Hybrid Diaphragm development for A MEMS based Stirling engine

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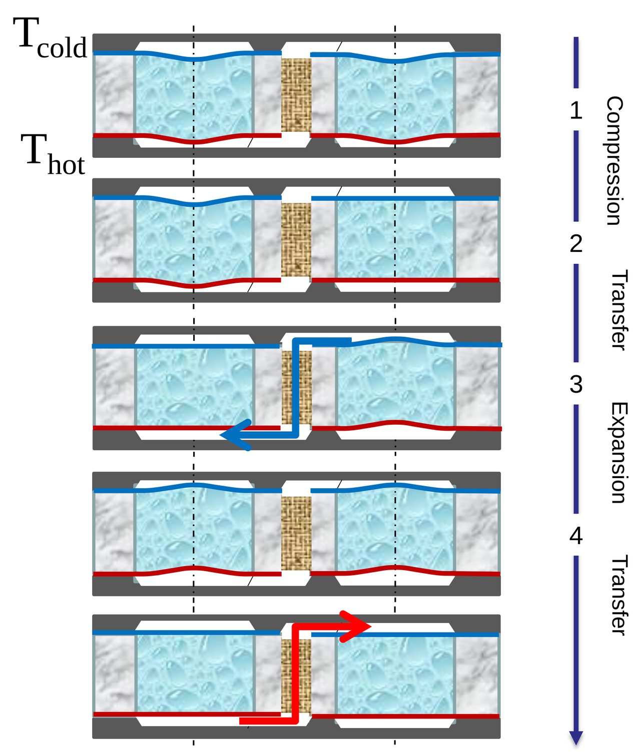
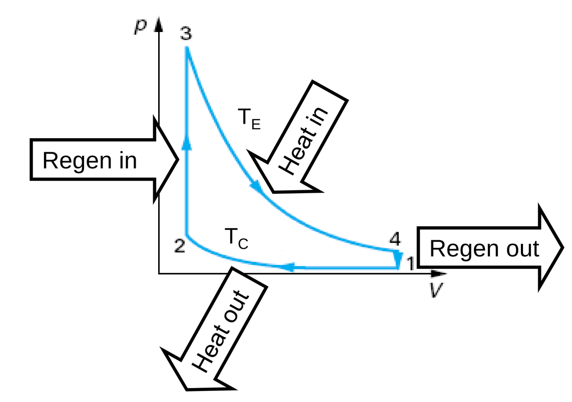
Abstract: The paper describes the microfabrication of an innovative double acting Stirling engine for low temperature heat recovery. The usual pistons are replaced by hybrid RTV silicone - planar Si spring - fluid diaphragm (HFD). The proposed fabrication process ensures the fabrication of a free suspended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

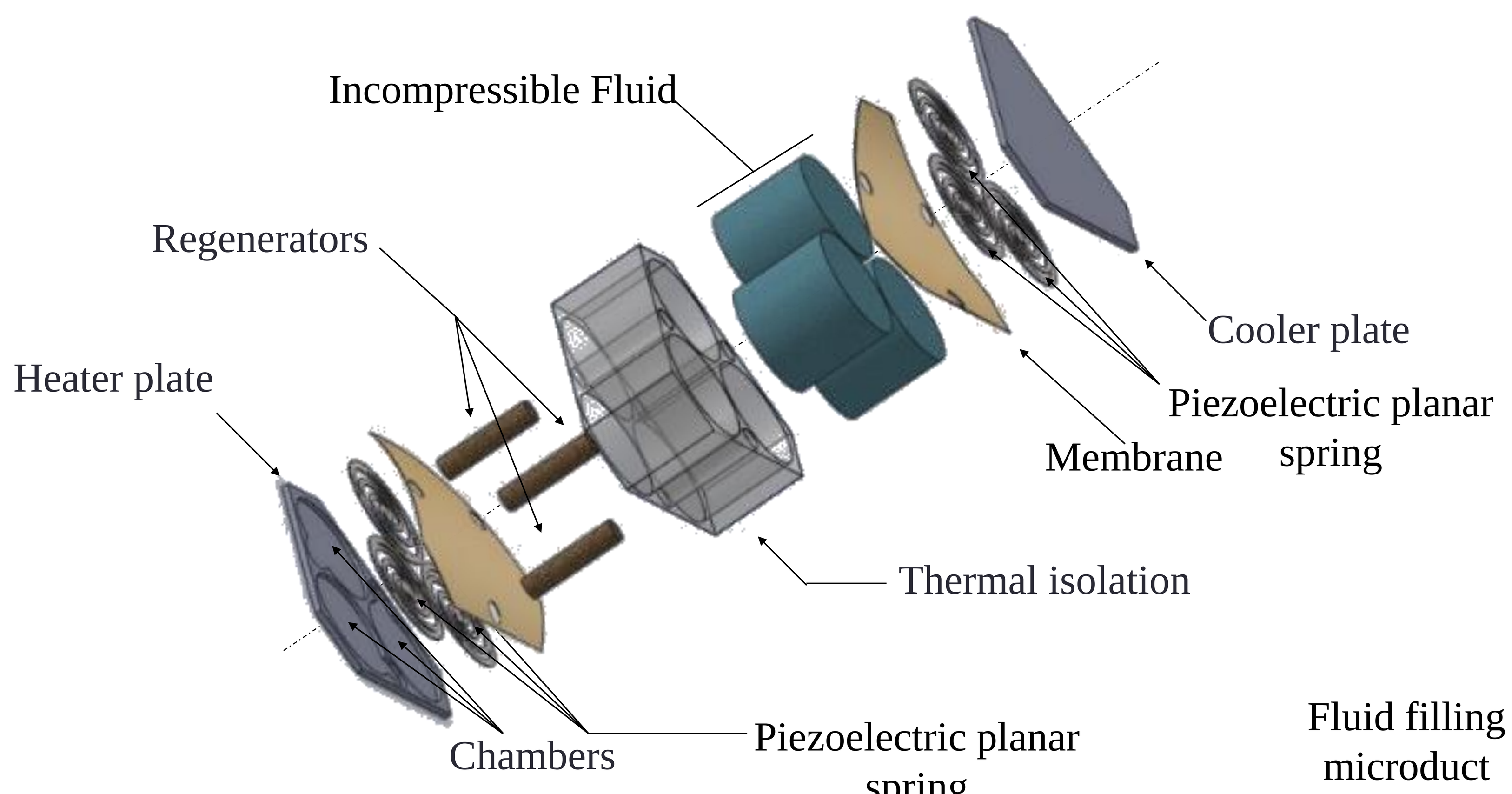
GENERAL ARCHITECTURE AND WORKING PRINCIPLE



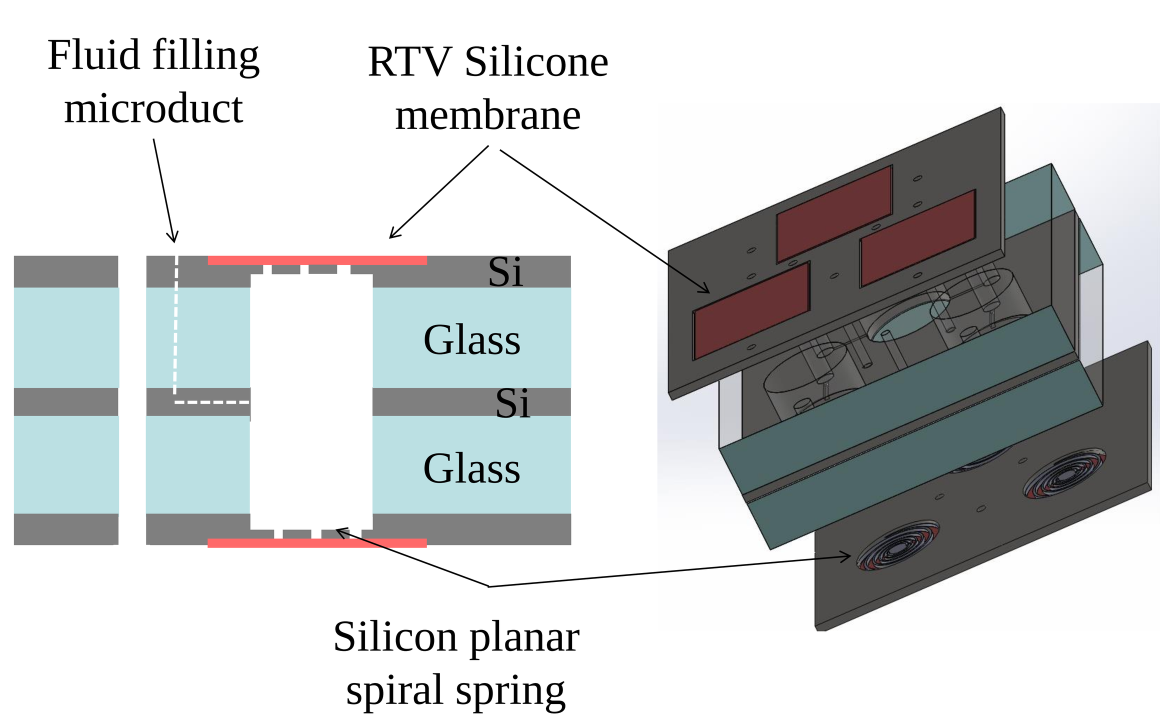
- **Ideal Stirling cycle:**
  - Isothermal compression and expansion
  - Constant volume heating and cooling in the regenerators

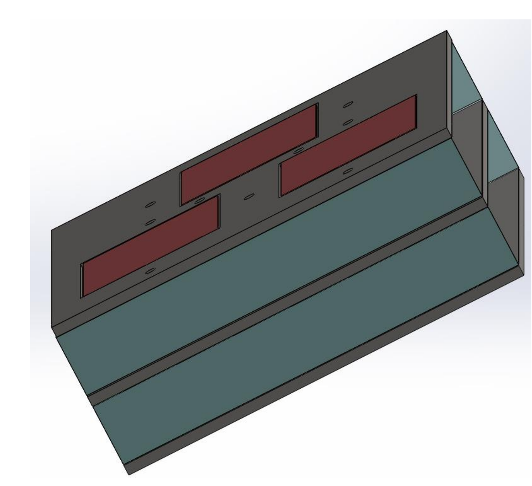


- **CAD view of the microStirling engine**

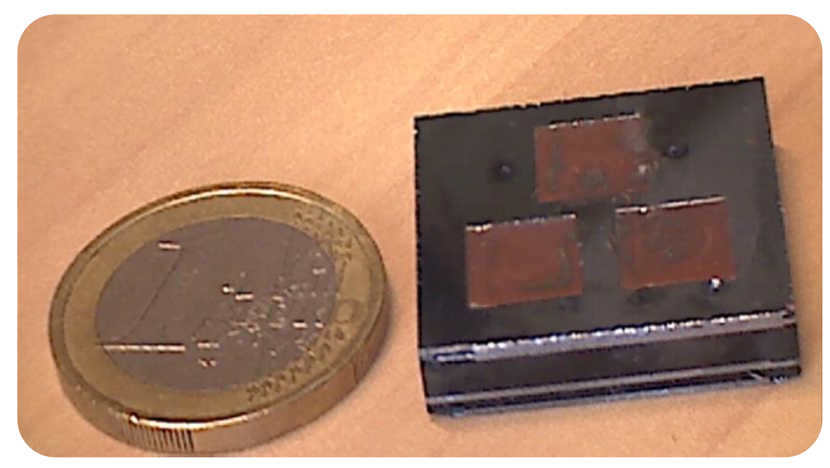


- **Details of the HFD and technical requirements**
  - Ø = 5 mm
  - Incompressible fluid sealing
  - No air bubble to ensure the proper dynamic characteristics
  - High quality factor
  - Mechanical robustness for 20°C ≤ T ≤ 150 °C
  - Thermal insulation



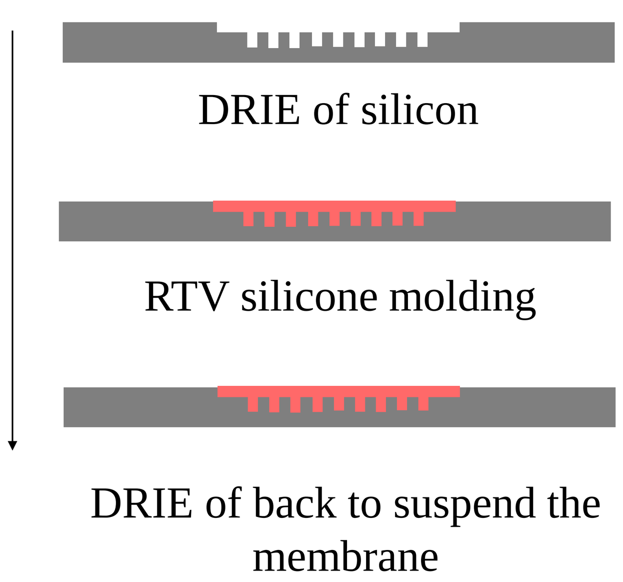


- **Hybrid fluid diaphragm cluster**

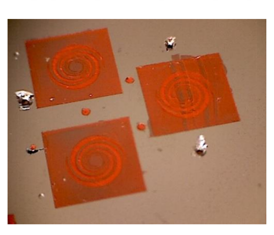


MICROFABRICATION

I. Microfabricted RTV silicone membrane integrated on silicon wafer

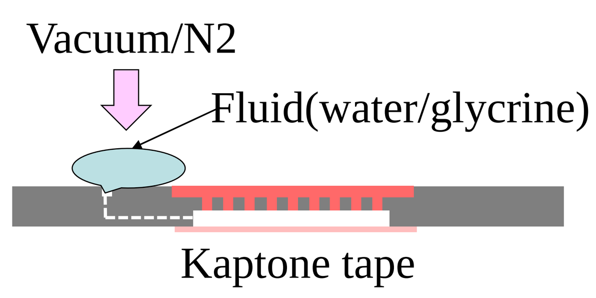


Optical micrograph of free suspended RTV silicone membrane



II. Wafer level fluid filling process

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



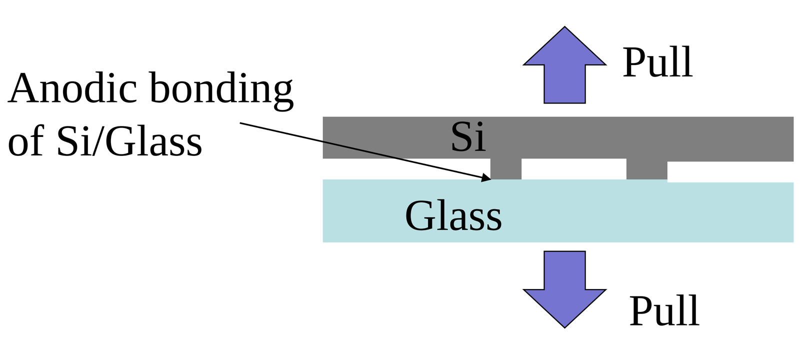
Vacuum chamber

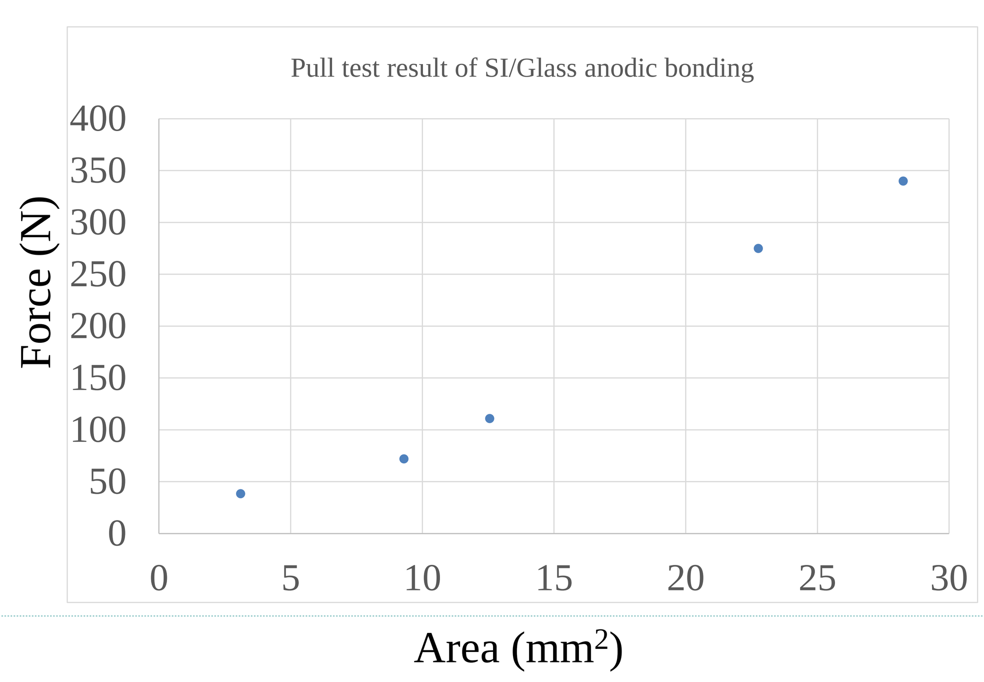
Air bubble in cavity when pressure in chamber is 800 mbar

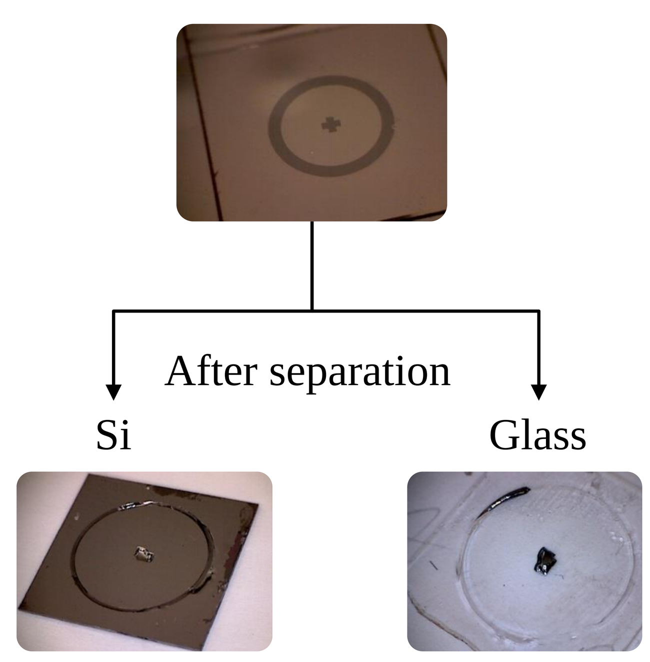
No Air bubble in cavity when pressure in chamber is ≤ 500 mbar

CHARACTERIZATION

- **Pull test of low temperature (250°C) anodic bonding**







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

- **Conclusions**

✓ Wafer level fabrication of thin RTV silicone membrane is successfully demonstrated.

✓ Multiple anodic bonding is validated and followed by the fabrication of an HFD.

✓ The process to fill the engine HFD has been tested with water and glycerine.

✓ The low temperature anodic bonding is validated.

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