Optimization of a Microfabrication Process of a thermomechanical micro actuator: The Bimorph Cantilever

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Abstract

MEMS (microelectromechanical systems) is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometers to millimeters. These devices can sense, control and actuate on the micro scale, and generate effects on the macro scale when subjected to external bias. A micro actuator device converts electrical energy into action as an output. This work focused on optimizing the fabrication steps of a bimorph cantilever actuator fabricated on a silicon substrate wafer and modeling the displacement as a function of the applied voltage.

Introduction

A bimorph cantilever is a suspended micro beam fixed at one end and fixed at other end and can take two shapes. The thermo-mechanical device in this work are made using bulk micromachining of silicon substrate. The bimorph cantilevers work by applying a voltage to the electrodes, heating up the heater circuit which induces deflection due to a difference in the thermal coefficient of the two layers. Equation 1 shows the radius of curvature (r), measure of deflection as a function of change in temperature (**Δ**T) and Thermal expansion coefficient (α).

$$\frac{1}{r} = \beta\alpha\Delta T \quad \text{Equation 1}$$

Design and Simulations

COMSOL Multiphysics was used to perform finite element modelling (FEM) simulations (Figure 1) to evaluate the resonance frequency of cantilevers with different beam lengths and thicknesses. Also, displacements were evaluated as a function of voltage.

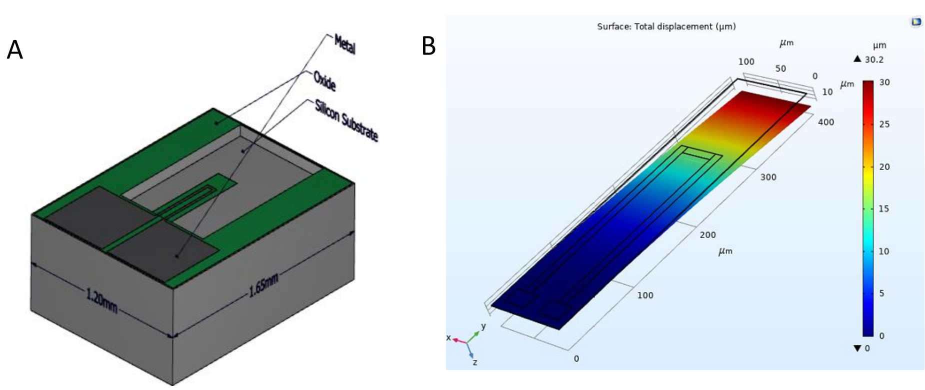

Figure 1 - (A)Design, (B) FEM Displacement Result

Fabrication Process

The bimorph cantilevers were fabricated at University of New Mexico's Manufacturing Training and Technology Center (MTTC) class 1000 cleanroom. The fabrication process is shown in Figure 2. Low stress 1 µm thick Silicon Nitride film was deposited by LPCVD (low pressure chemical vapor deposition) method and etched by reactive ion etching (RIE) using Tetrafluoromethane and Oxygen. The cantilever and heater pattern were transferred using UV Photolithography.

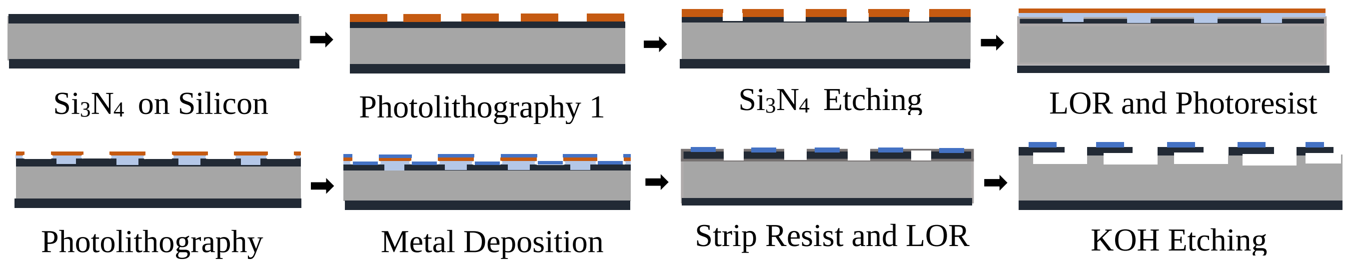

Figure 2 - Fabrication Process Steps

The AJA sputter tool was used to deposit four metal layers: aluminum, chromium, nichrome and copper. Anisotropic wet etching using potassium hydroxide (KOH) of the underlying crystal silicon substrate was employed to release the cantilever resulting in free standing structures. A scanning electron microscope and a profilometer were used to characterize the process results.

Results

Wet etching of the underlying crystal silicon substrate resulted in stiction, over etching of metal and silicon. and breaking of the cantilever devices. Employing supercritical drying after KOH etching resolved the stiction issue. Chromium was found to be the most stable in KOH etching. Working devices were obtained as the result. Mechanical Probe station was utilized to observe the movement in the cantilever devices with the voltage supply.

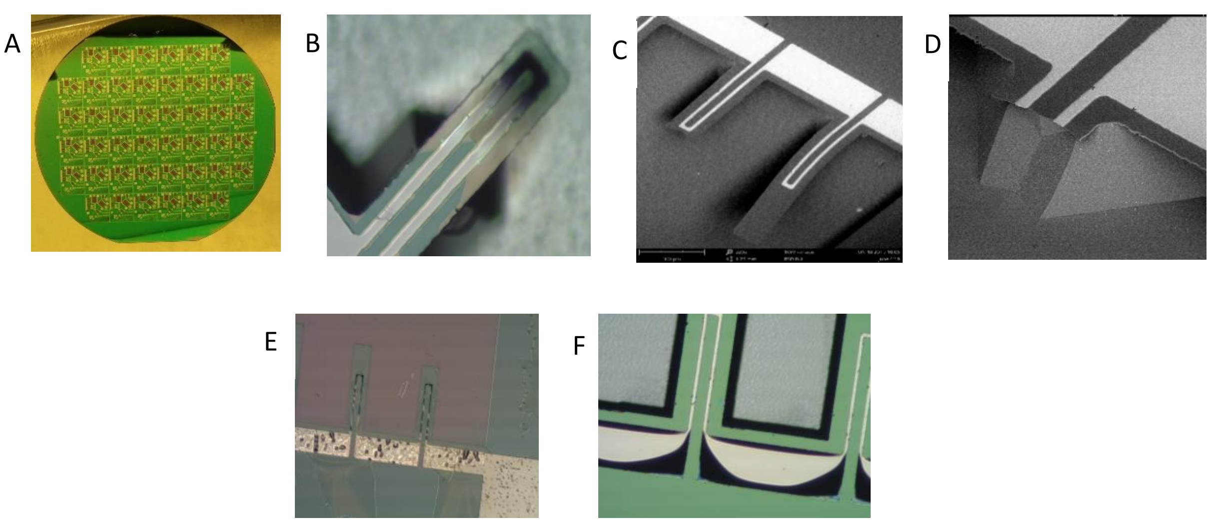

Figure 3 - (A) Devices on wafer, (B) released cantilever, (C) SEM image of cantilever, (D) broken device and underlying silicon crystal etch profile, (E) aluminum pinholes created during KOH etching, (F) nichrome metal peeling due to low adhesiveness during KOH etching .

Conclusion

Variations of the bimorph cantilever fabrication process were investigated and modeled. Simulations were in good agreement with Equation 1. Several problems were discovered and resolved during the optimization of the fabrication steps. The process and design will be refined further, and actual voltage vs displacement experiments will be done. Future work will include measurement of initial deflection using Zygo profilometer and Laser Doppler Vibrometer for dynamic displacement measurement.

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References

1. Brugger J., Gijs M., Case study: Thermo-mechanical micro-actuator.

2. *Mere V., Maharshi V., Aditi Ms. and Agarwal A. (2014). Thermally actuated MEMS micromirror: design aspects. Asian J Physics. 23,631-40.*

3. *Lva X., Wei W., Mao X., Chen Y., Yang J. and Yanga F. (2015). A novel MEMS electromagnetic actuator with large displacement. Sensor Actuators A,221 22-8.*

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Pallavi Sharma is a graduate student pursuing Ph. D in Mechanical Engineering at University of New Mexico. Her research interests are Micro electromechanical systems and smart materials.