Hybrid Membrane development for A MEMS based Stirling engine

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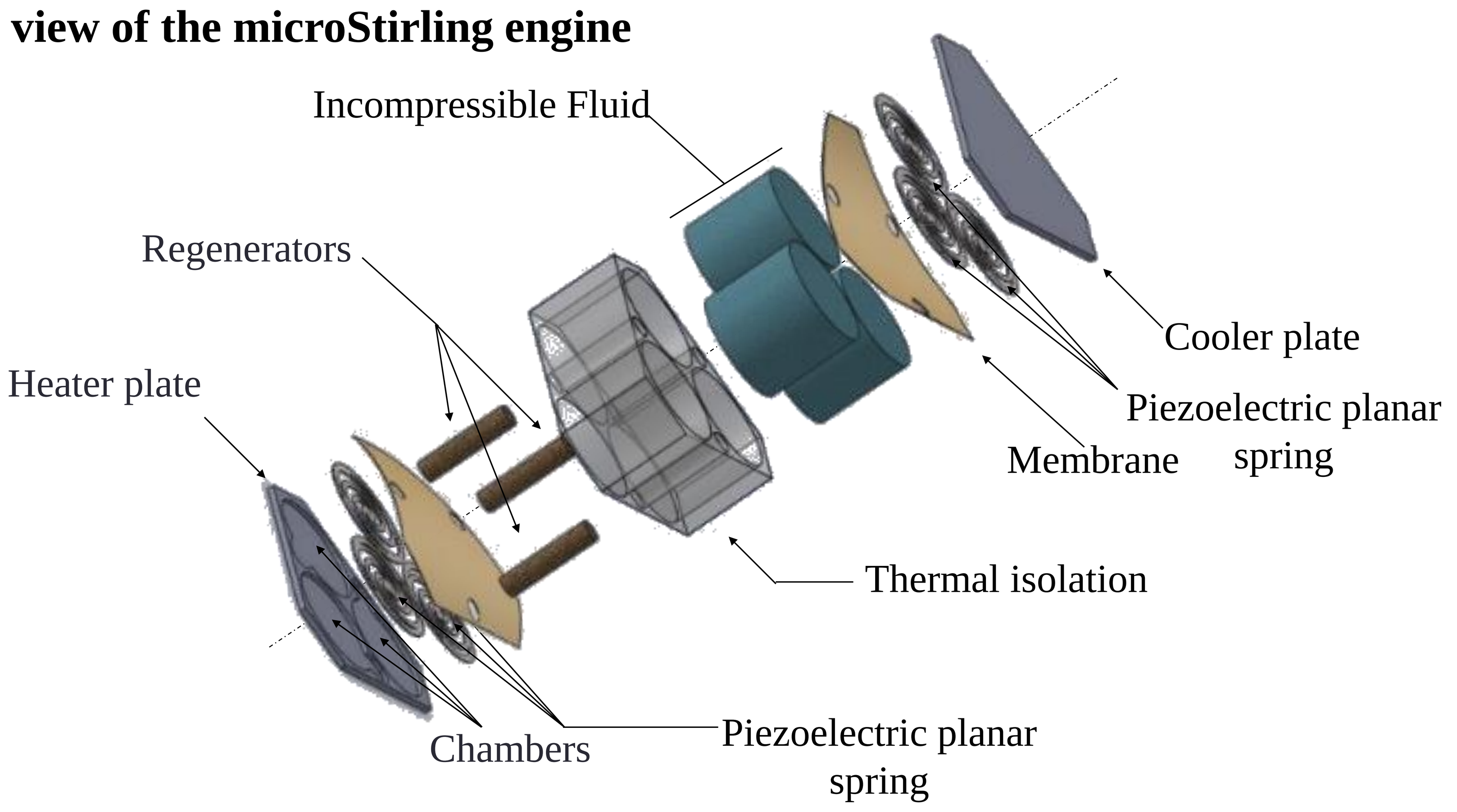
Abstract: The paper describes the microfabrication of an innovative double acting Stirling engine for low temperature heat recovery. The usual pistons are replaced by hybrid RTV silicone - planar Si spring - fluid diaphragm (HFD). The proposed fabrication process ensures the fabrication of a freely suspended RTV silicone membrane on silicon wafer, the anodic bonding of membrane wafer with glass wafer and the incompressible fluid filling done at the wafer level.

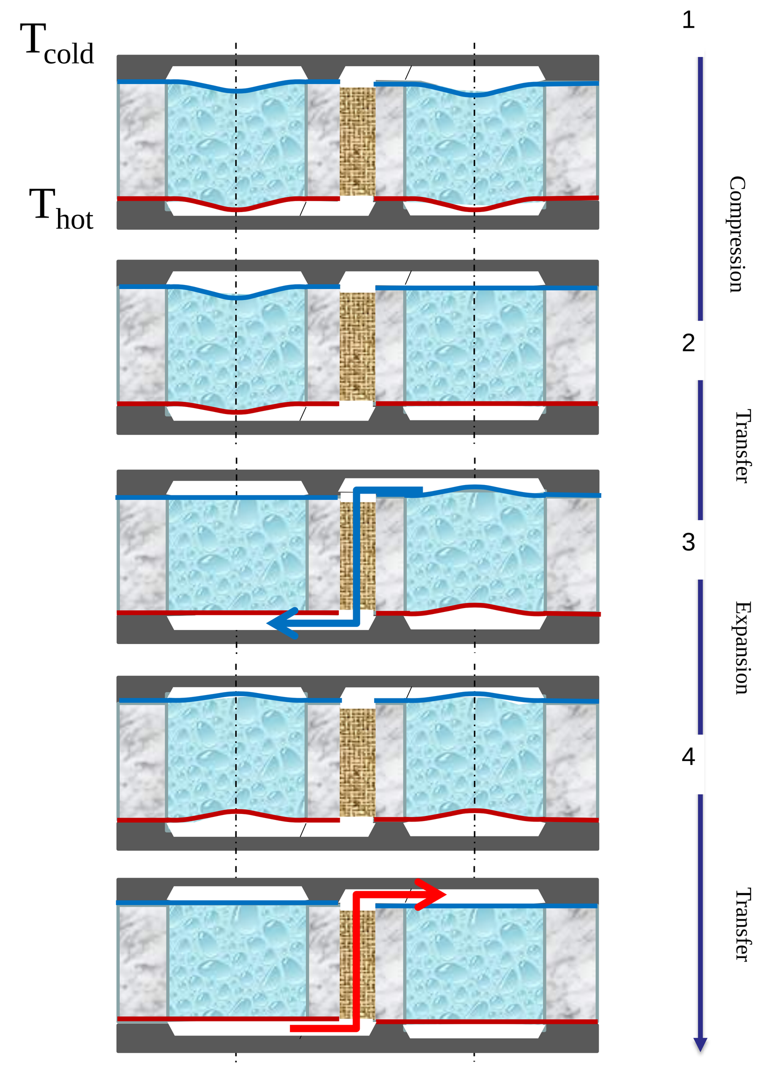
GENERAL ARCHITECTURE

- **CAD view of the microStirling engine**



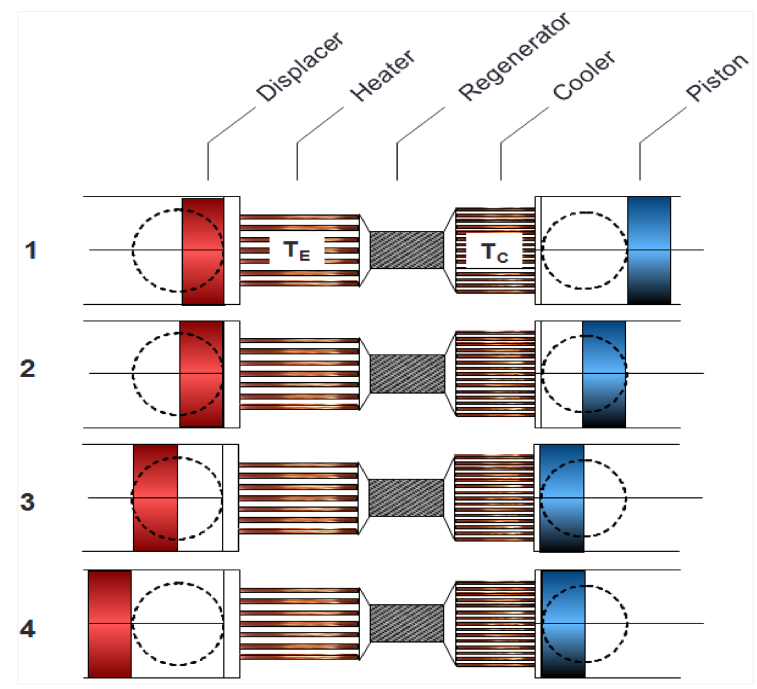
- **Details of the HFD and technical requirements**
  - Chamber diameter : Ø = 5 mm
  - Thin soft membrane ensure gas and fluid filling
  - Incompressible fluid (glycerin, vaseline oil) sealing
  - No air bubble in chamber filled with fluid to ensure the proper dynamic characteristics
  - High quality factor
  - Temperature tolerance for anodic bonding 250 ≤ T ≤ 300 °C (Limited by membrane material)
  - Thermal insulation

WORKING PRINCIPLE



HFD working Principle

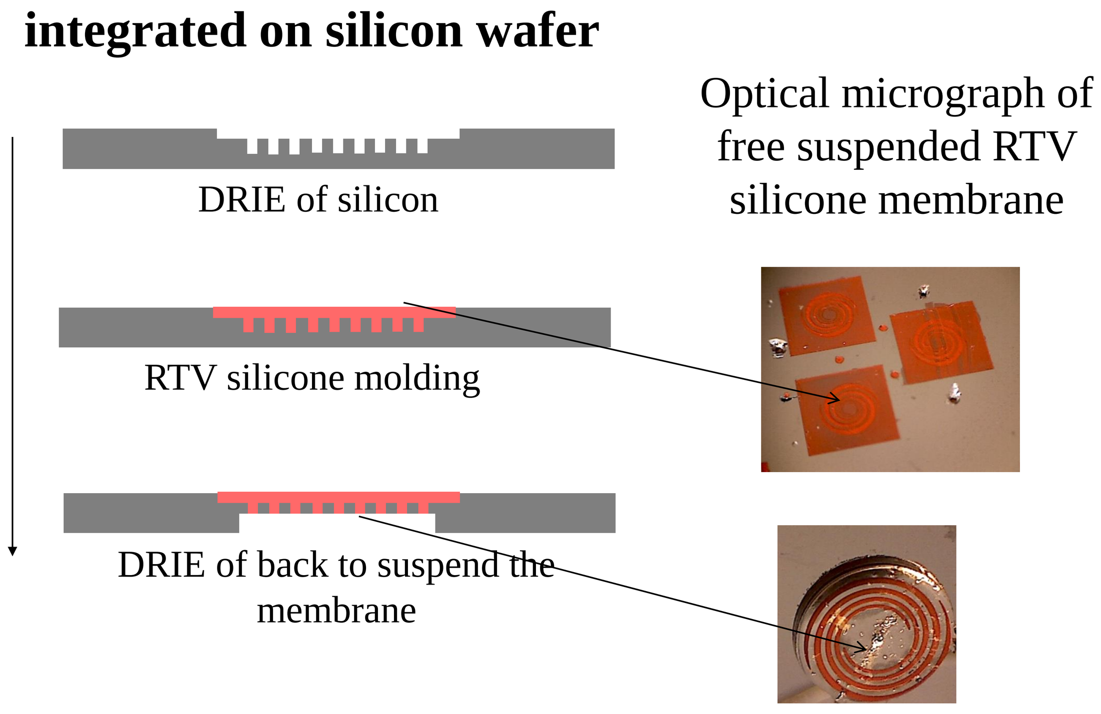
- **Ideal Stirling cycle:**
  - Isothermal compression and expansion
  - Constant volume heating and cooling in the regenerators



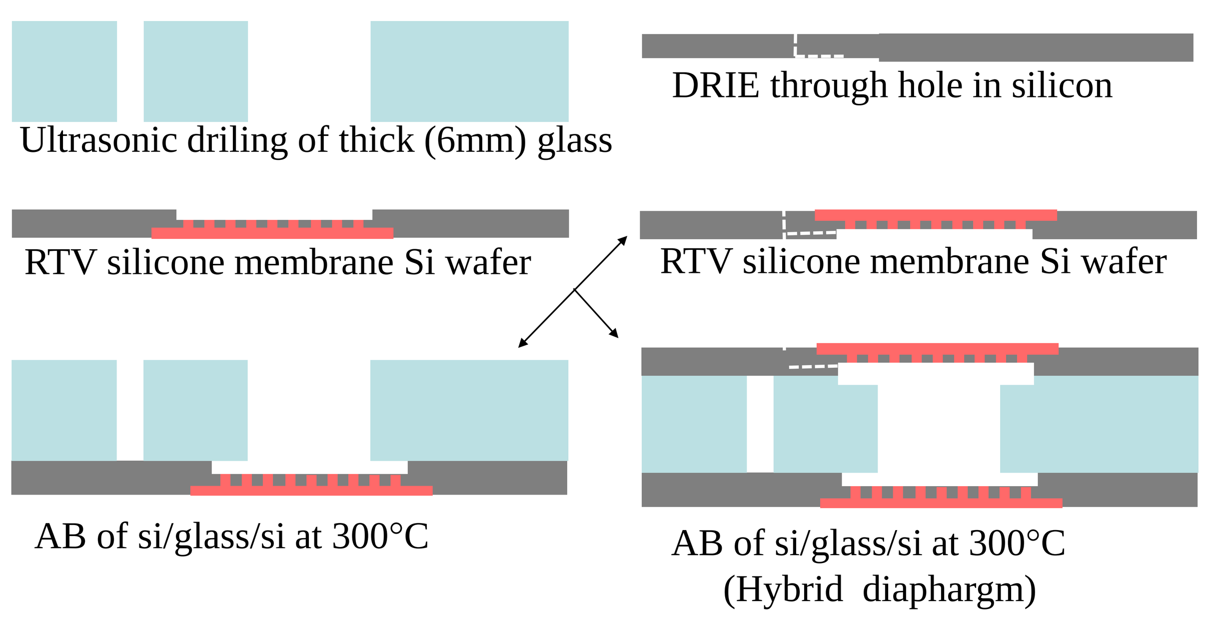
Stirling working Principle

MICROFABRICATION

I. Microfabricted RTV silicone membrane integrated on silicon wafer

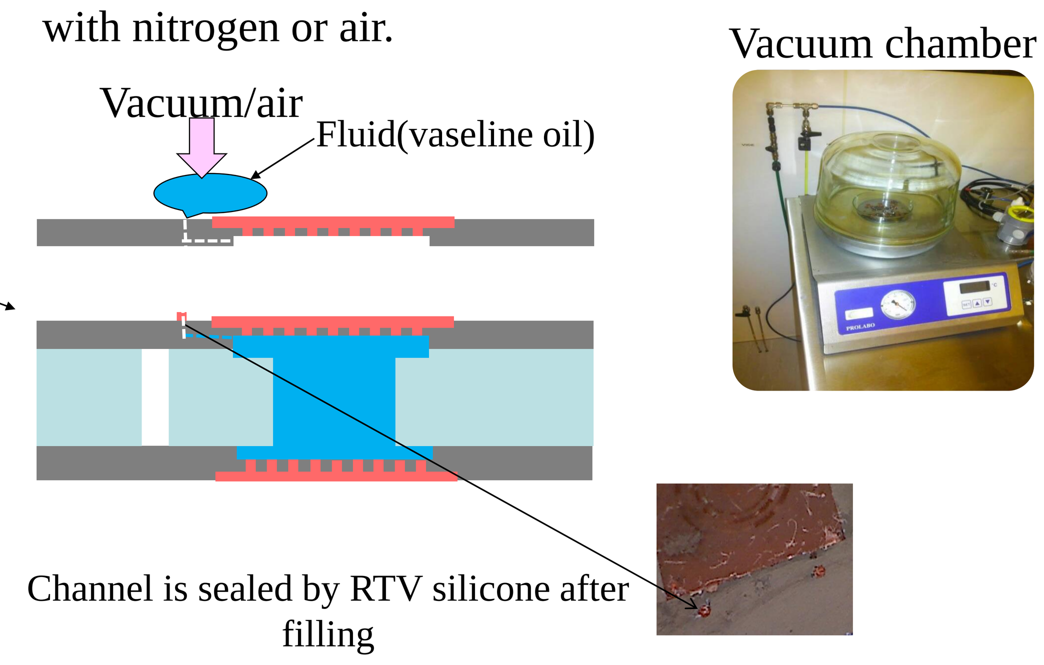


II. Anodic bonding (AB) of wafers to fabricate HFD



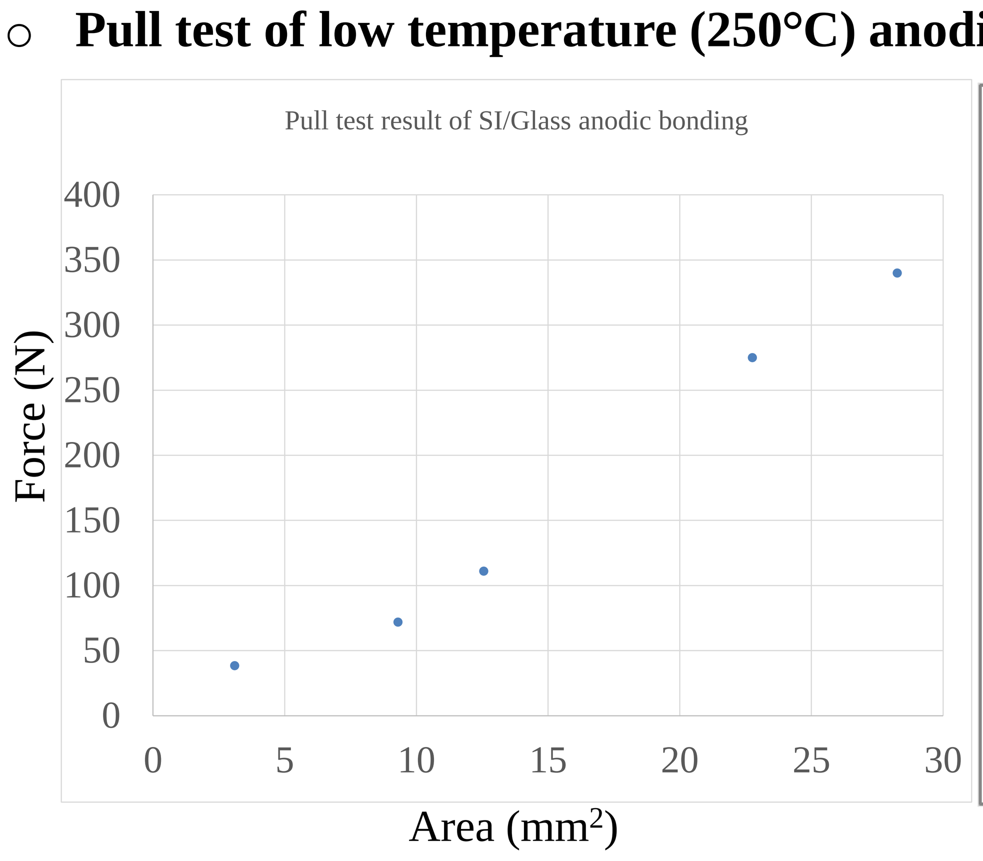
III. Wafer level fluid filling test

Fluid is filled in the cavity with pull-push method by creating a low vacuum followed by venting with nitrogen or air.

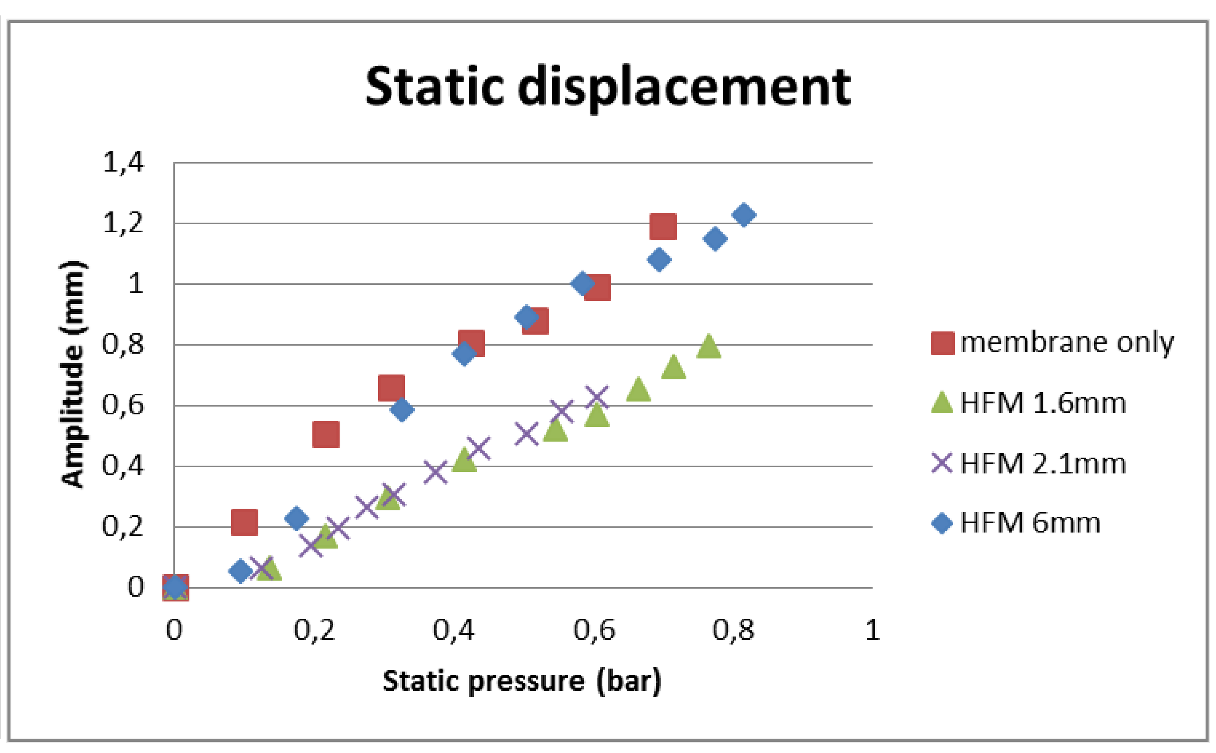


PRELIMINARY CHARACTERIZATION

- **Pull test of low temperature (250°C) anodic bonding and Static displacement measurements**

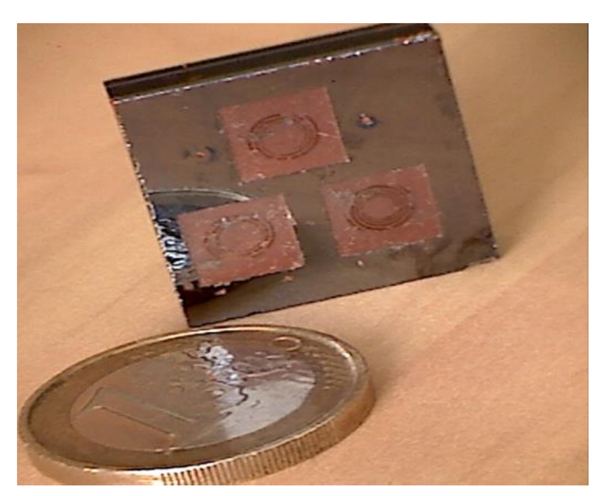


Bond strength was measured ~12 MPa which is sufficent for machine hermitical sealing



Static displacement was measured ~0.8mm which is sufficent for piston mode driving membrane

- **Microfabricated HFD chip**



- **Conclusions**

✓ Wafer level fabrication of HFD is successfully demonstrated.
✓ Multiple anodic bonding is validated and followed by the fabrication of an HFD.
✓ The low temperature anodic bonding is validated.

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