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

Maria Dolores Manrique-Juarez, Fabrice Mathieu, Guillaume Libaude, Véronique Conédéra, David Bourrier, Samuel Charlot, Thierry Leichle, Laurent Mazenq, Ludovic Salvagnac, Isabelle Dufour, et al.

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HAL Authorization

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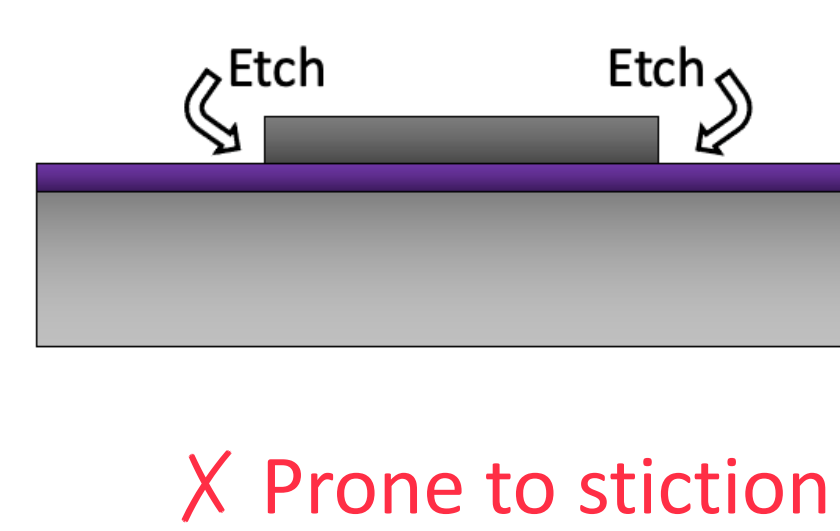
### Novelty / Progress Claim:

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

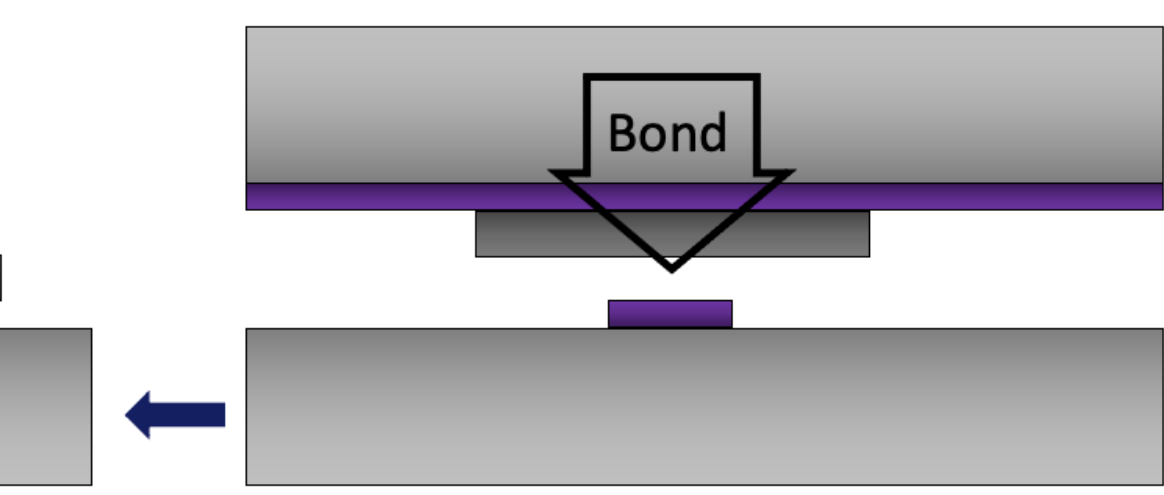
### State of the art: 2 routes to electrostatic MEMS

1. Surface micromachining using a sacrificial layer



X Prone to stiction

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

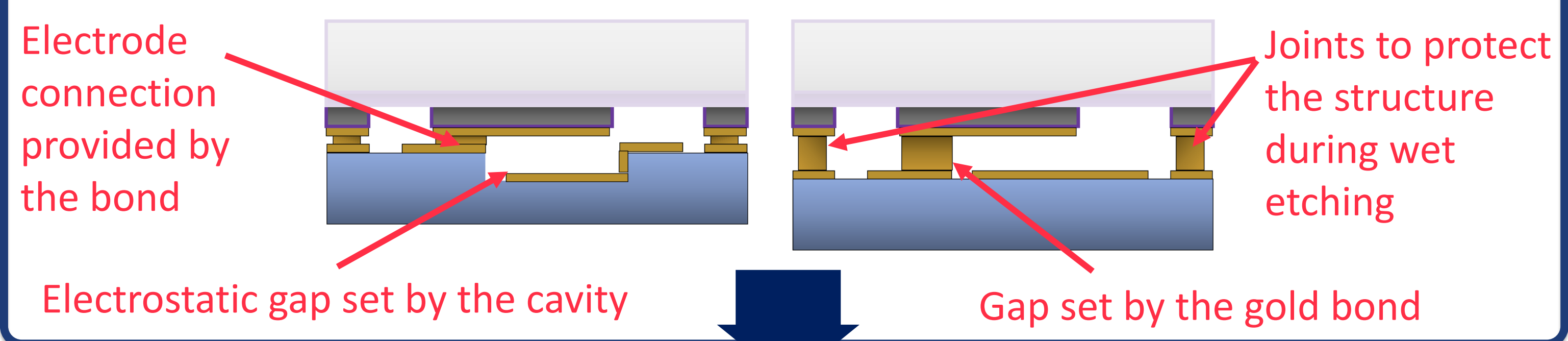


X Difficult electrode integration

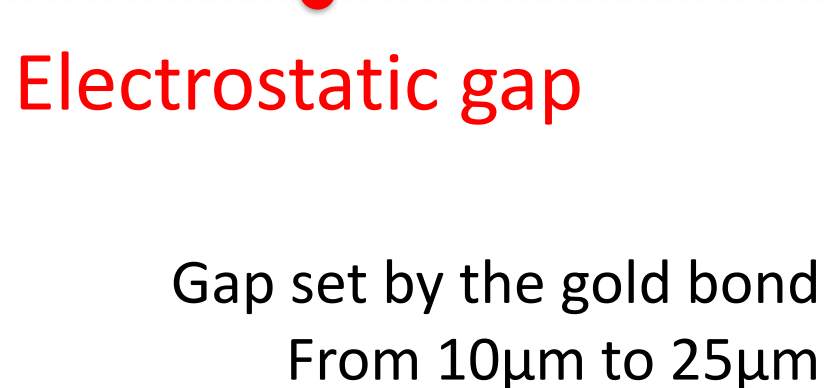
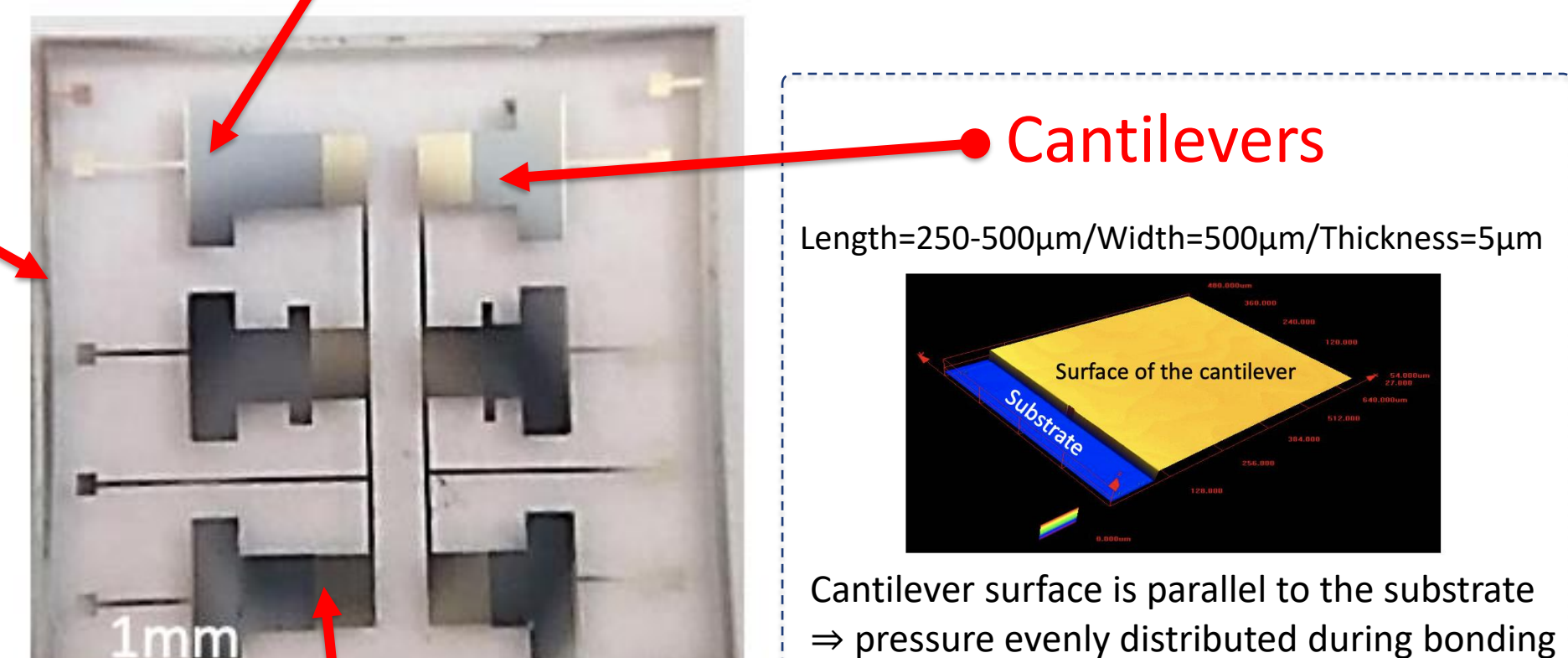
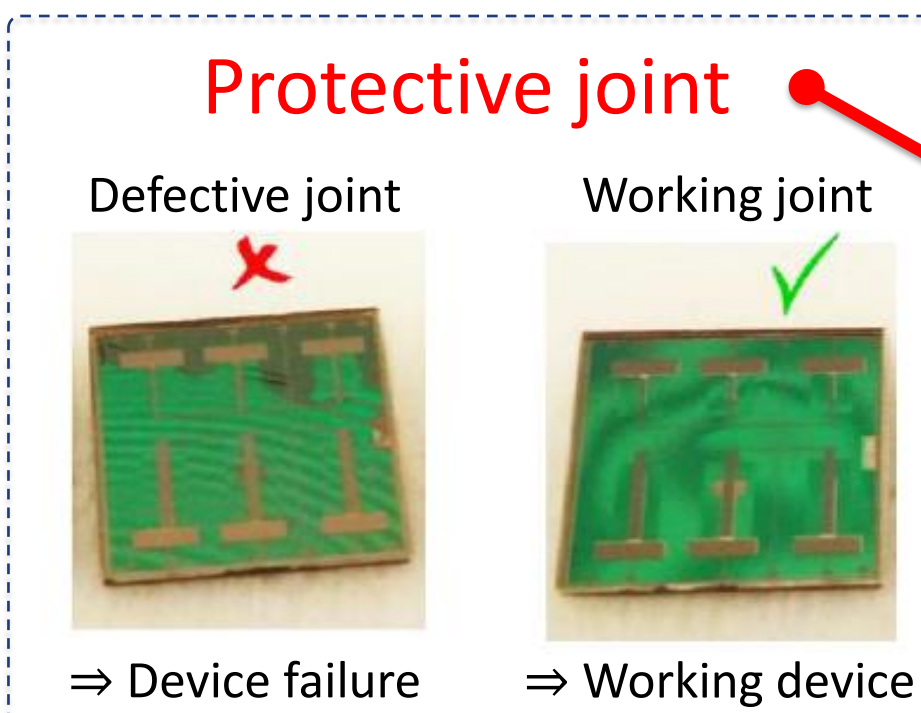
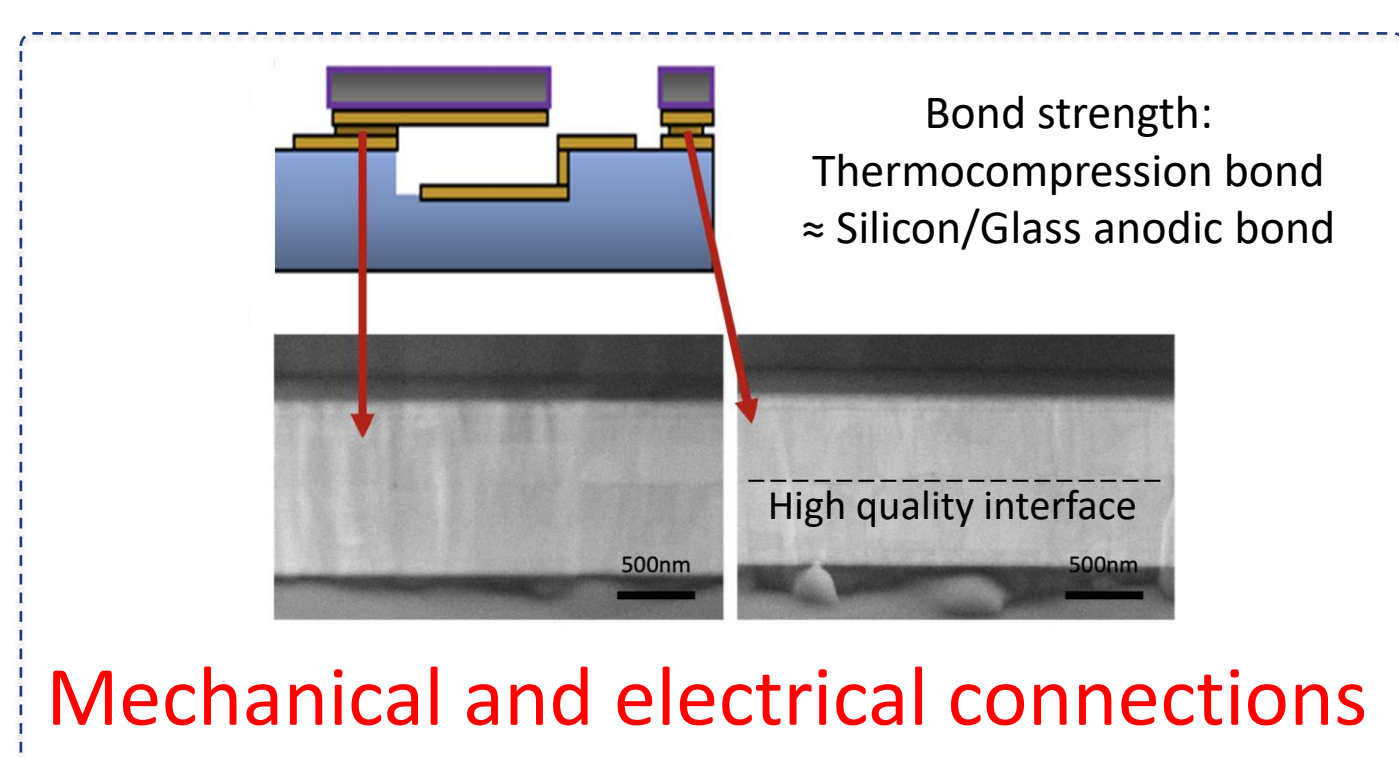
### Our approach

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

2 gap configurations

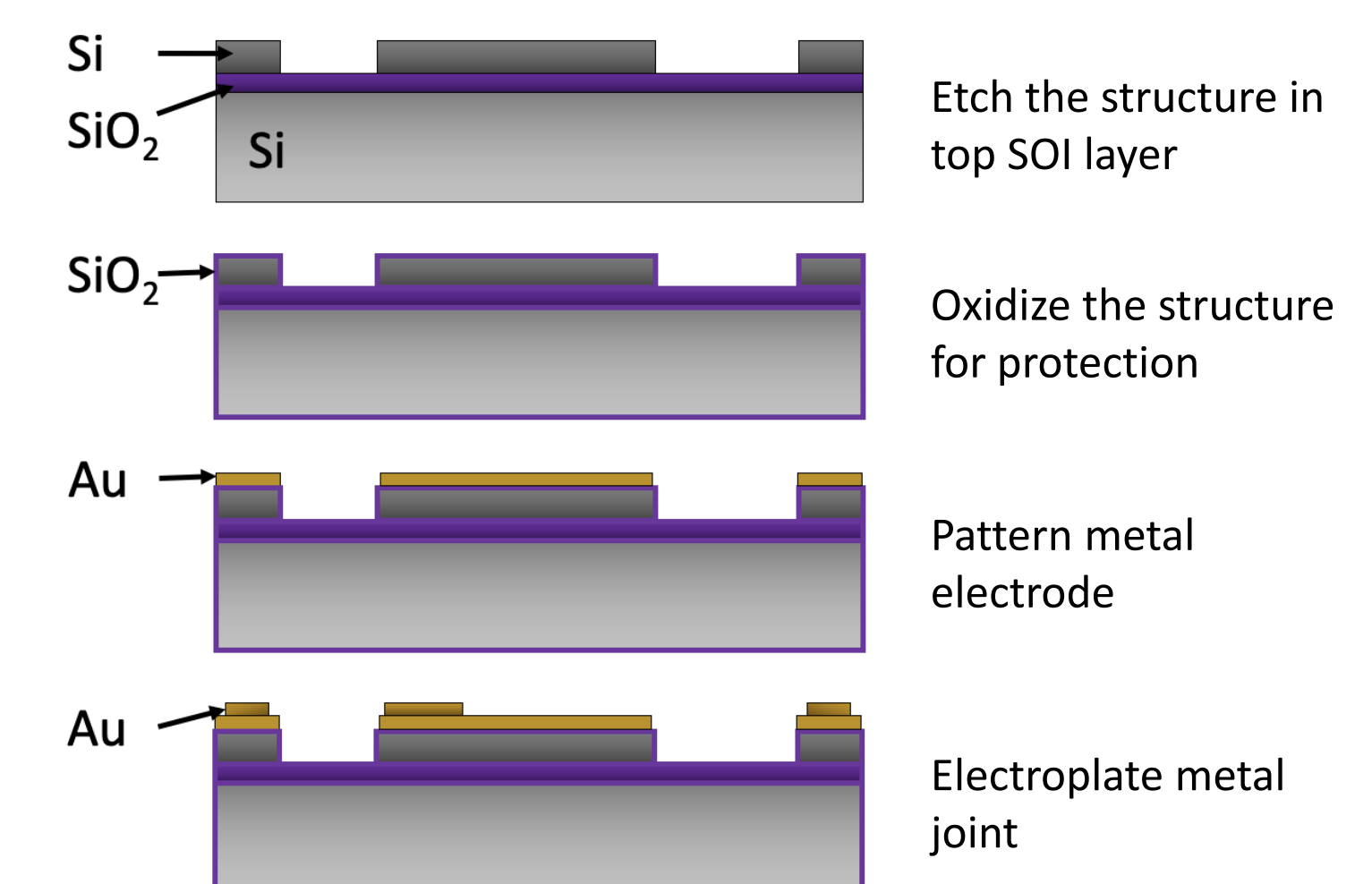


### Fabricated devices

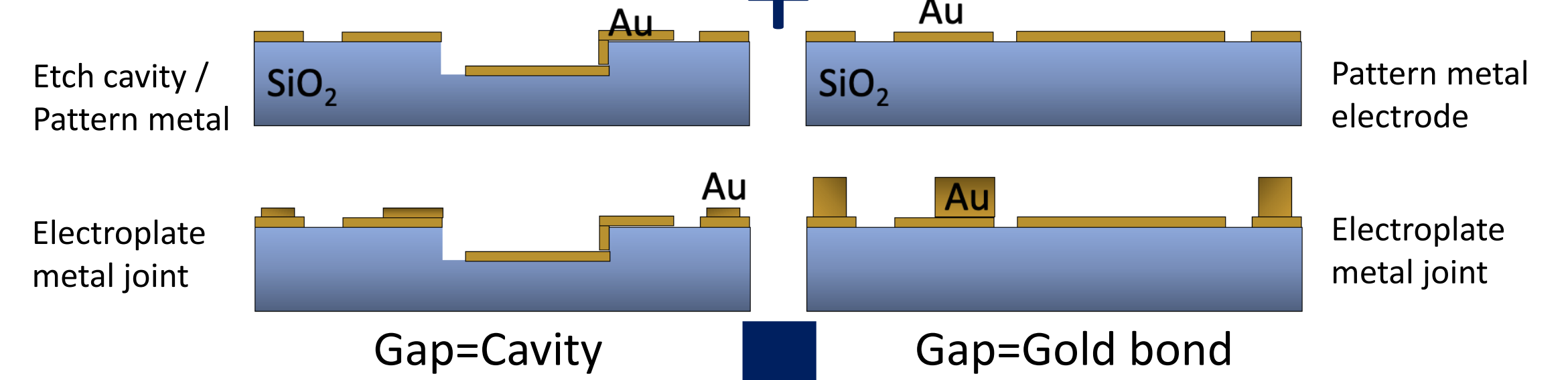


### Fabrication process

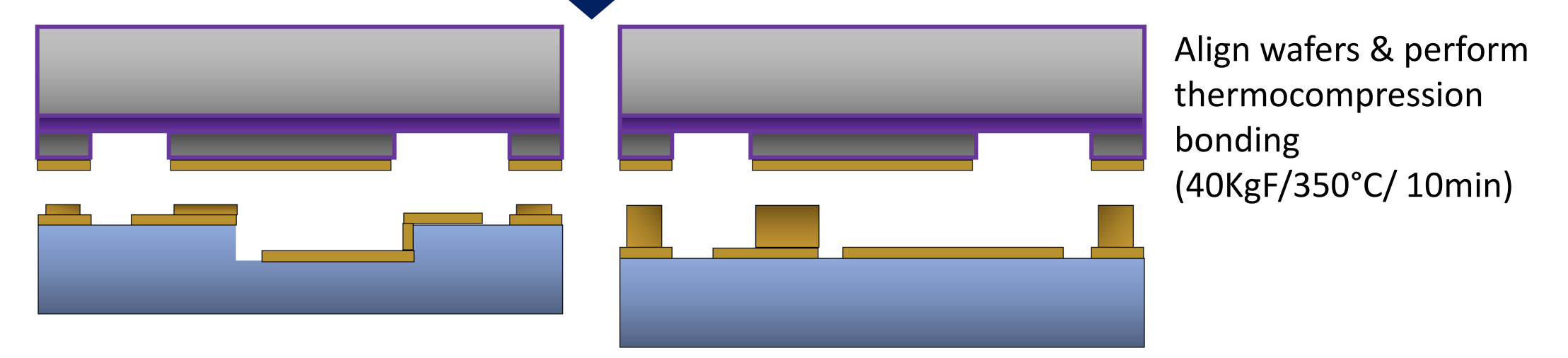
1. Device processing



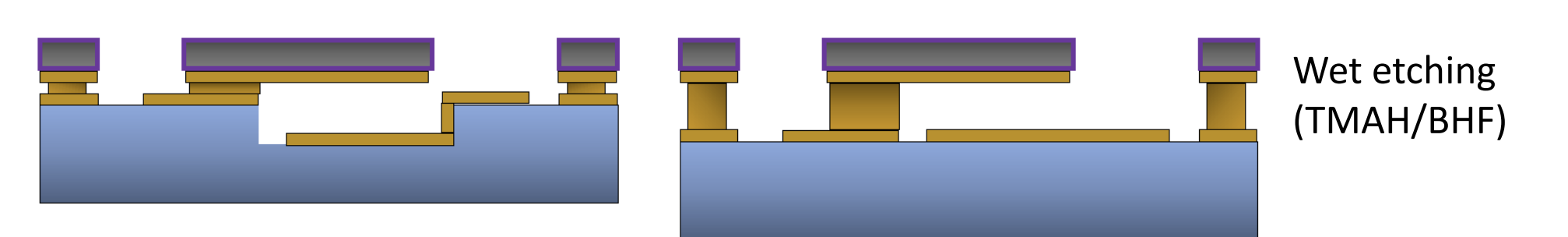
2. Substrate processing



3. Bonding

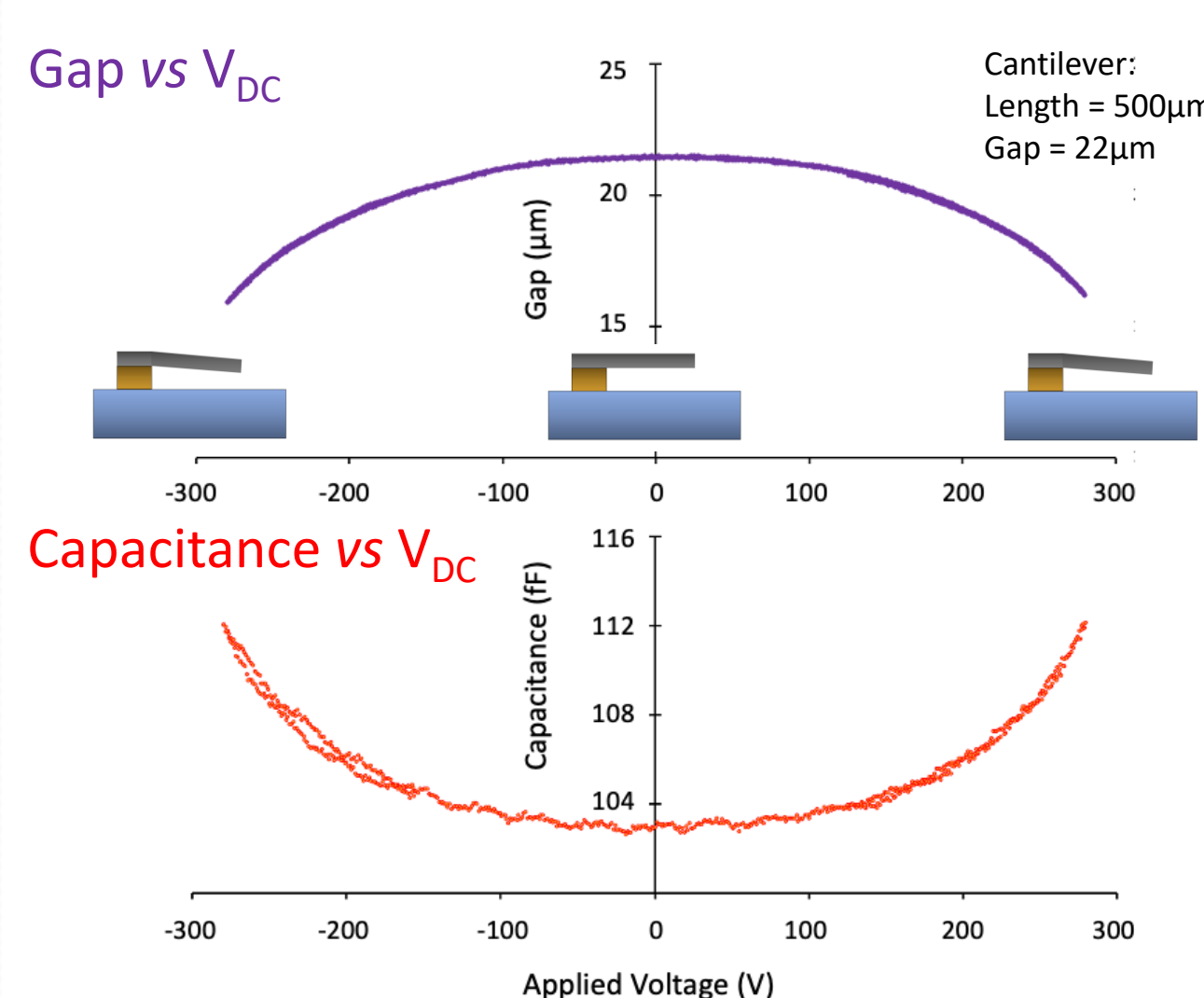


4. Release



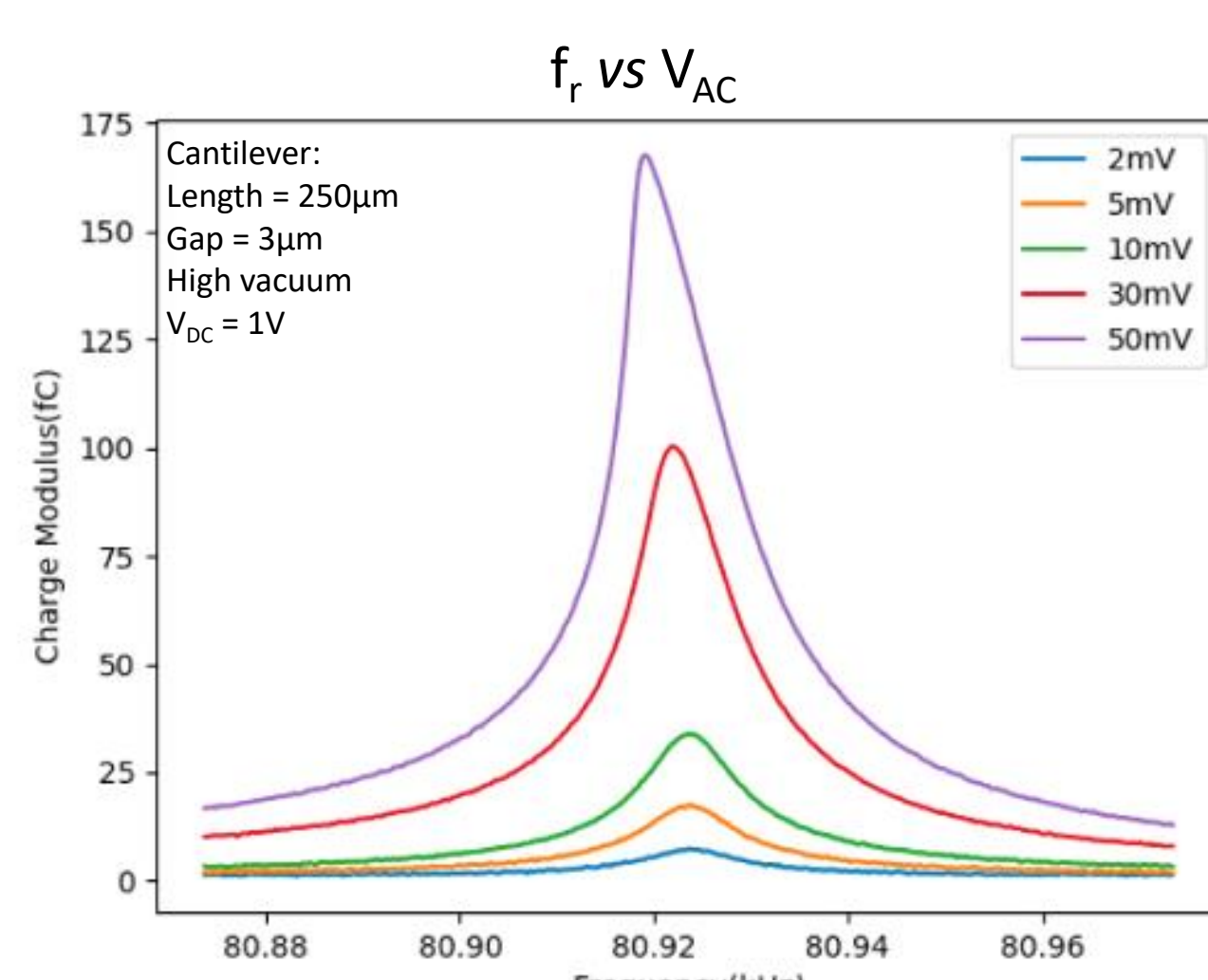
### Characterizations

#### Static mode

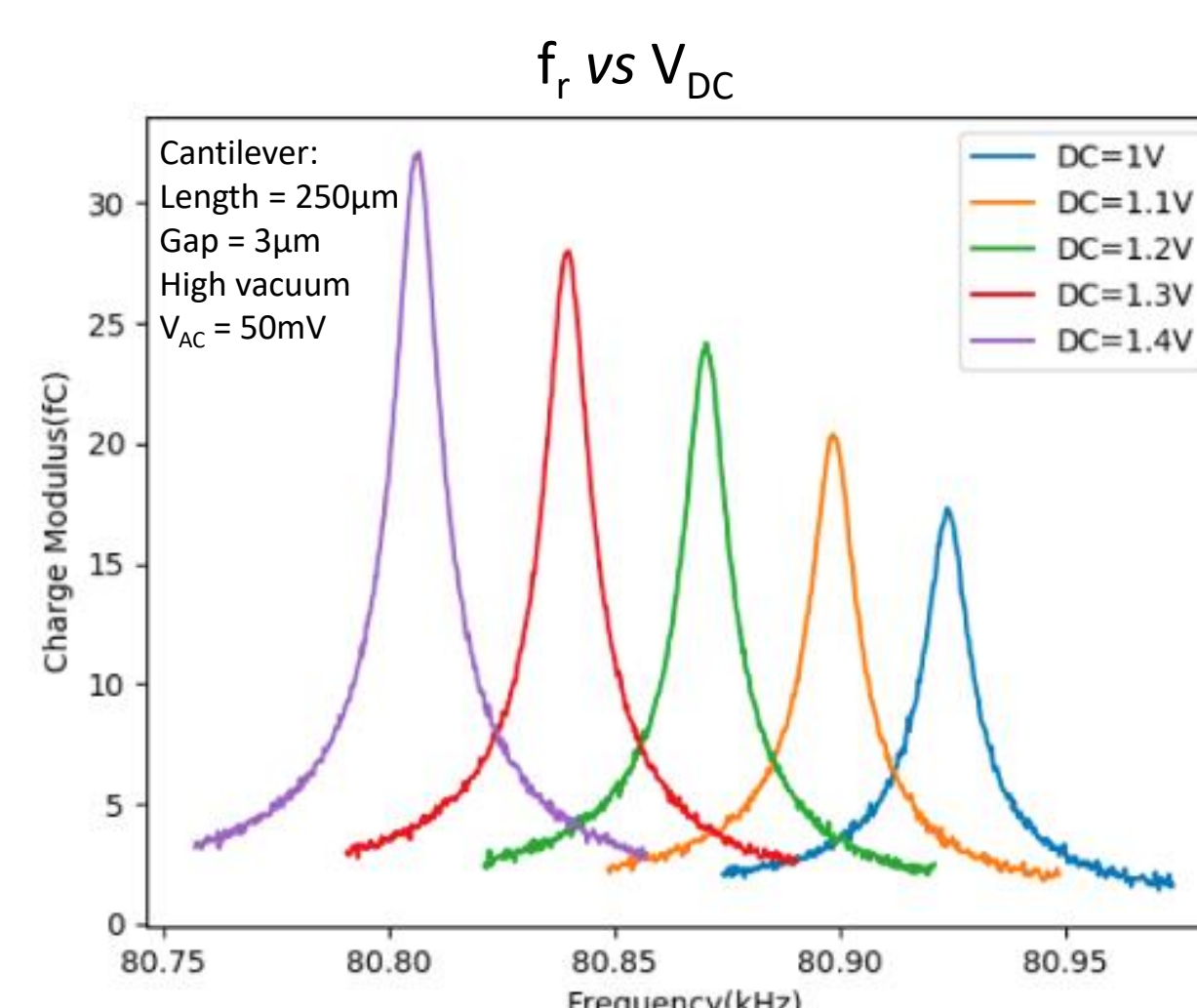


$\checkmark$  Quadratic dependance of the gap and capacitance with applied voltage

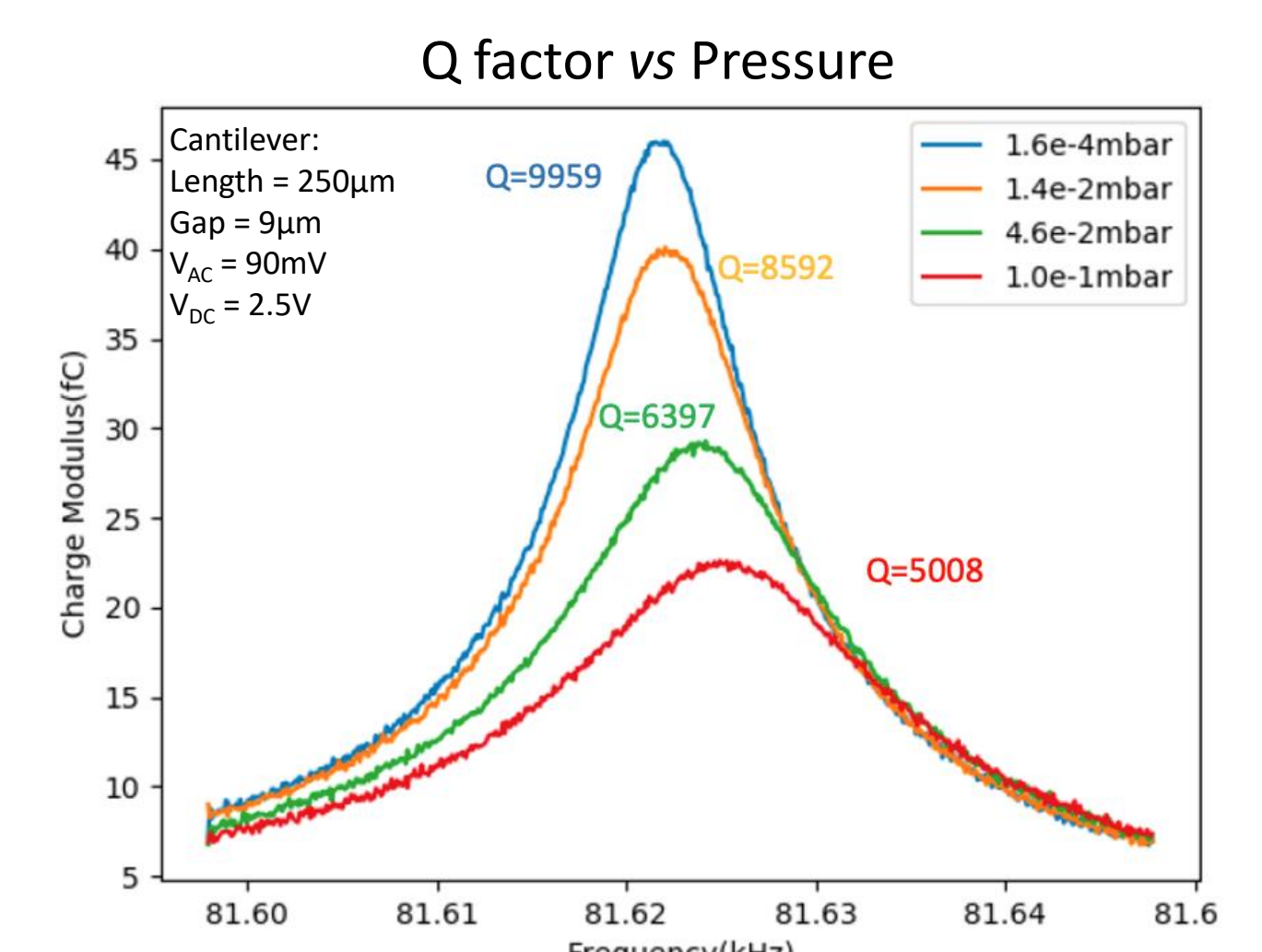
#### Dynamic mode



$\checkmark$  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 $\mu$ m gap in air  $\Rightarrow$  Q = 45 for 25 $\mu$ m gap