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

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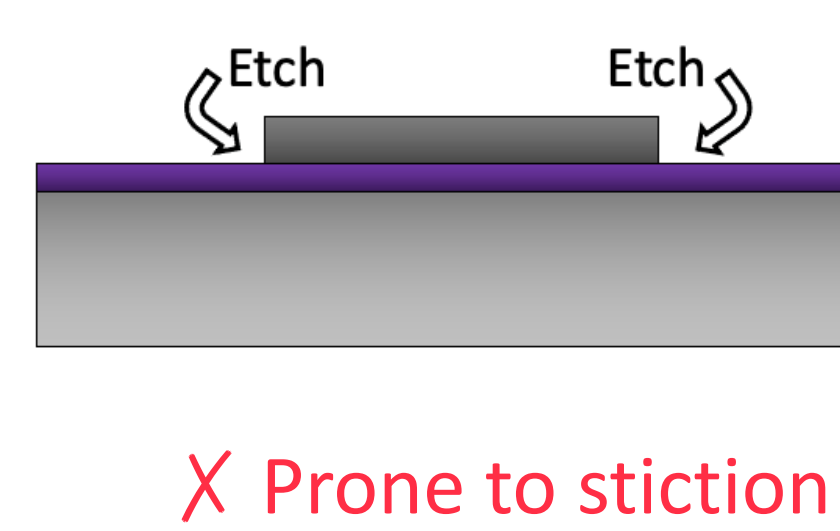
Novelty / Progress Claim:

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

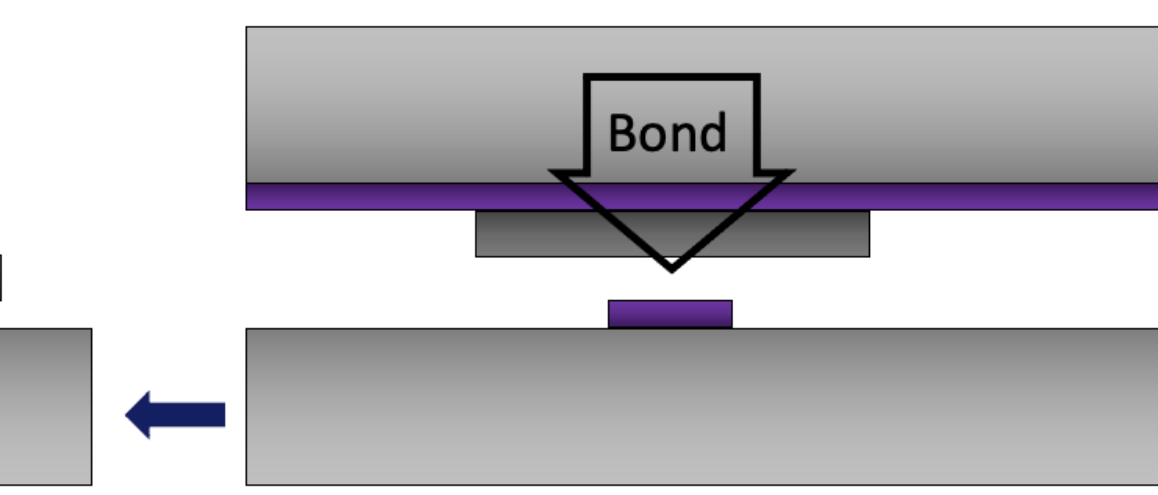
State of the art: 2 routes to electrostatic MEMS

1. Surface micromachining using a sacrificial layer



X Prone to stiction

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

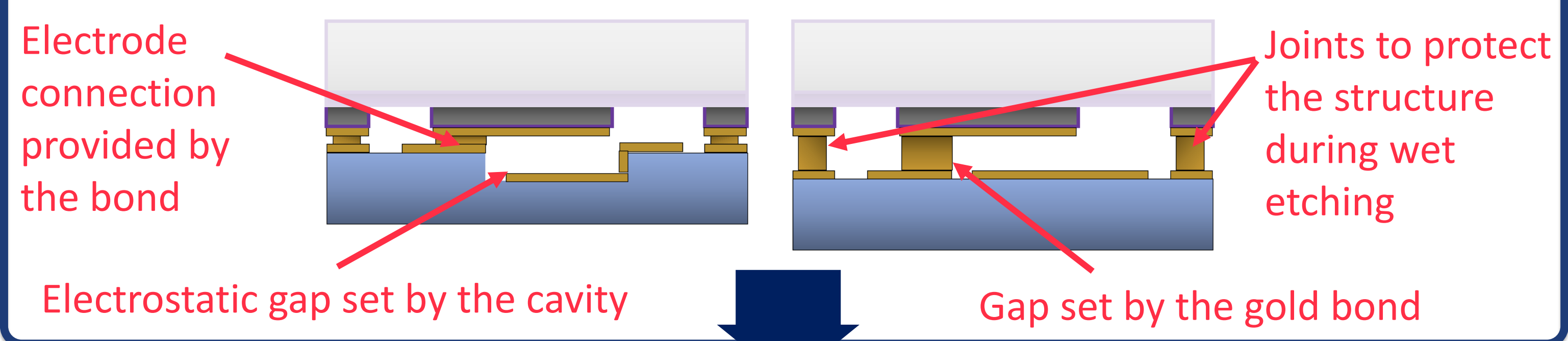


X Difficult electrode integration

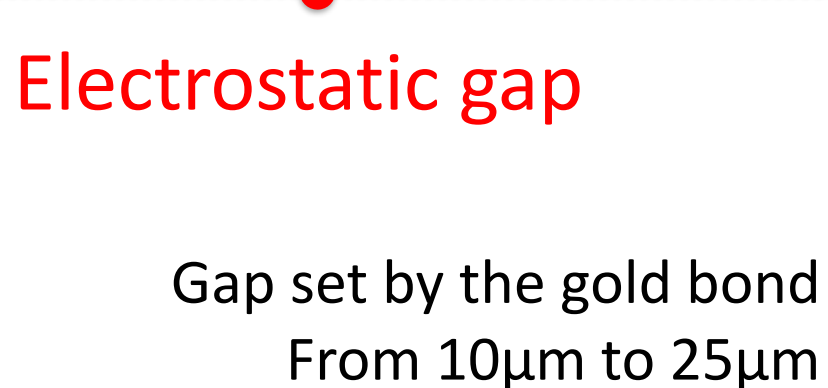
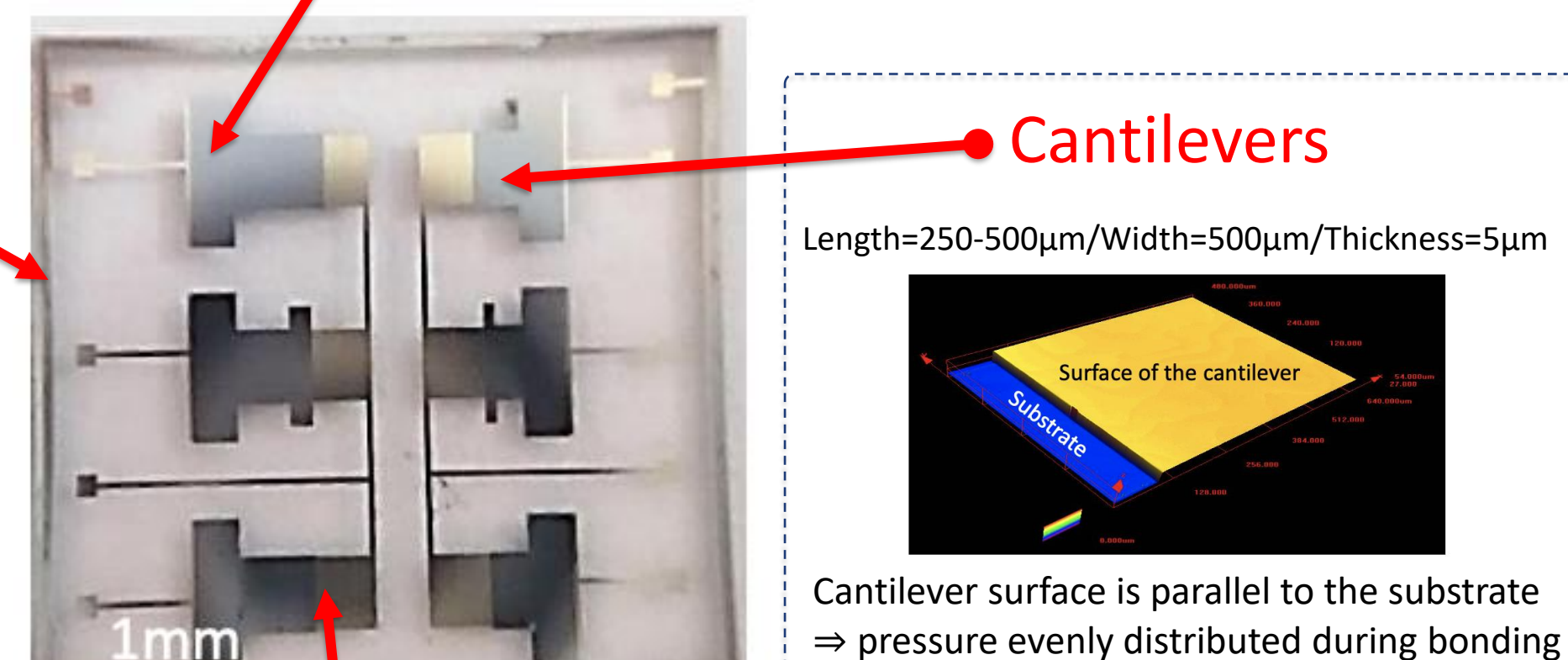
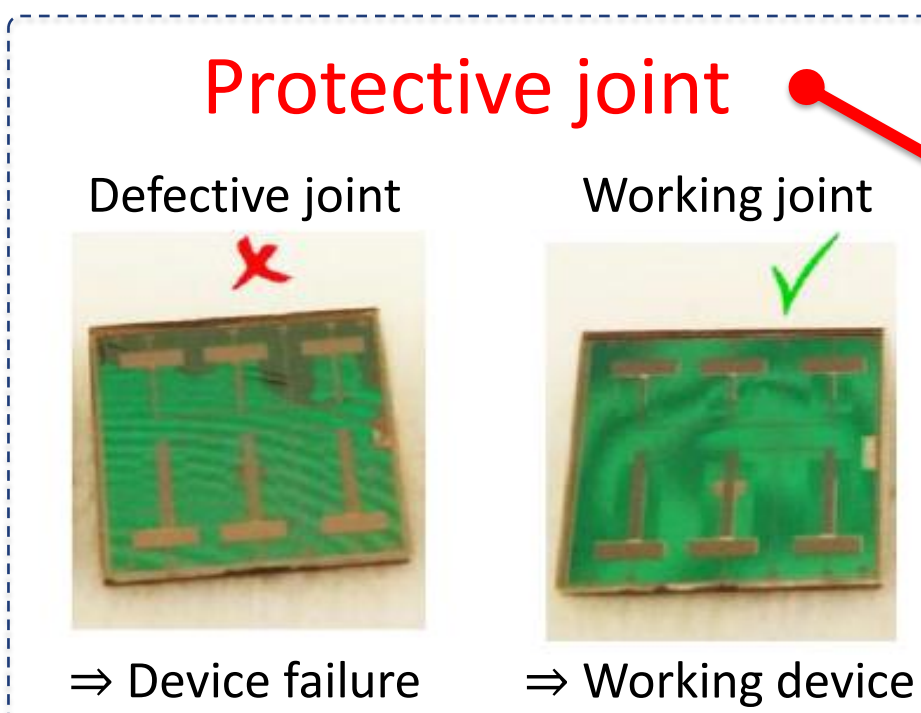
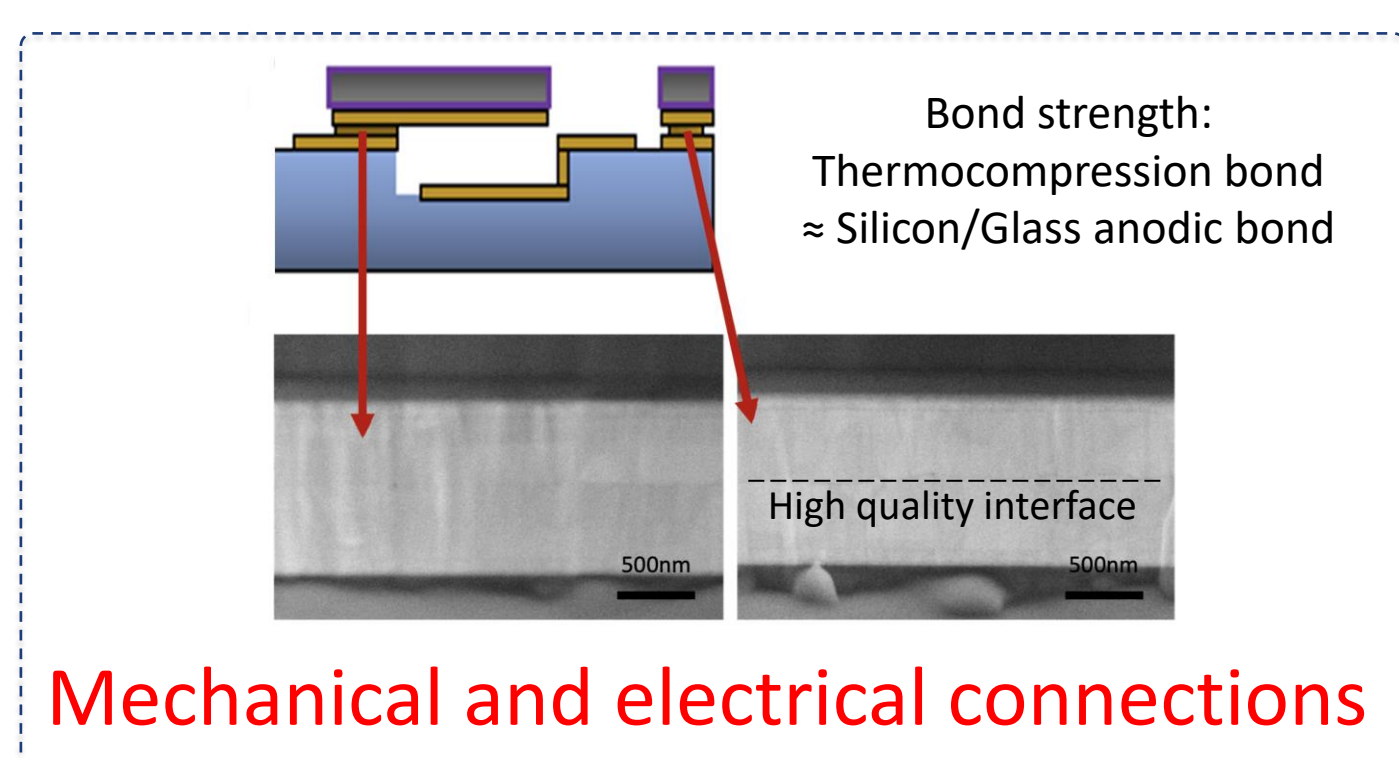
Our approach

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

2 gap configurations

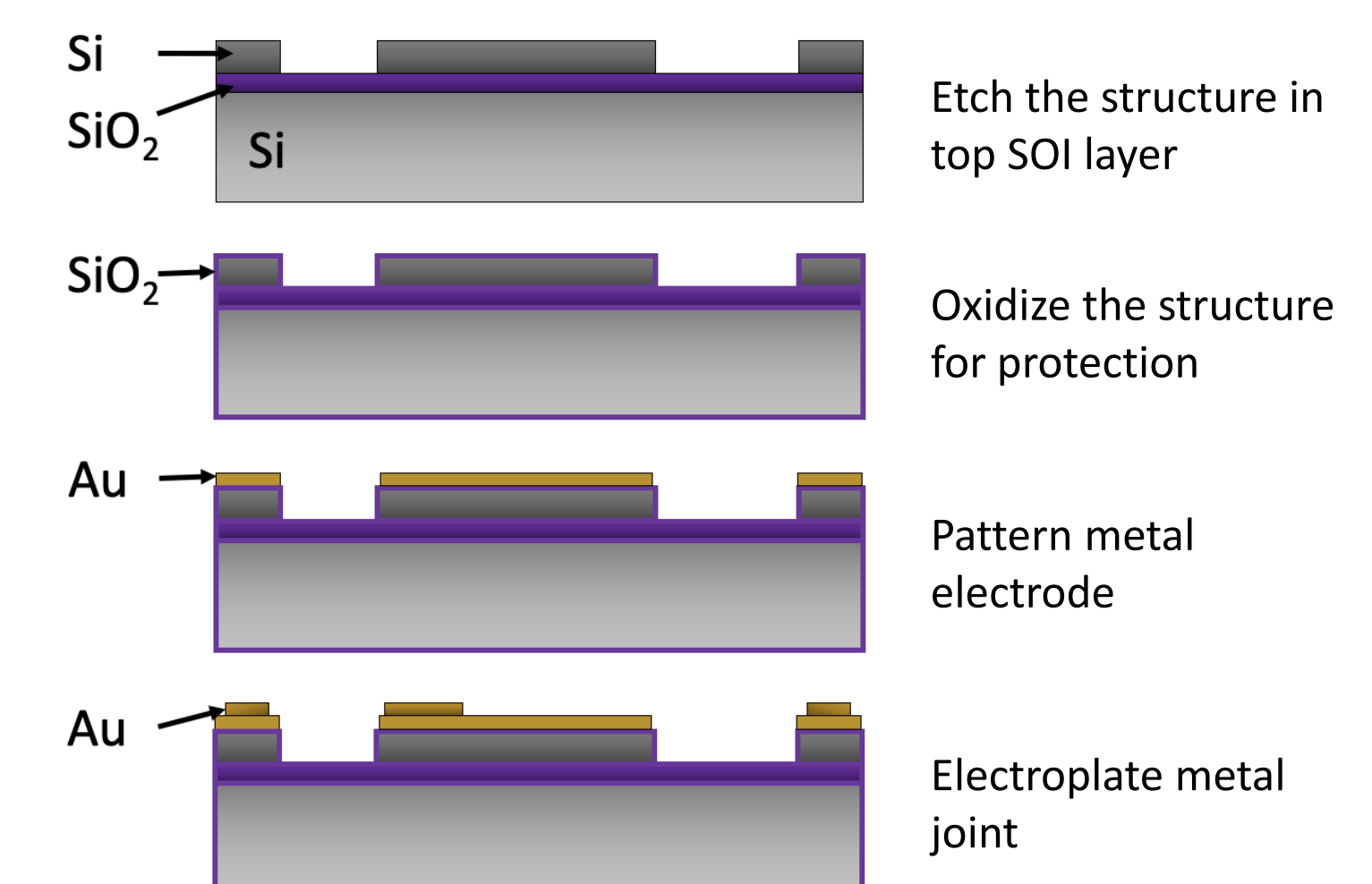


Fabricated devices

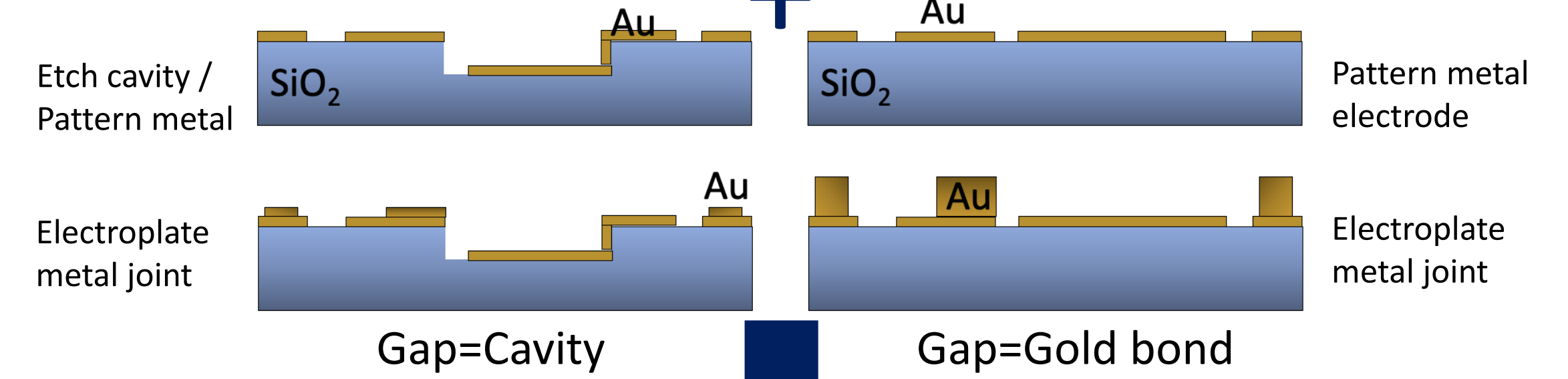


Fabrication process

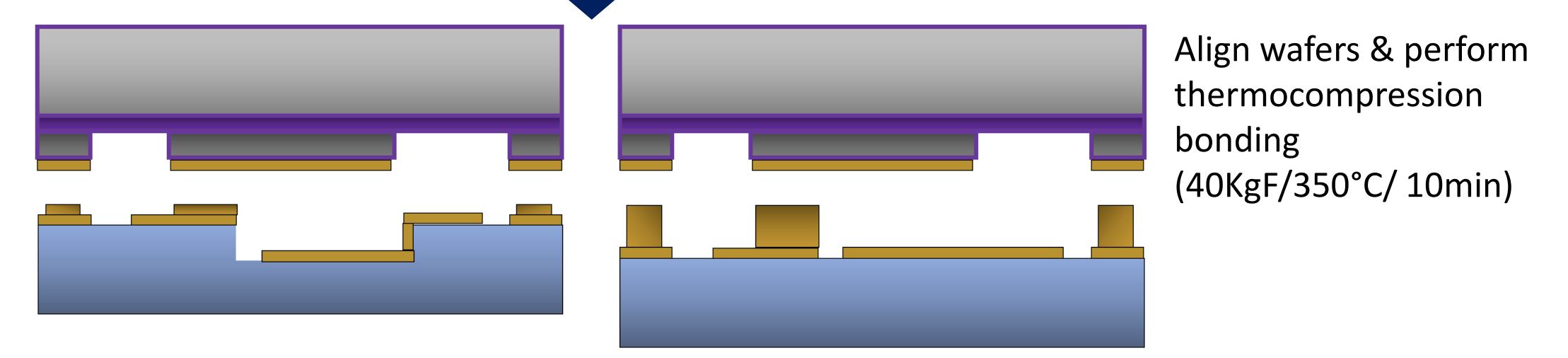
1. Device processing



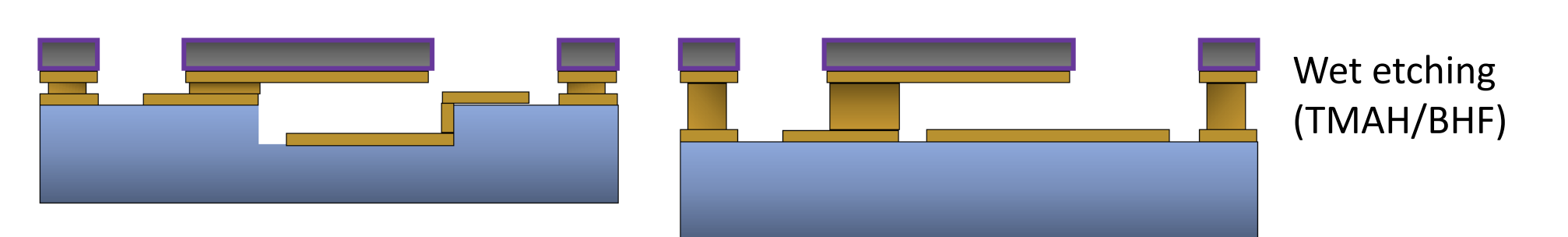
2. Substrate processing



3. Bonding

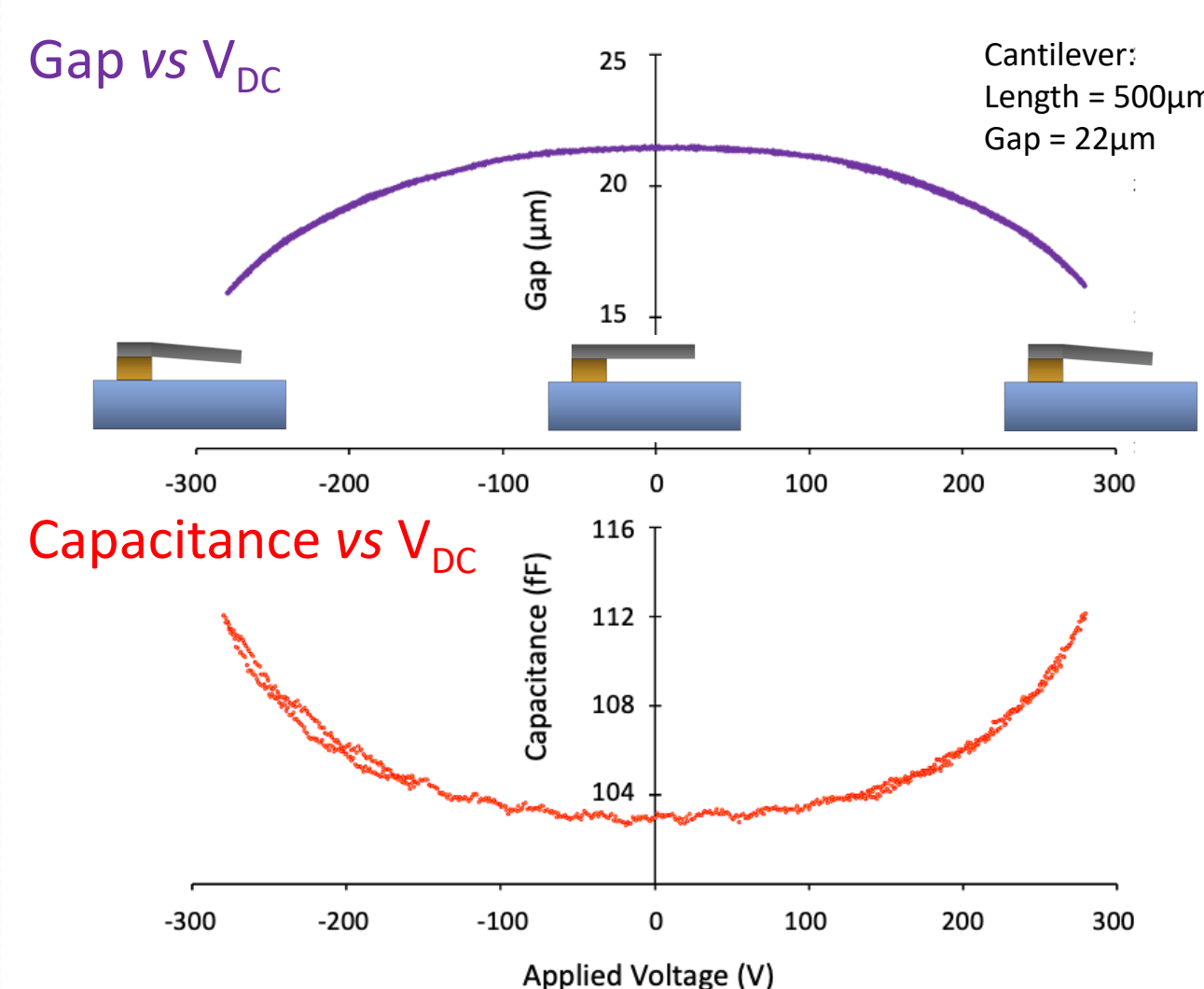


4. Release



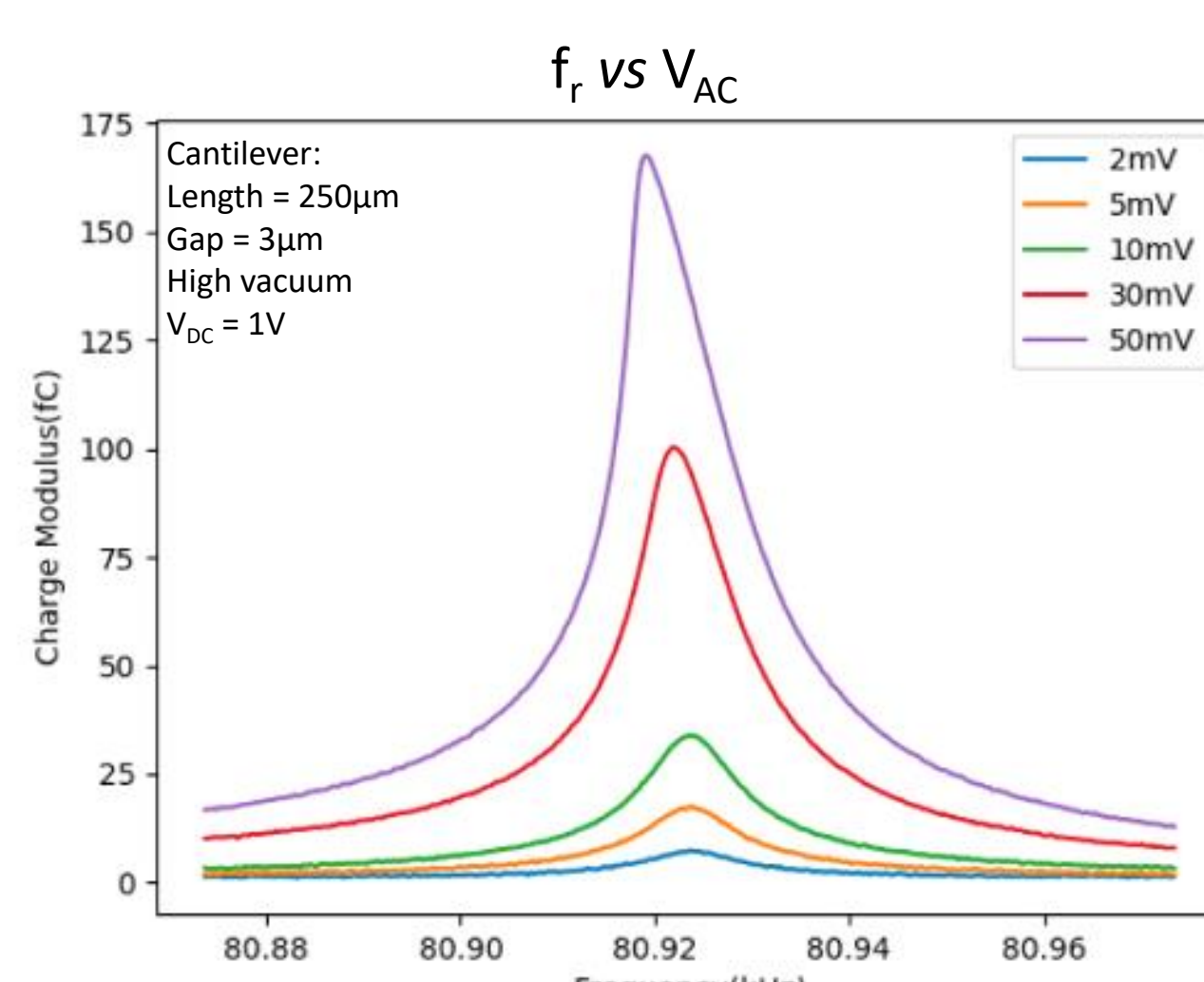
Characterizations

Static mode

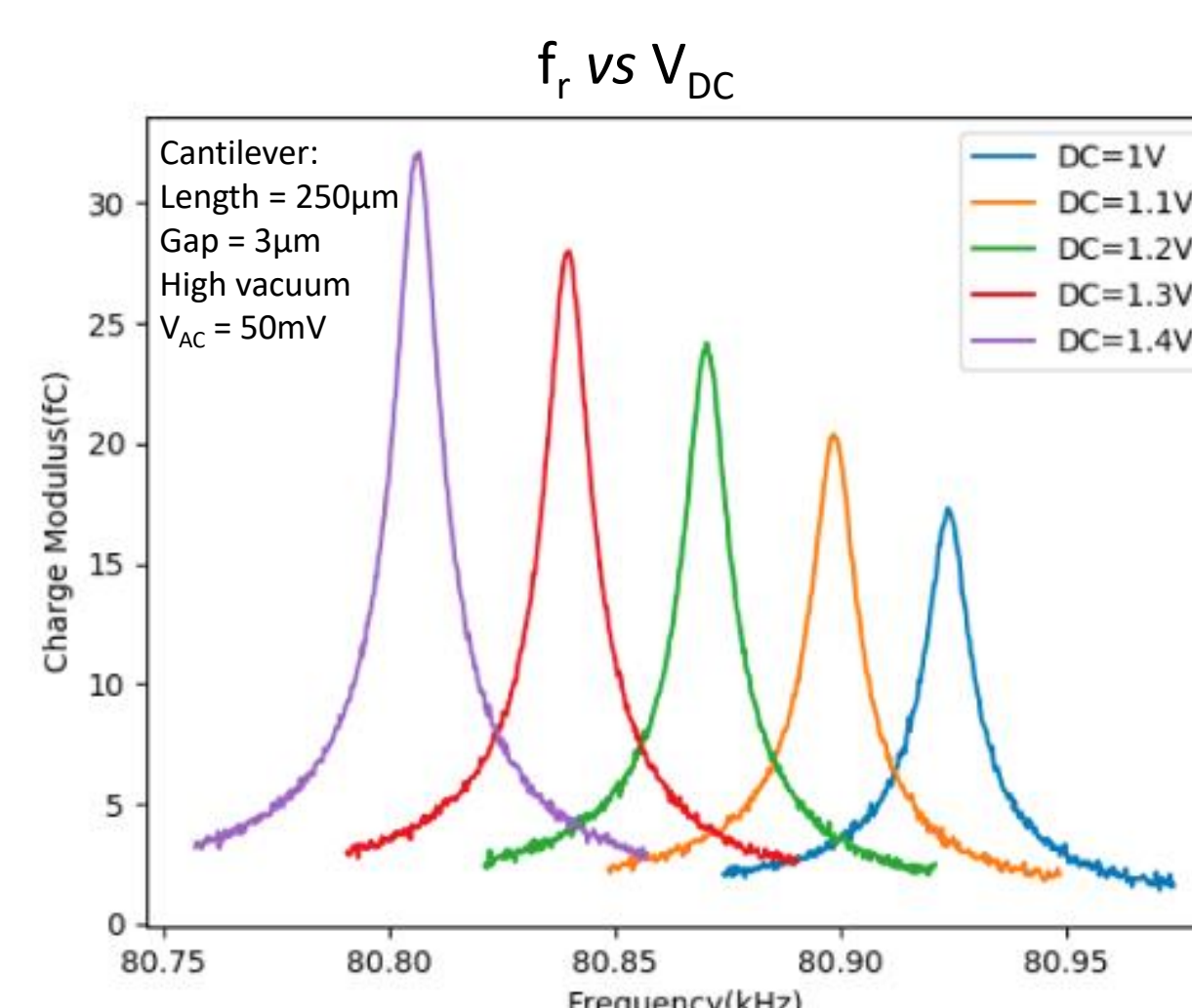


\checkmark Quadratic dependance of the gap and capacitance with applied voltage

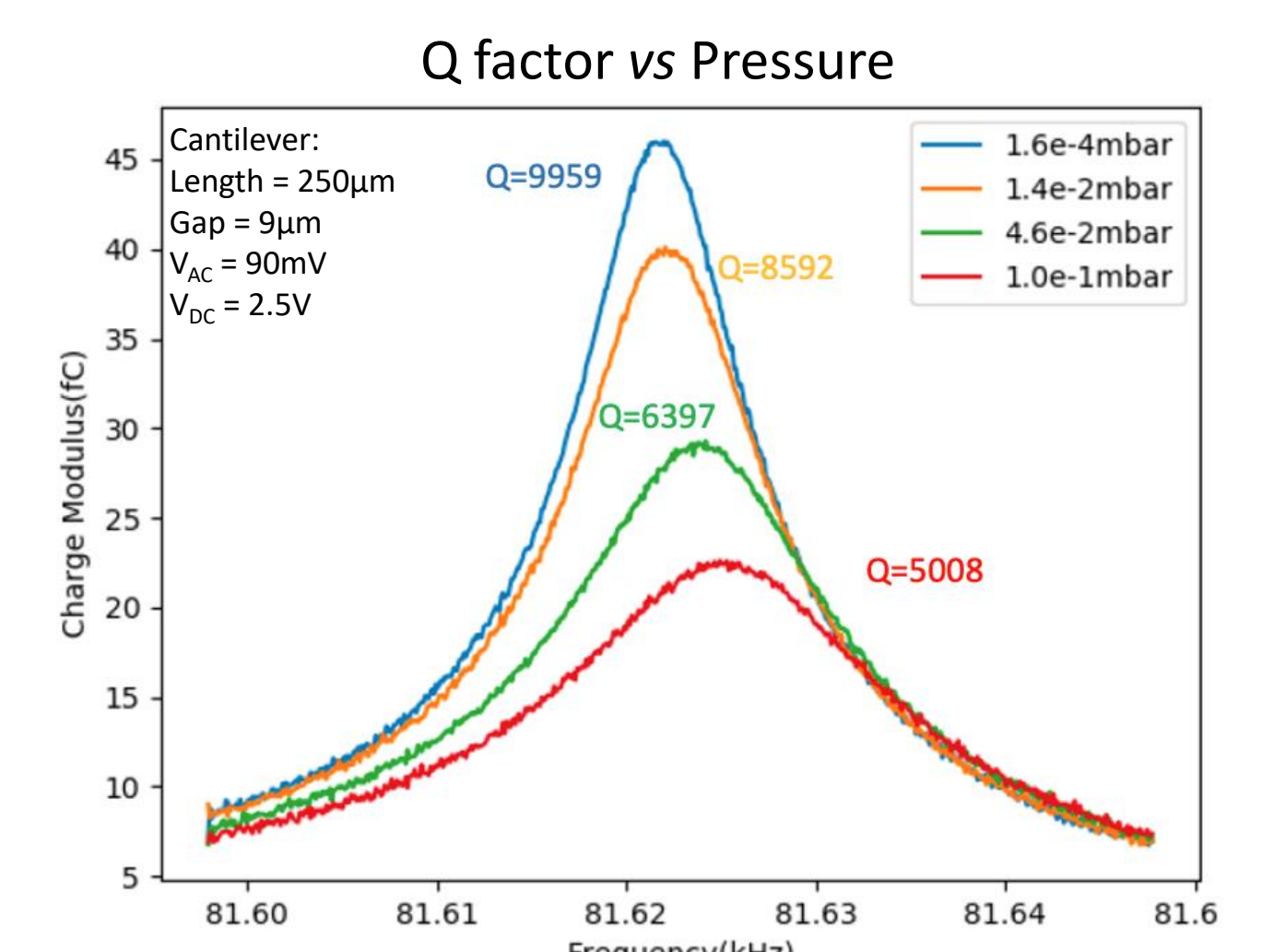
Dynamic mode



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



\checkmark Spring softening effect is observed with increasing DC voltage



\checkmark 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 3 μ m gap in air \Rightarrow Q = 45 for 25 μ m gap