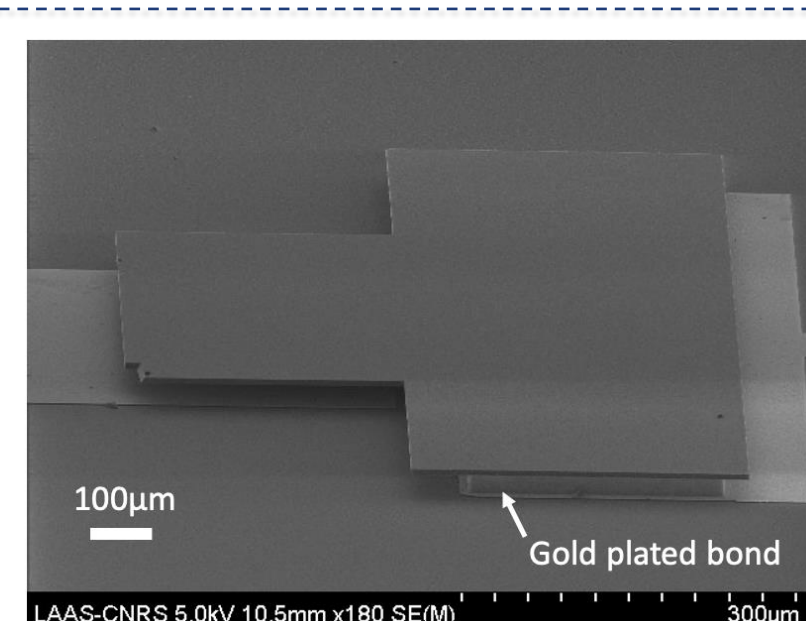


Cantilever surface is parallel to the substrate  $\Rightarrow$  pressure evenly distributed during bonding

### Electrostatic gap

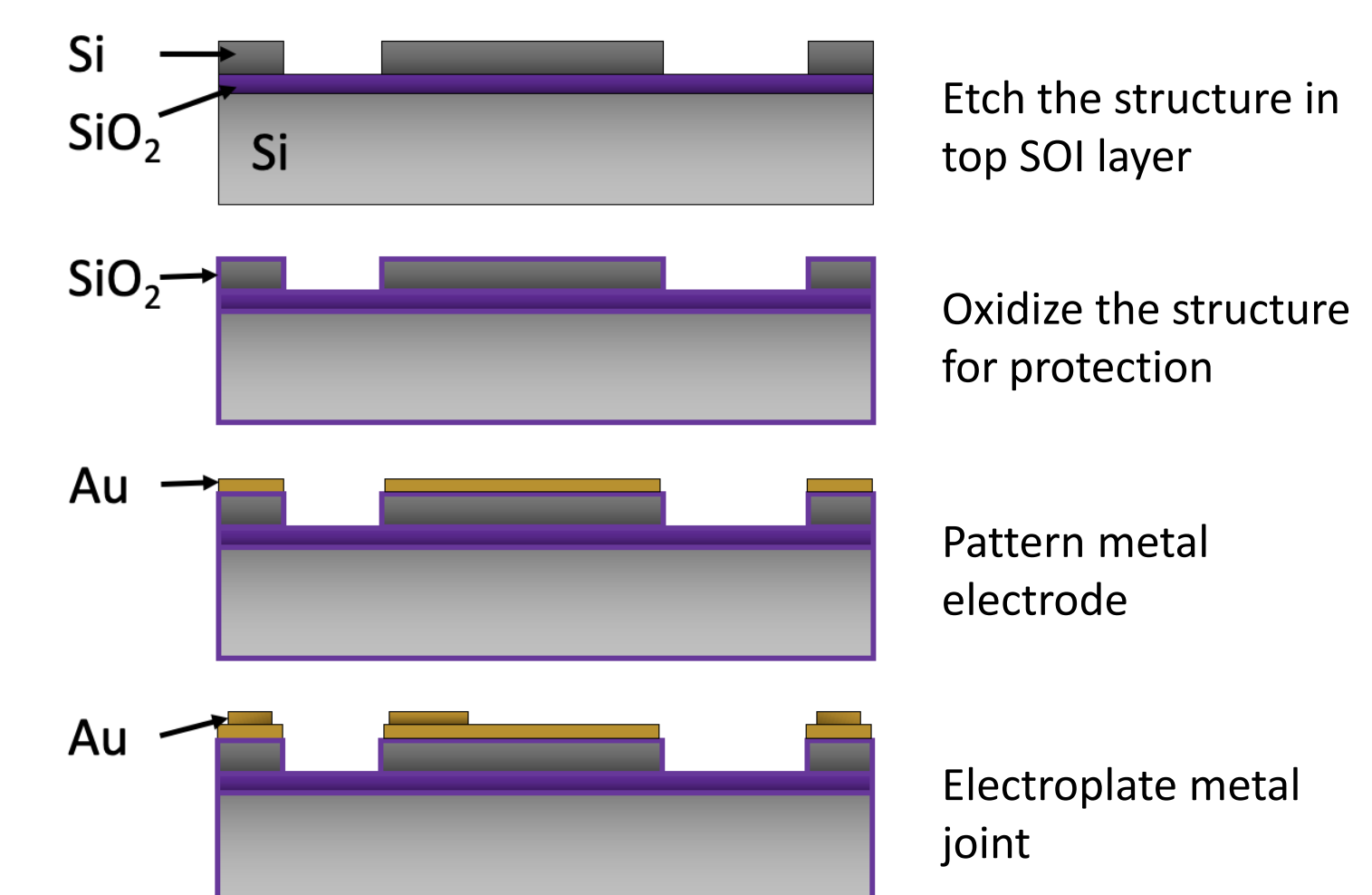
Gap set by the gold bond From 10µm to 25µm

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

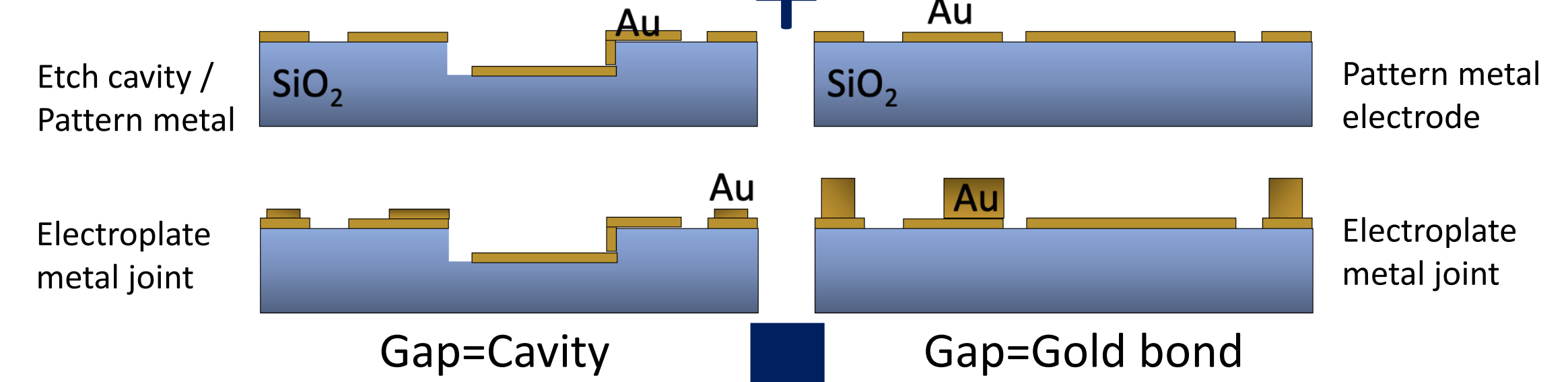


## Fabrication process

### 1. Device processing



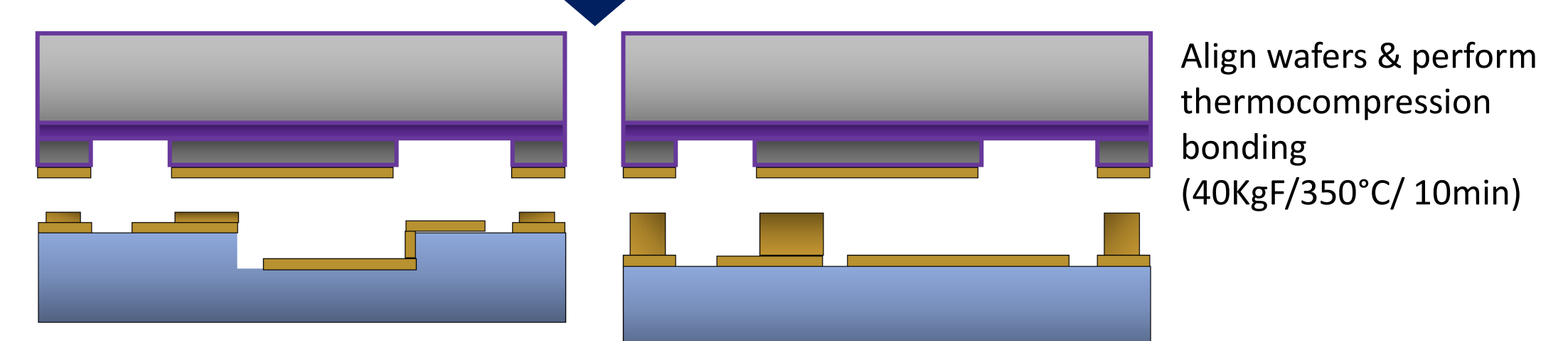
### 2. Substrate processing



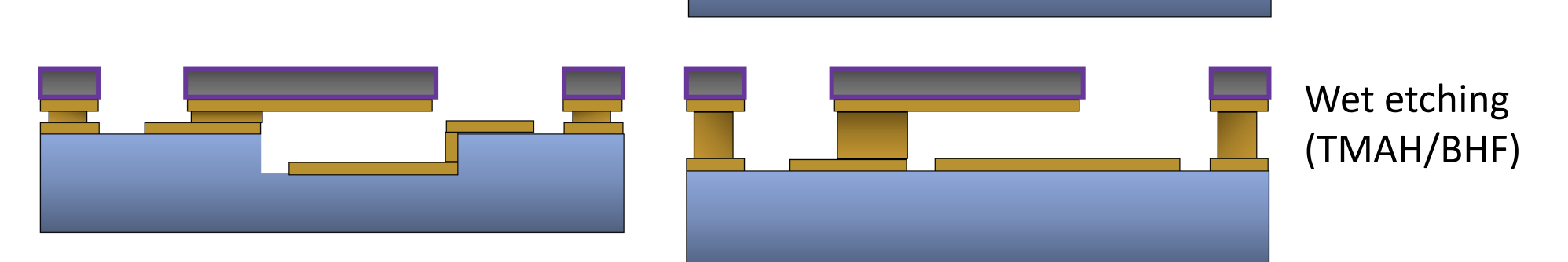
Gap=Cavity

Gap=Gold bond

### 3. Bonding

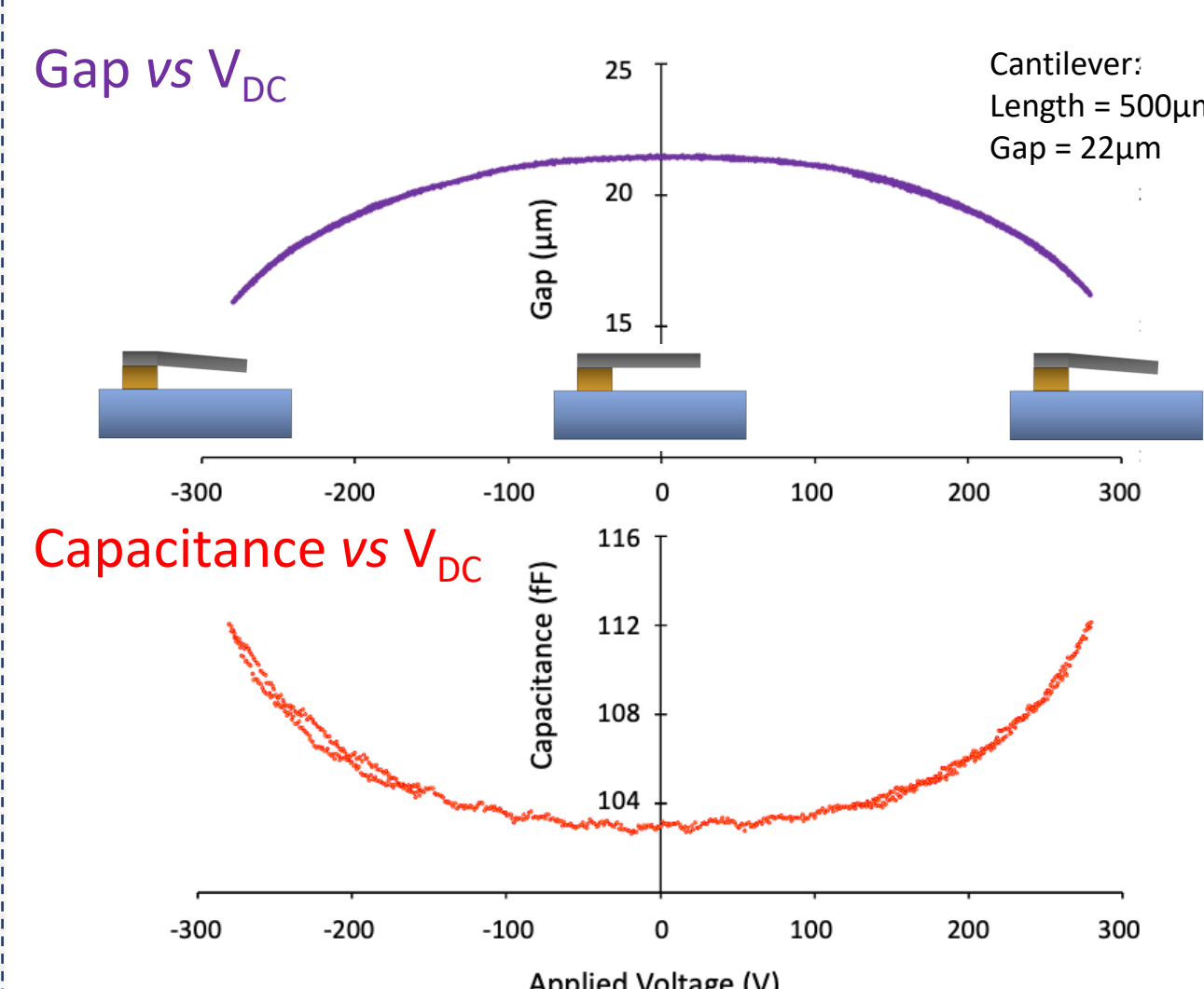


### 4. Release



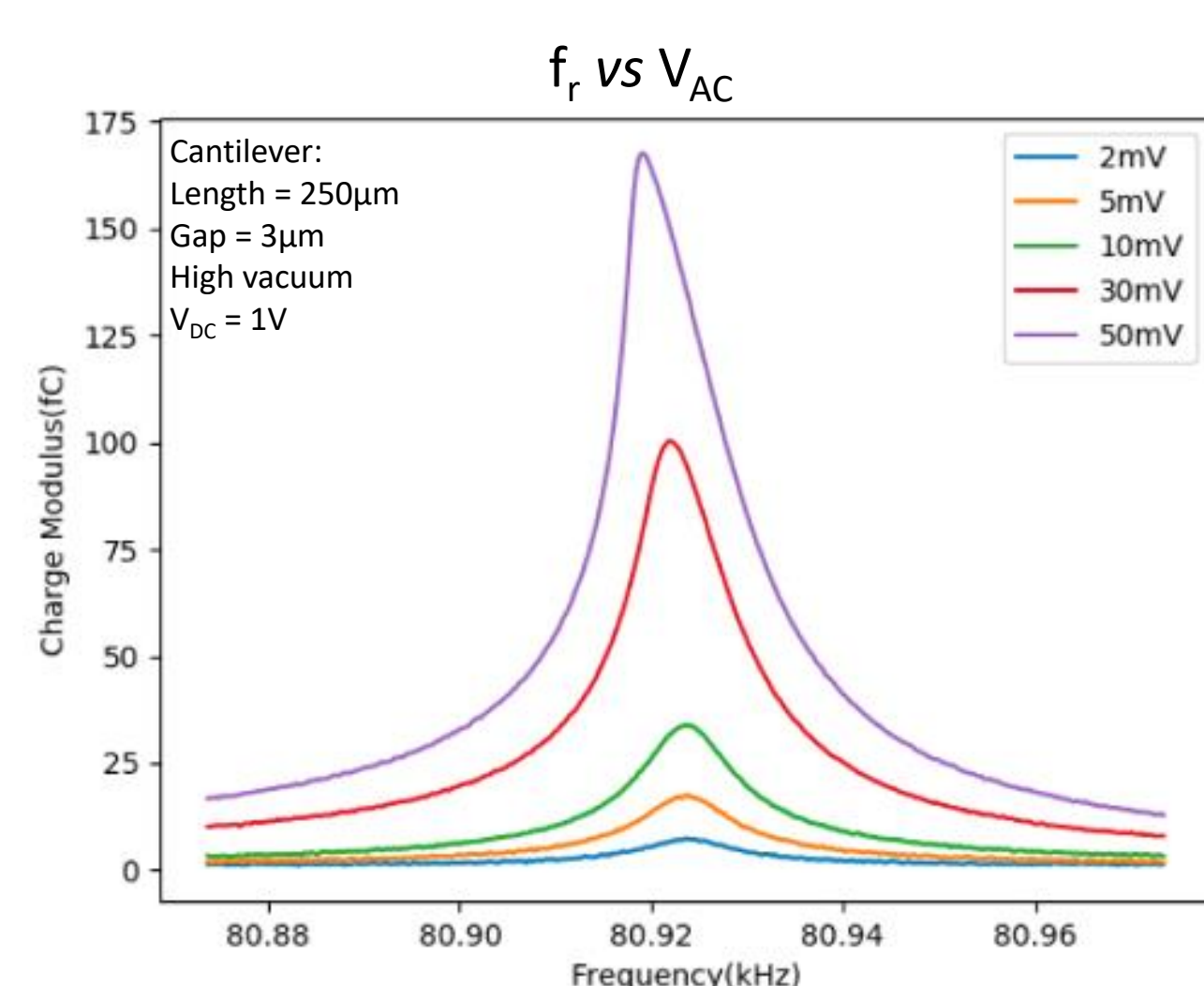
## Characterizations

### Static mode

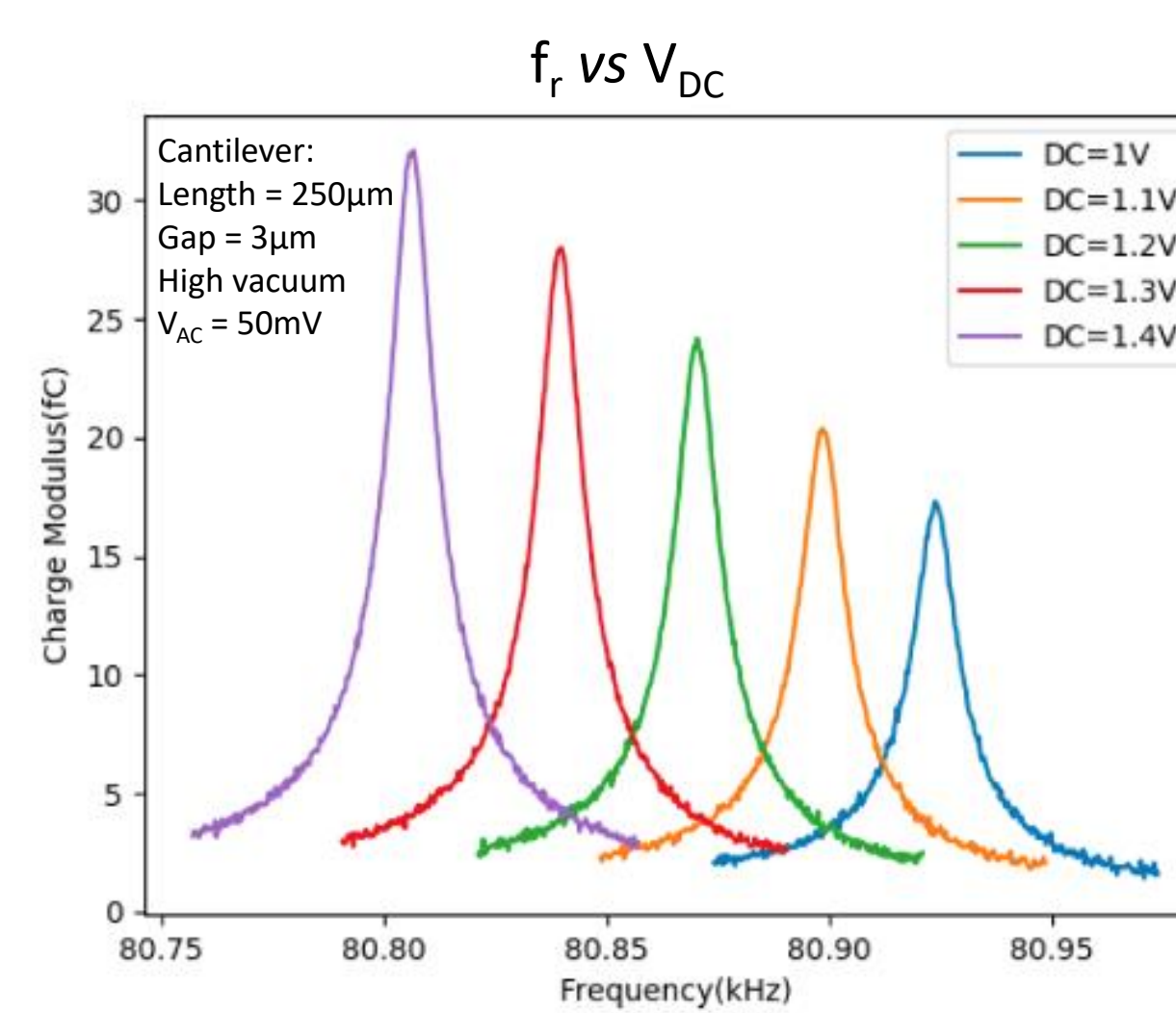


✓ Quadratic dependence of the gap and capacitance with applied voltage

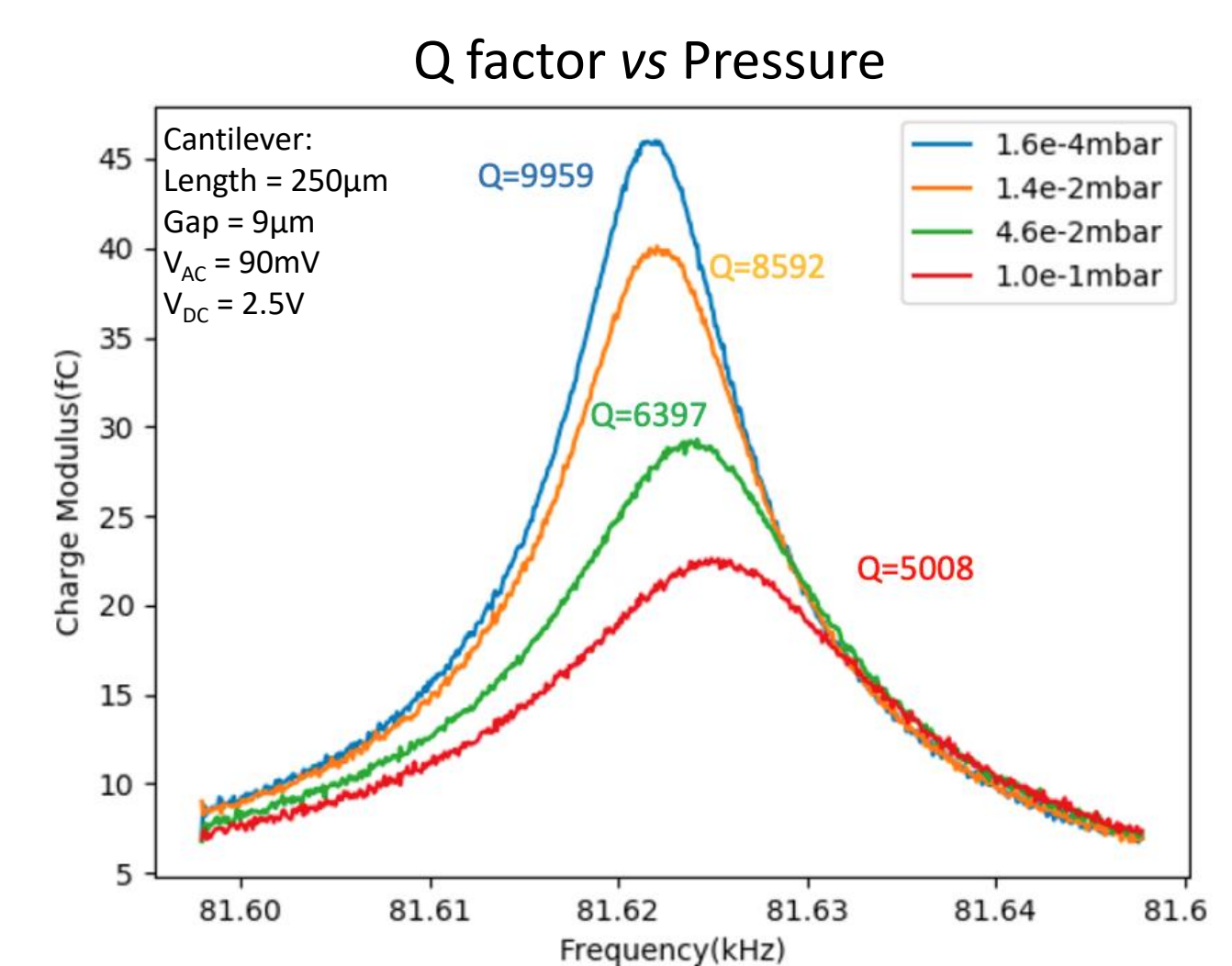
### Dynamic mode



✓ 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

**Conclusions:** • 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  $\Rightarrow$  Q = 45 for 25µm gap