



HAL
open science

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 Mazon, Ludovic Salvagnac, Isabelle Dufour, et al.

► To cite this version:

Maria Dolores Manrique-Juarez, Fabrice Mathieu, Guillaume Libaude, Véronique Conédéra, David Bourrier, et al.. A simple process for the fabrication of parallel-plate electrostatic MEMS resonators by gold thermocompression bonding. The 36th International Conference on Micro Electro Mechanical Systems (IEEE MEMS 2023), Jan 2023, Munich, Germany. 10.1109/MEMS49605.2023.10052563 . hal-03951363

HAL Id: hal-03951363

<https://laas.hal.science/hal-03951363v1>

Submitted on 6 Mar 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Dolores Manrique Juarez¹, Fabrice Mathieu¹, Guillaume Libaude¹, David Bourrier¹, Samuel Charlot¹, Laurent Mazonq¹, Véronique Conédéra¹, Ludovic Salvagnac¹, Isabelle Dufour², Liviu Nicu¹, and Thierry Leïchlé^{1,3}

¹LAAS-CNRS, Toulouse, FRANCE

²Université de Bordeaux, Laboratoire IMS UMR-CNRS 5218, Talence, FRANCE

³Georgia Tech-CNRS International Research Laboratory, School of Electrical and Computer Engineering, Atlanta, USA

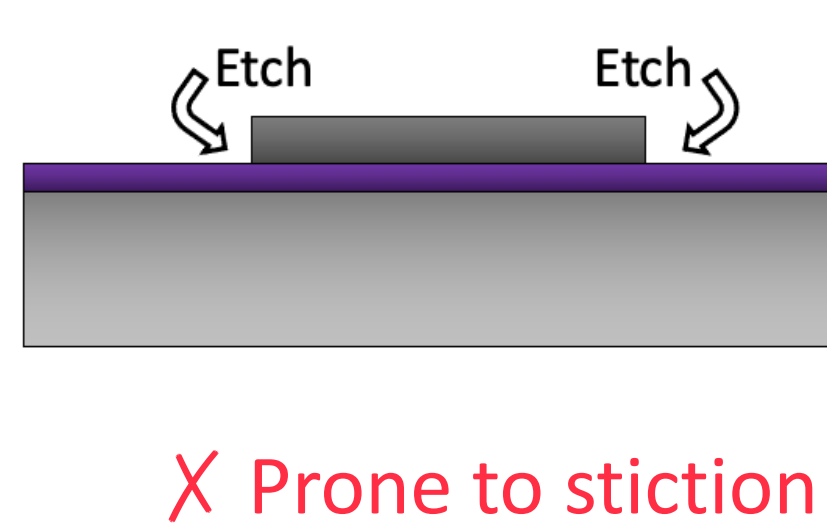
Novelty / Progress Claim:

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

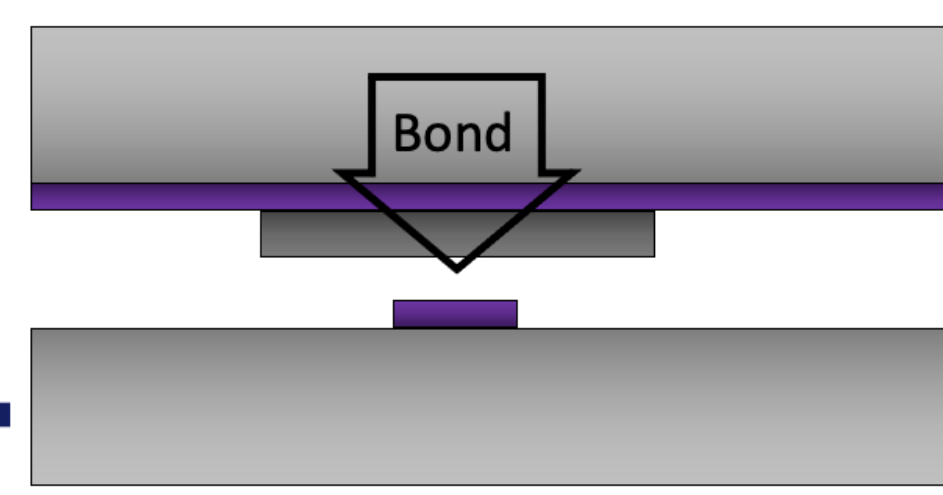
State of the art: 2 routes to electrostatic MEMS

1. Surface micromachining using a sacrificial layer



X Prone to stiction

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

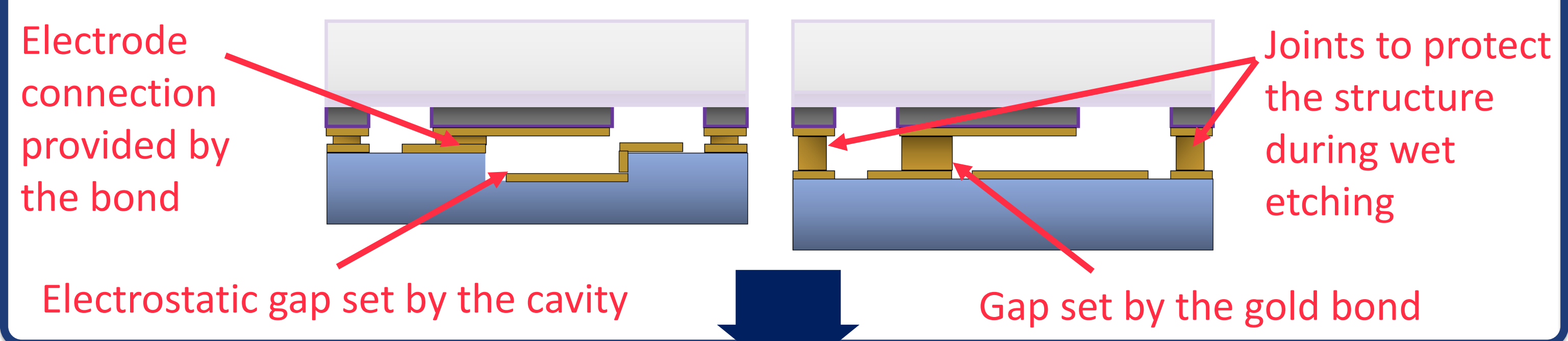


X Difficult electrode integration

Our approach

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

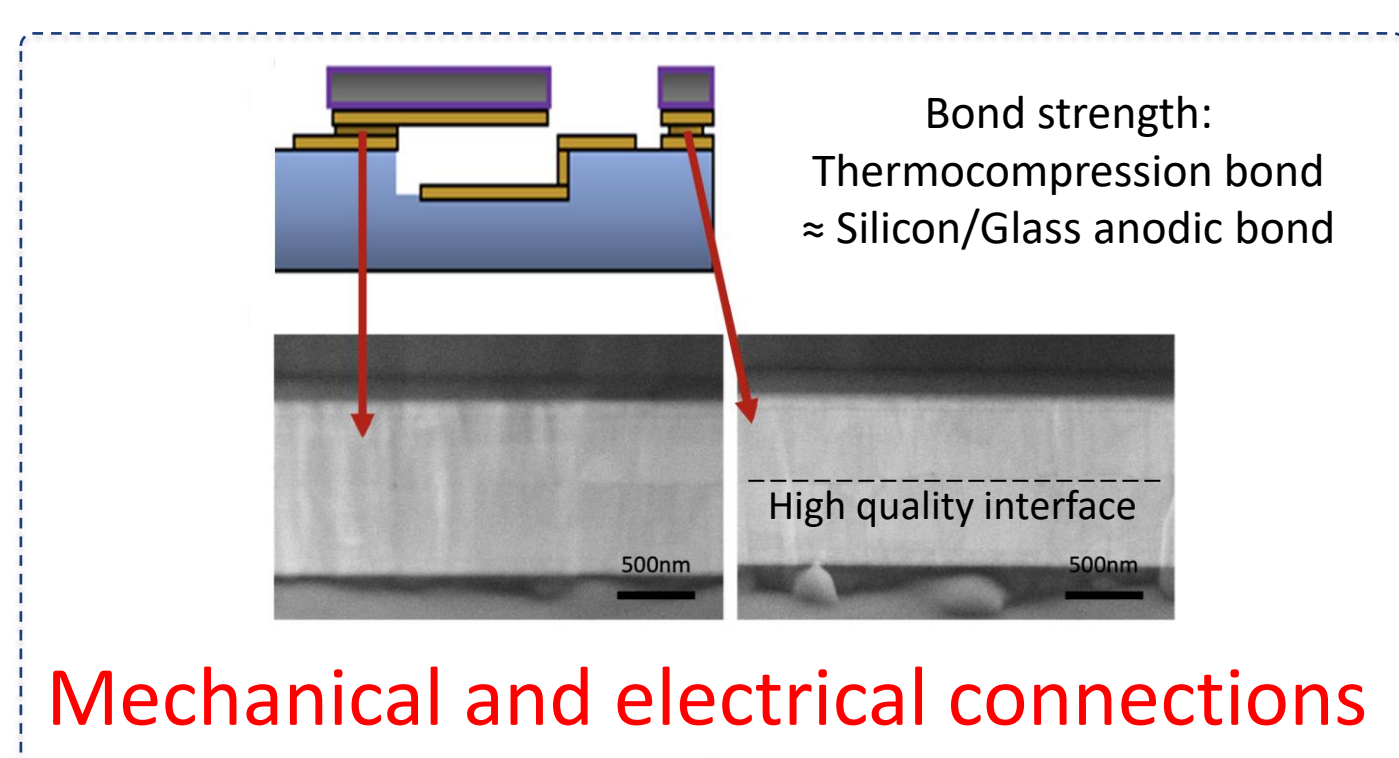
2 gap configurations



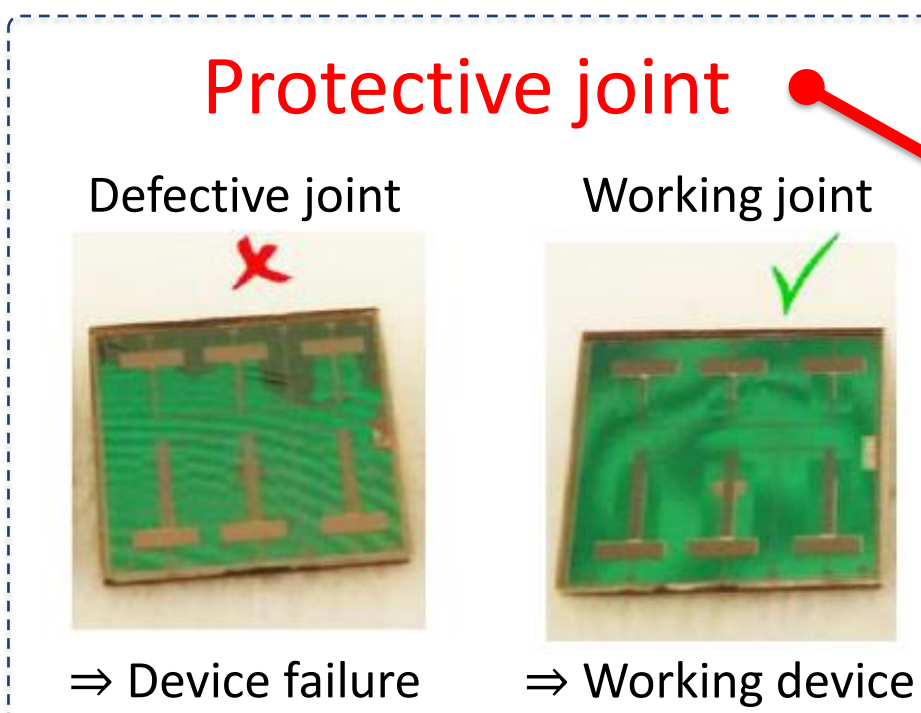
Electrostatic gap set by the cavity

Gap set by the gold bond

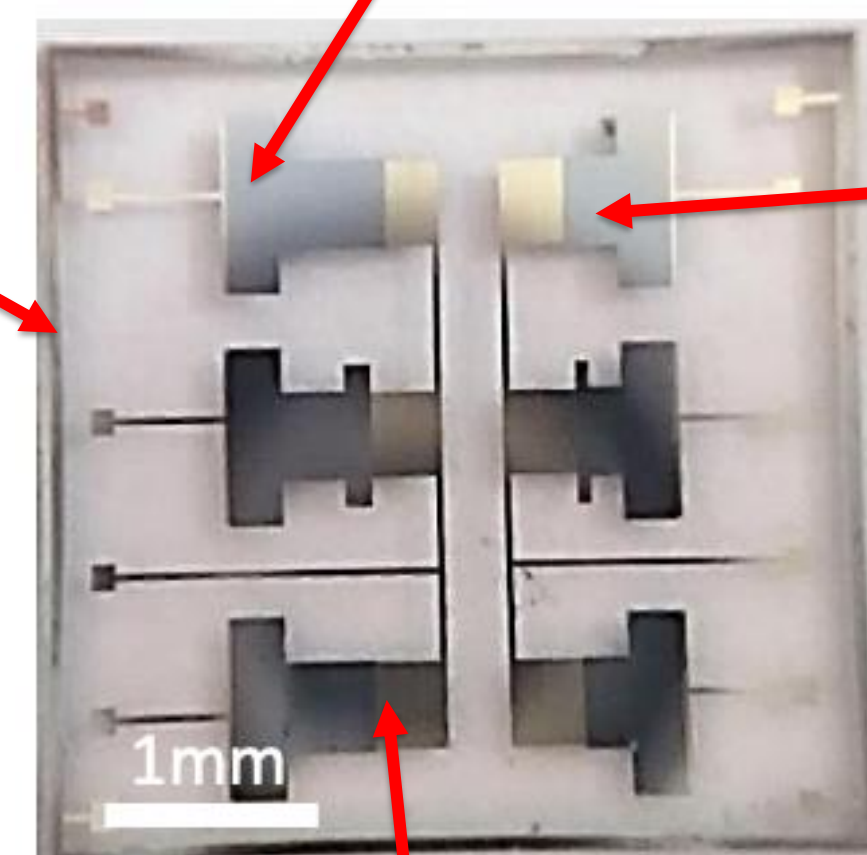
Fabricated devices



Mechanical and electrical connections

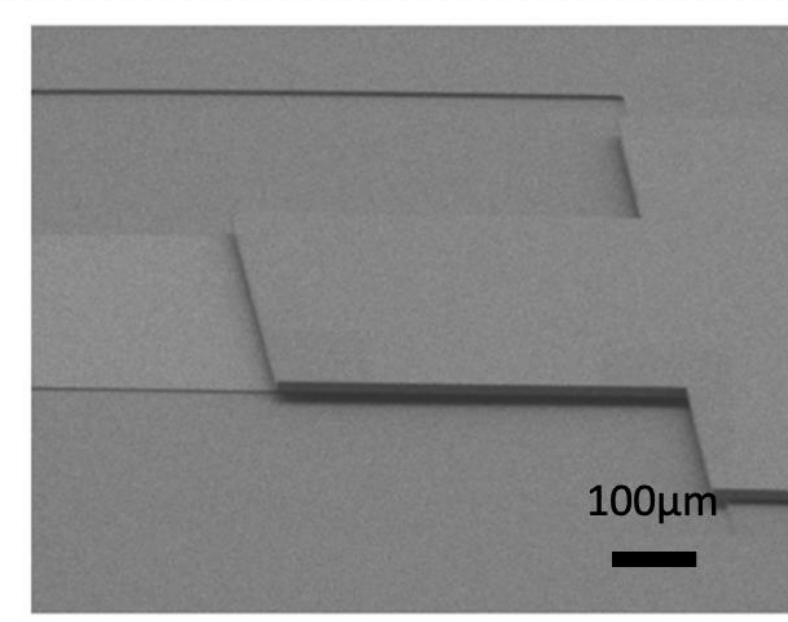


\Rightarrow Device failure \Rightarrow Working device

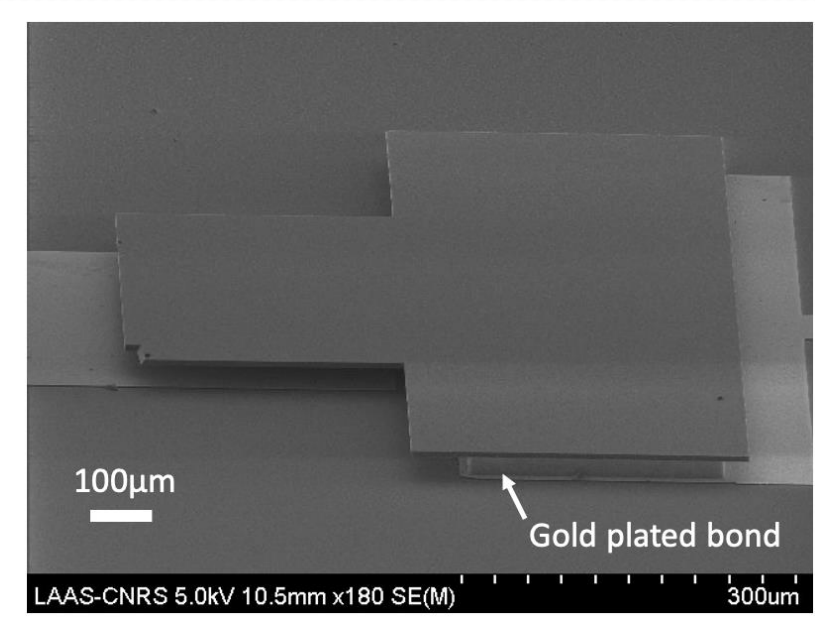


Cantilevers
Length=250-500 μ m/Width=500 μ m/Thickness=5 μ m
Surface of the cantilever
Cantilever surface is parallel to the substrate
 \Rightarrow pressure evenly distributed during bonding

Electrostatic gap



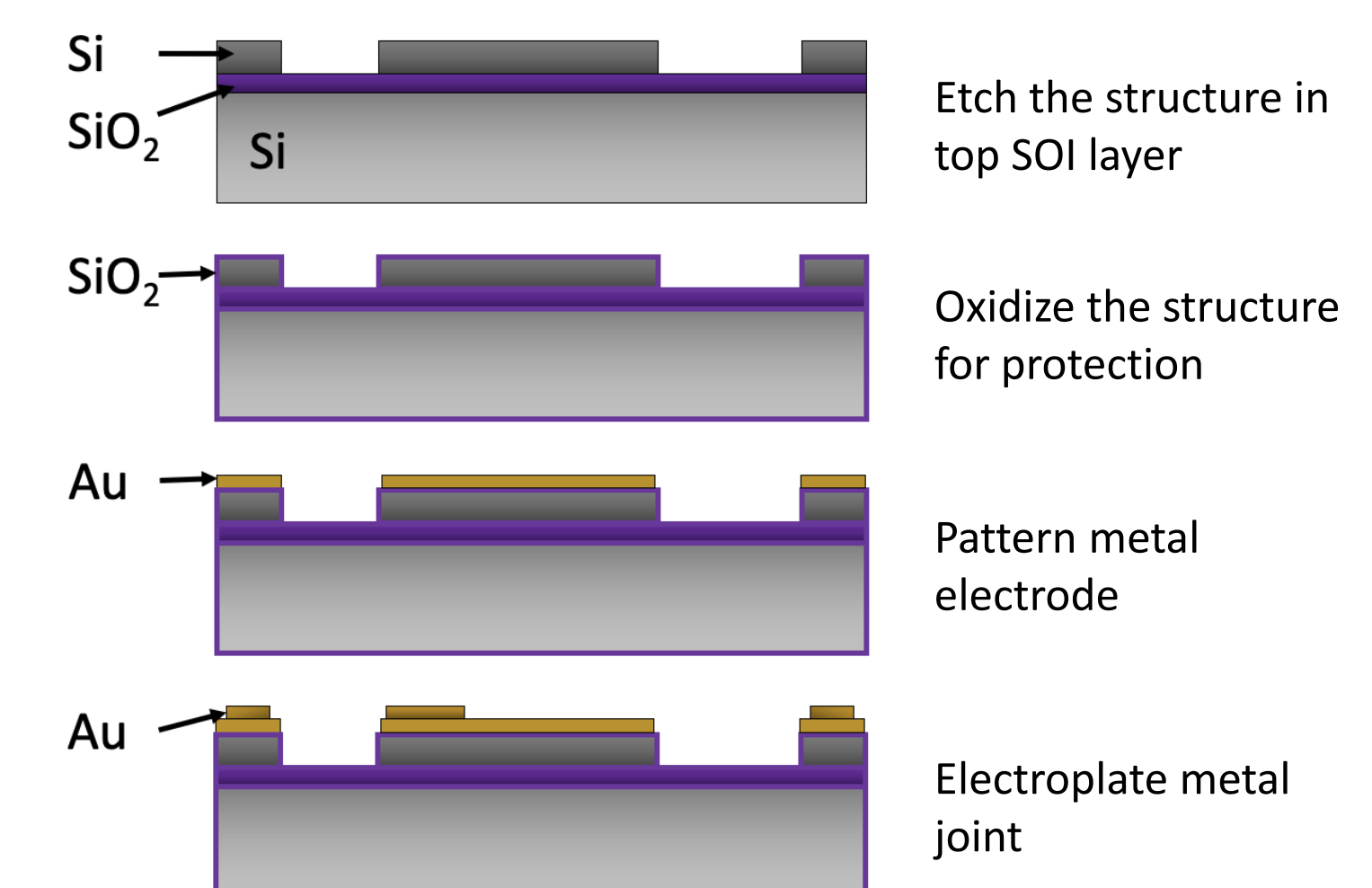
Gap set by the etched cavity
From 3 μ m to 9 μ m



Gap set by the gold bond
From 10 μ m to 25 μ m

Fabrication process

1. Device processing



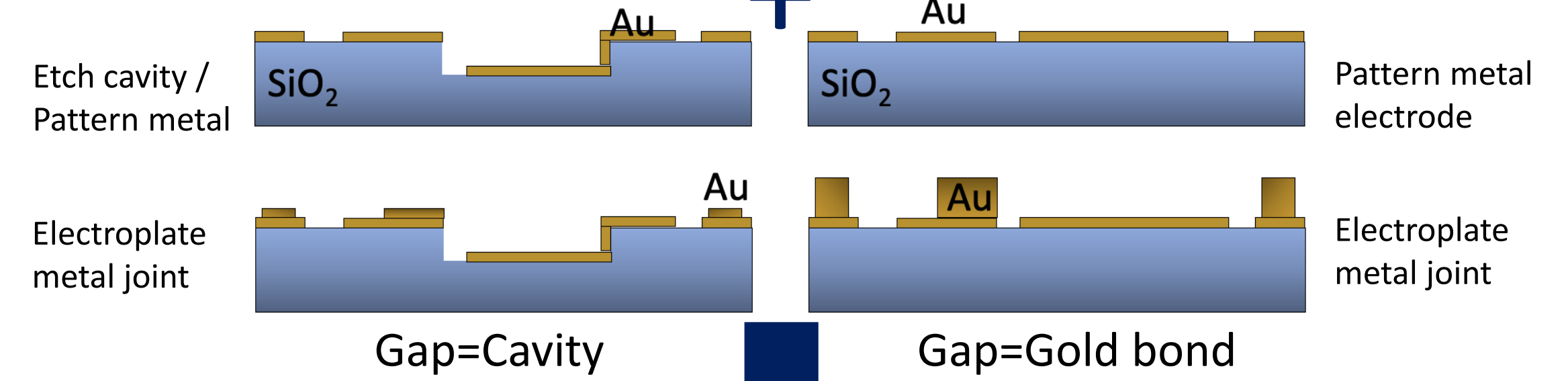
Etch the structure in top SOI layer

Oxidize the structure for protection

Pattern metal electrode

Electroplate metal joint

2. Substrate processing



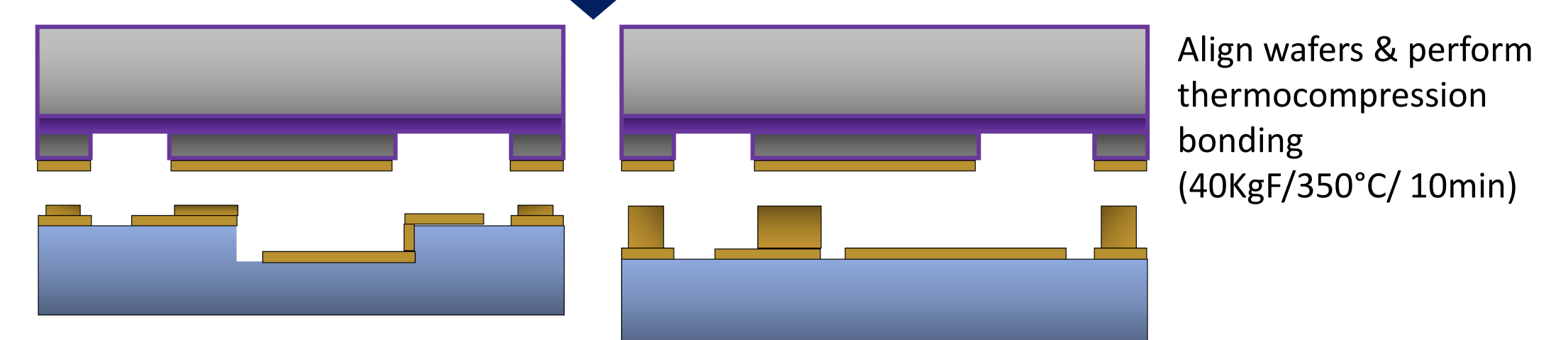
Etch cavity / Pattern metal

Electroplate metal joint

Gap=Cavity

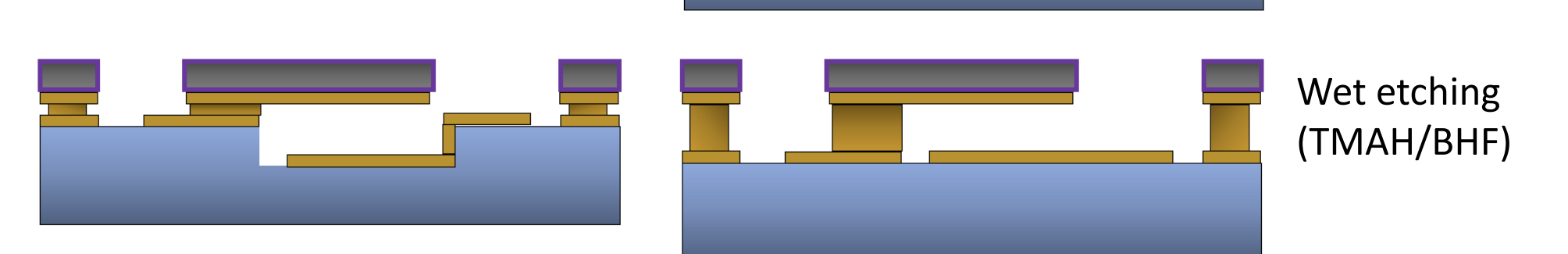
Gap=Gold bond

3. Bonding



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

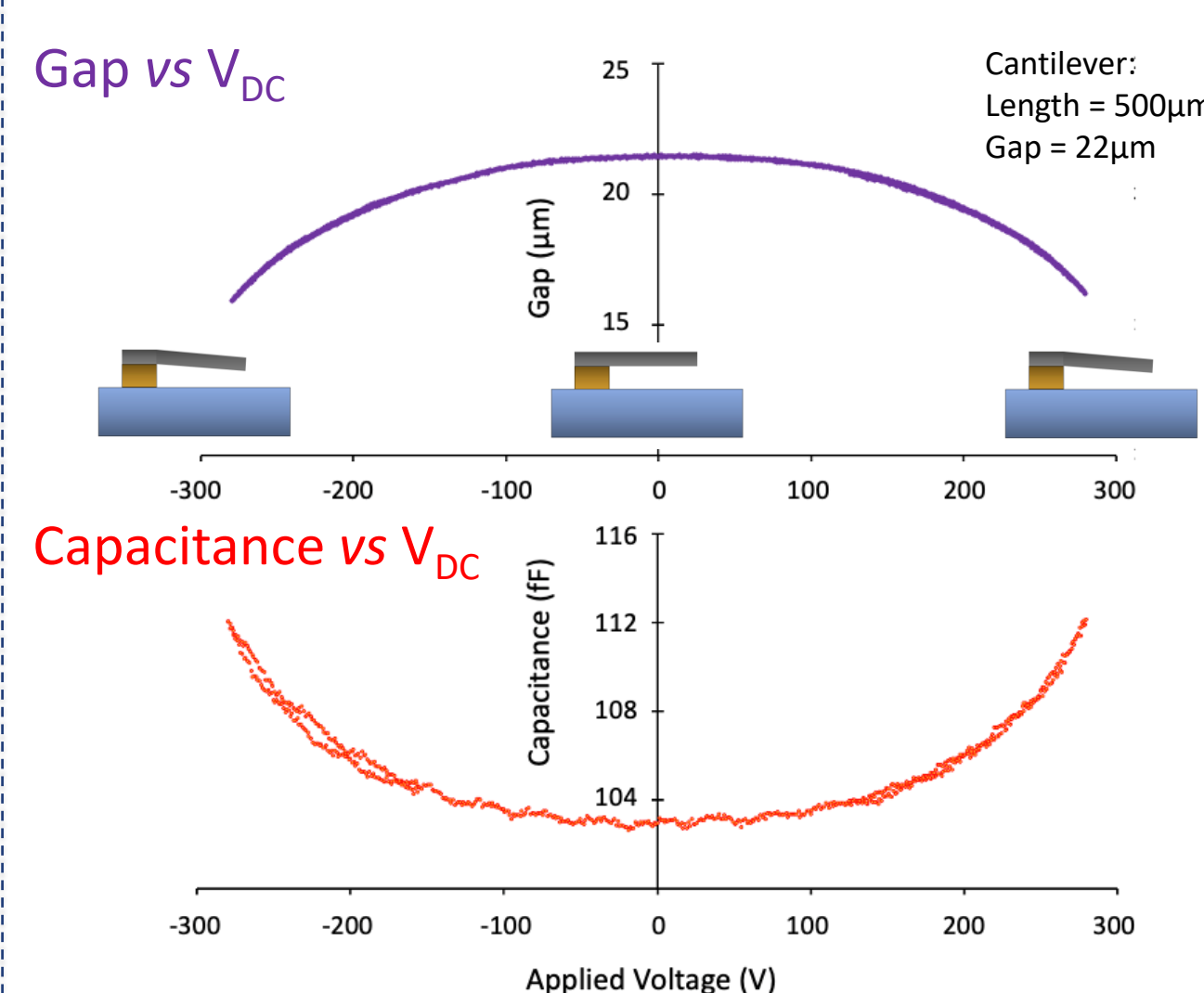
4. Release



Wet etching (TMAH/BHF)

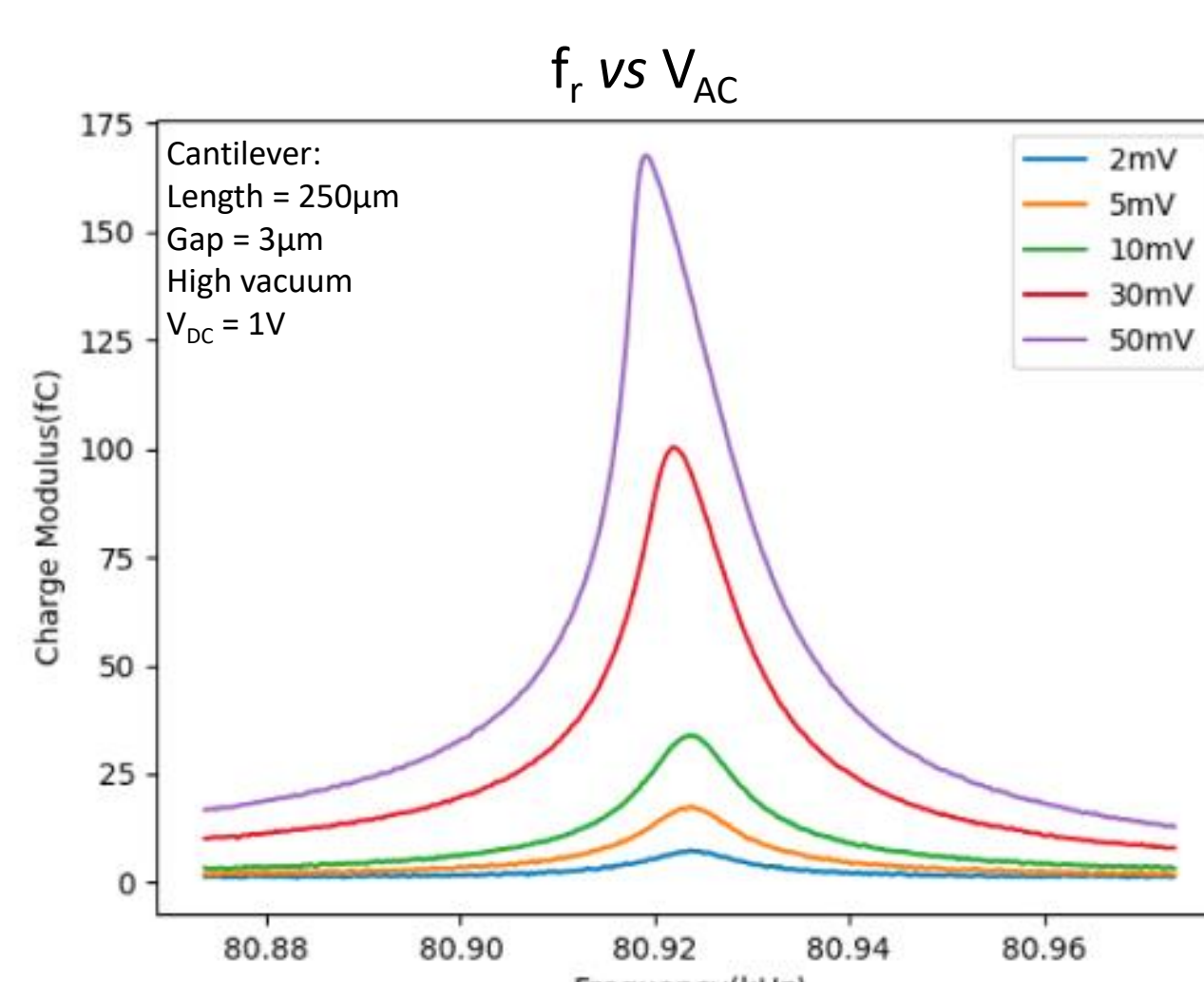
Characterizations

Static mode

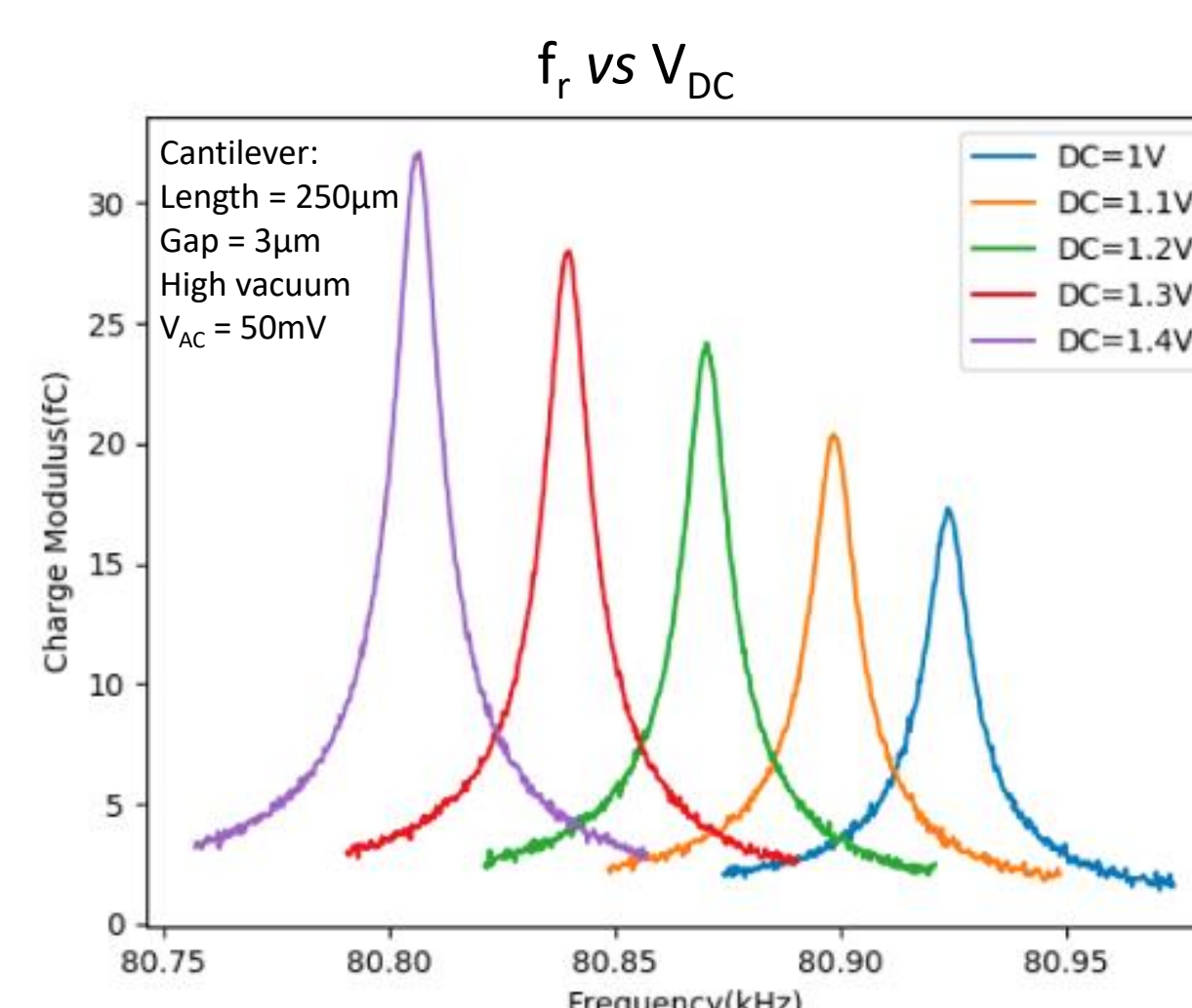


\checkmark Quadratic dependance of the gap and capacitance with applied voltage

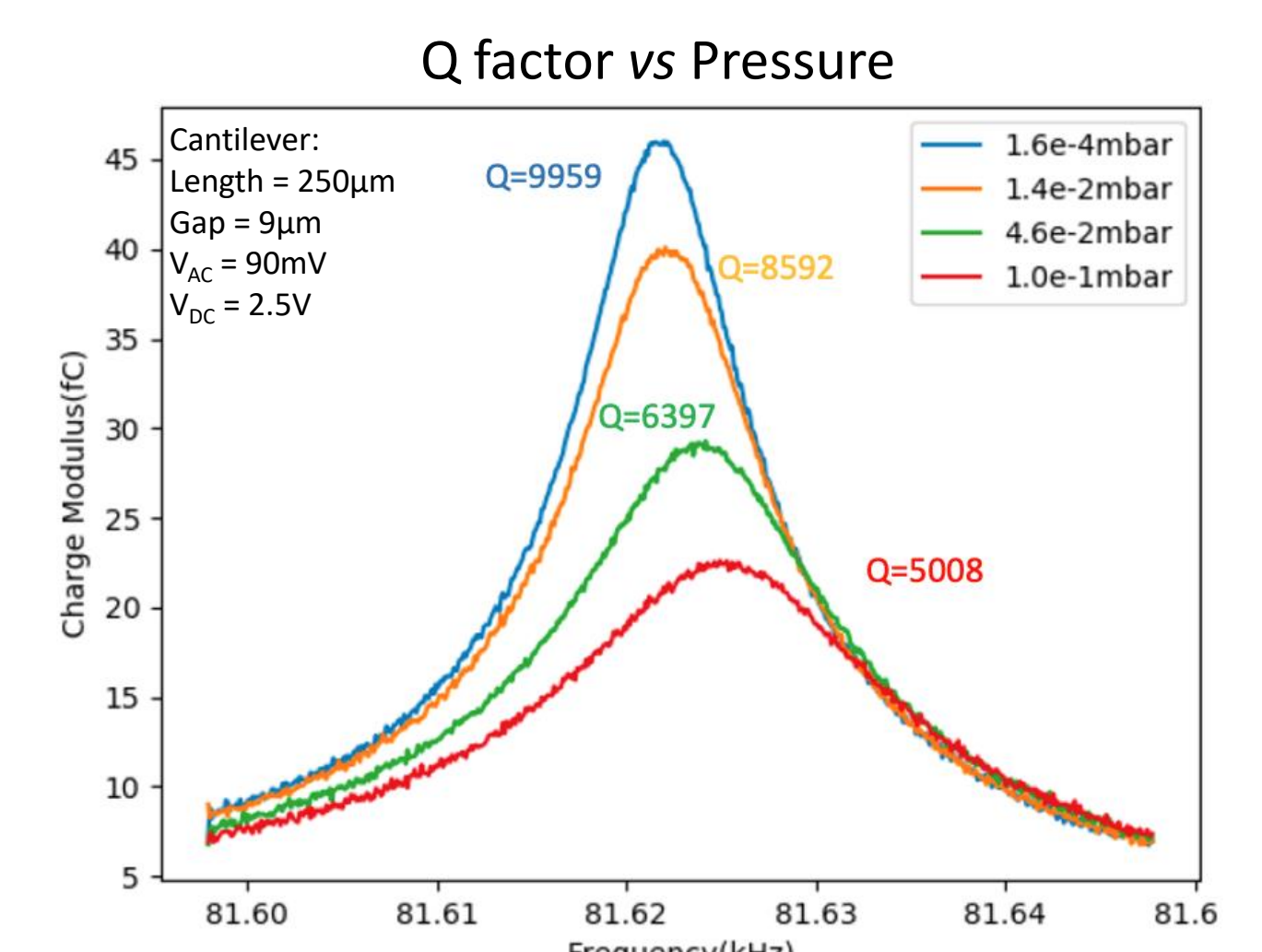
Dynamic mode



\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