Bulk-etched Surface Micromachained Process for Suspended MEMS Structures

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Presentation Outline

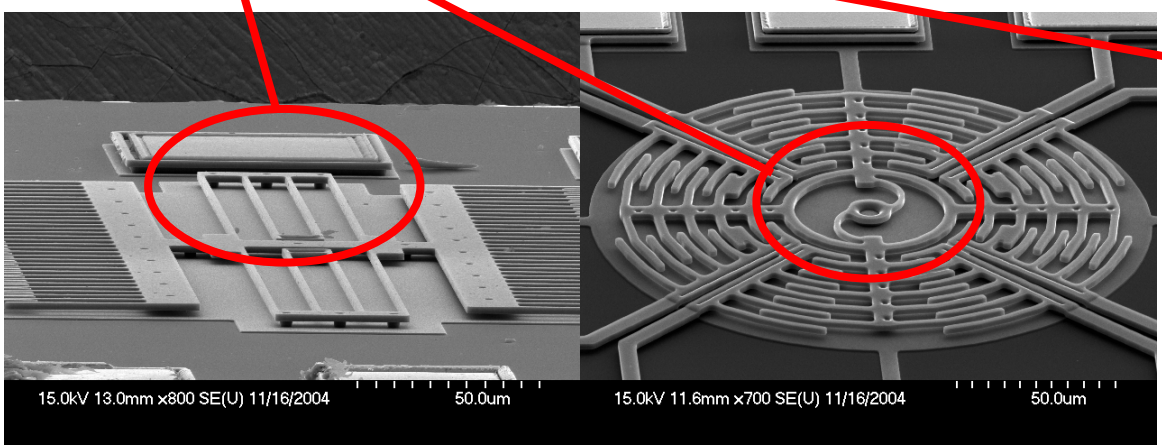
- Suspended MEMS structures
- Bulk and Surface micromachining
- Bulk-etched Surface Micromachining
- Layout and Modeling
- Chemical Wet Etching
- Experimental procedure
- Experimental results and discussion

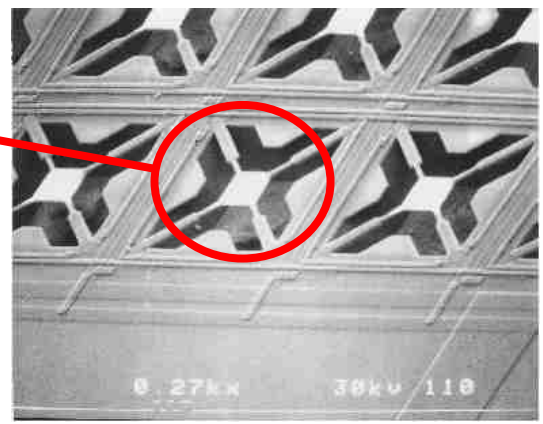
Suspended MEMS Structure

- MEMS stands for **Micro Electro Mechanical Systems**.
- "Micro" : Size definition,

  "Electro" : Electricity or electronics is involved,

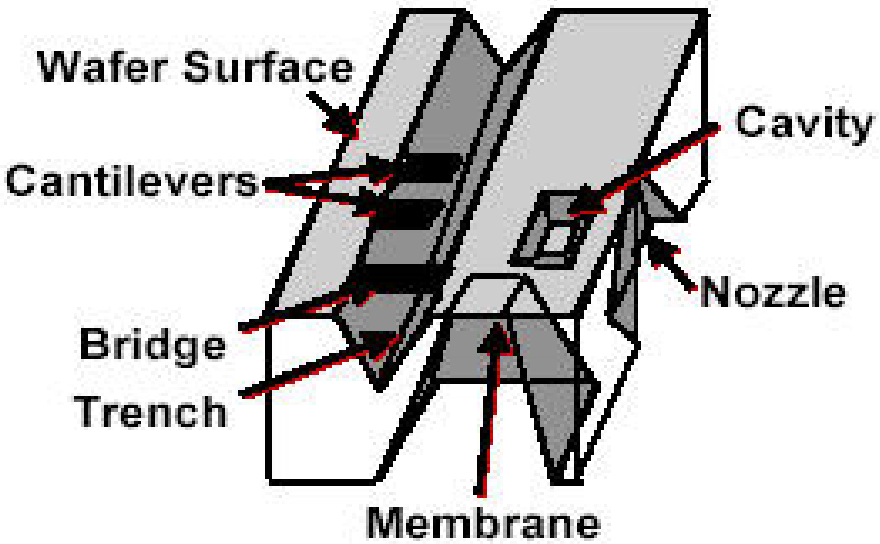
  "Mechanical" : Moving structures (***Suspended***)
- Suspended structure ⟶ floating + bending



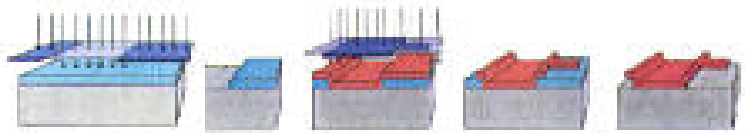


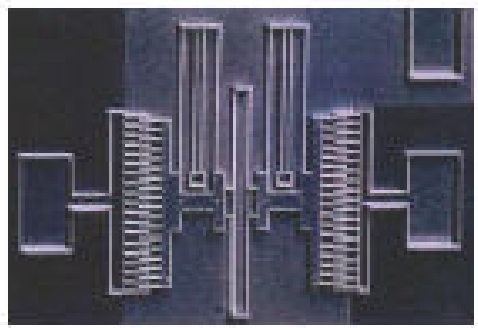
Bulk and Surface Micromachining

Bulk Micromachining



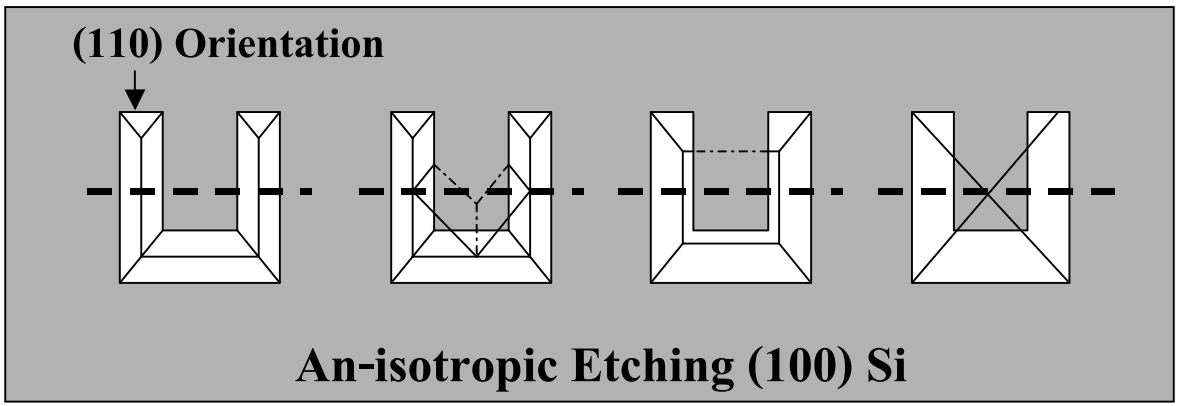
Surface Micromachining

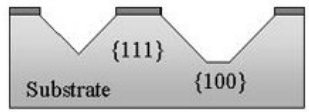




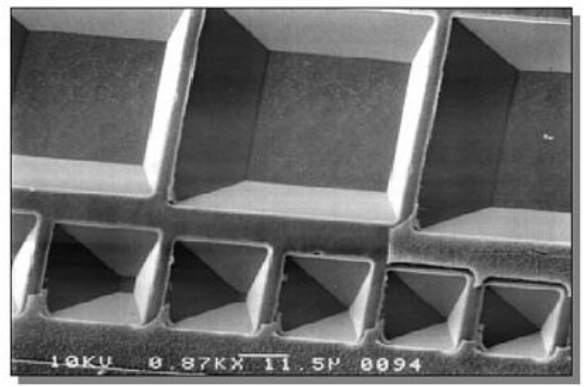
Two main processes of MEMS fabrication

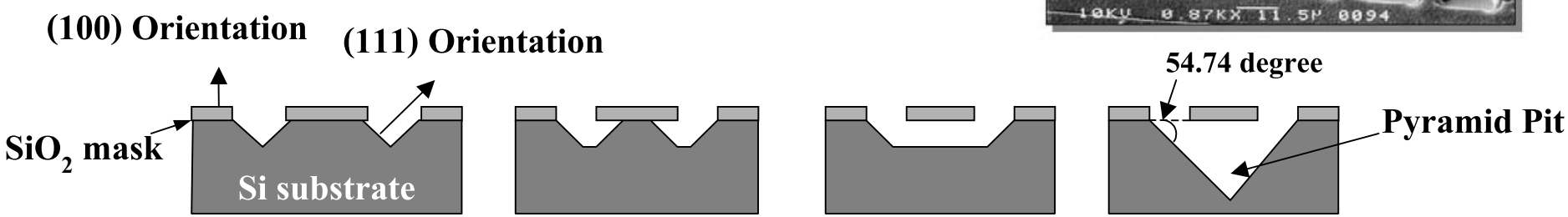
Bulk micromachining





Anisotropic





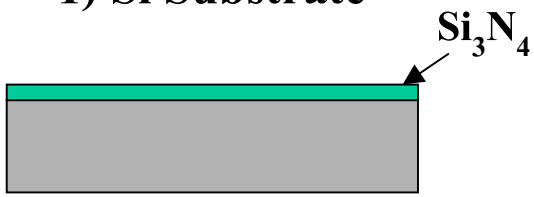
Anisotropic Etchant: TMAH (Tetramethyl Ammonium Hydroxide)

EDP (Ethylene Diamine Pyrochatechol) : Higher etching rate (100)

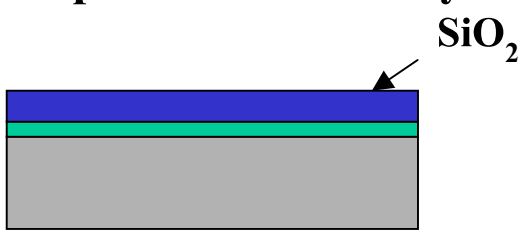
KOH (Potassium Hydroxide)

Surface micromachining

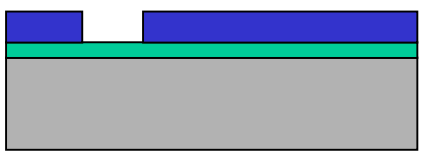
1) Si Substrate



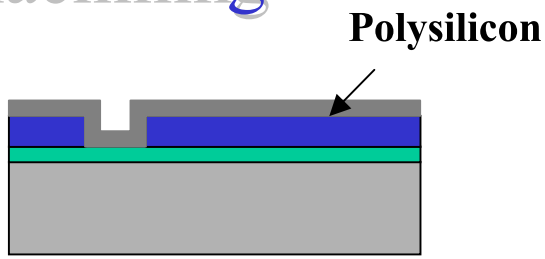
2) Deposit Isolation Layer



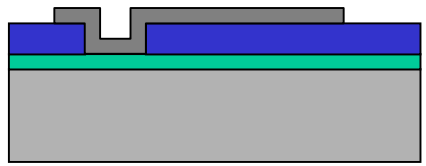
3) Deposit Sacrificial Layer



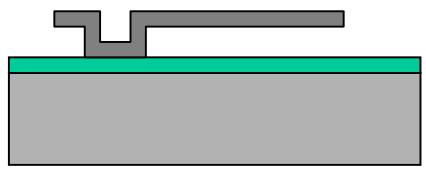
4) Pattern Sacrificial Layer



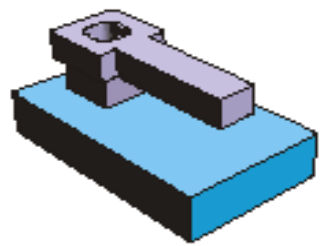
5) Deposit Structure Layer



6) Pattern Structure



7) Release Sacrificial Laye



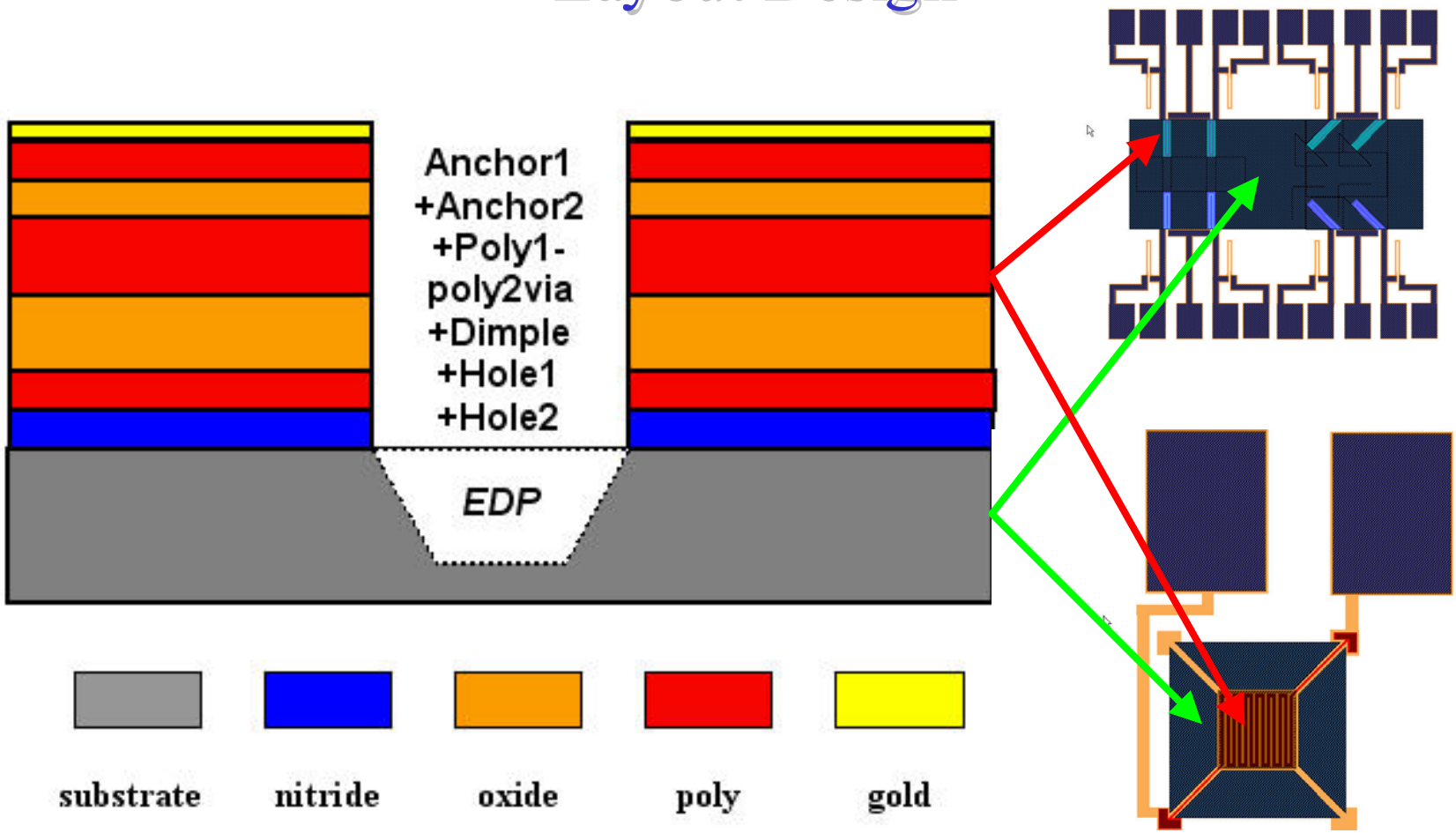
Bulk-etched Surface Micromachining

- The device fabrication consists of two main steps.

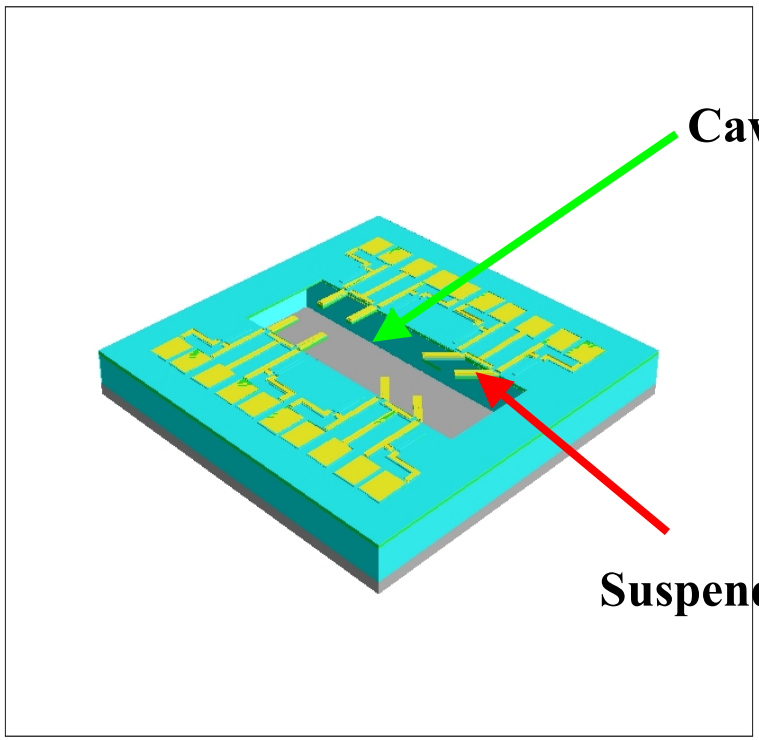
First, the commercial Multi-User-MEMS-Process (MUMPs) is used to fabricate the surface micromachined devices.

Next, the bulk micromachining is then performed by wet etching using EDP (Ethylene Diamine Pyrocatechol) solution to form deep cavity under the movable structure.

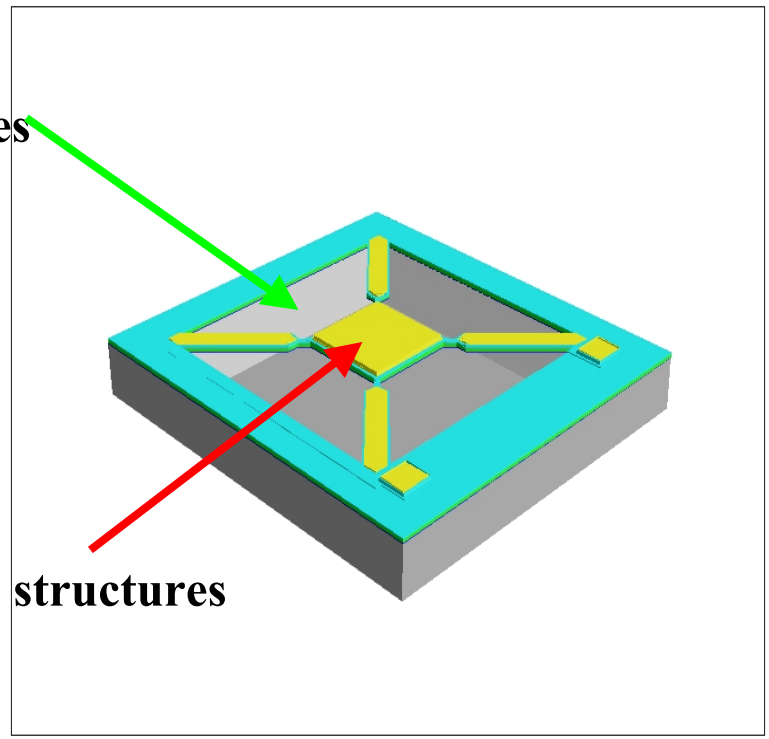
Layout Design



Devices Modeling



Micro-cantilever beam arrays



Micro-mirror

Chemical Wet Etching : EDP

Ethylene-Diamine-Pyrocatechol (EDP) is commonly used for bulk micromachining of silicon because it has moderately high etching rate suitable for a very deep trench formation under suspended MEMS structures and it has high etching selectivity over other materials.

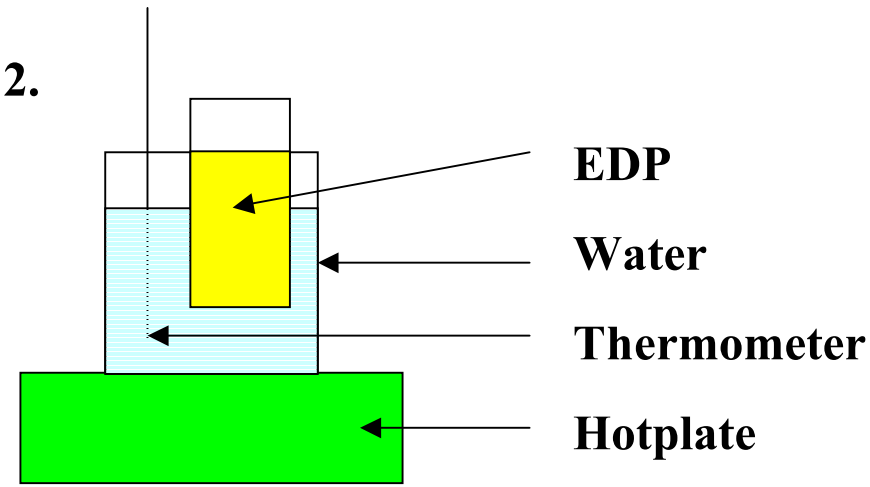
Ingredients	Composition	Temperature (°C)	Relative rate 100	110	111	Absolute rate†
KOH in water/ isopropanol	19 wt. % KOH	80	—	*400*	1	0.59 μm sec^{-1}
N_2H_4/water	100 g/50 mliters	100	*10*	1	—	0.3
Ethylenediamine/ Pyrocatecol/ water	17 mliters 3 g 8 mliters	110	*50*	30	3	50

Experimental Procedure

1. Preparing EDP, (Fast rate recipe)

Ethylene Diamine	25 ml.
Pyrocetachol	8 g.
DI water	8 ml.
Pyrazine	150 mg.

2.

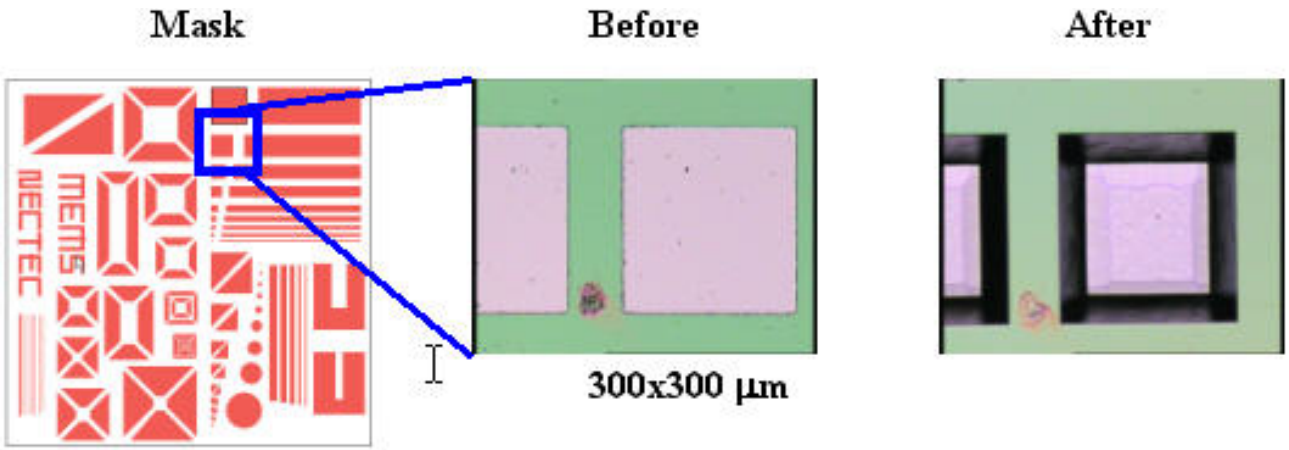


3. After EDP etching, the cleaning procedure starts with

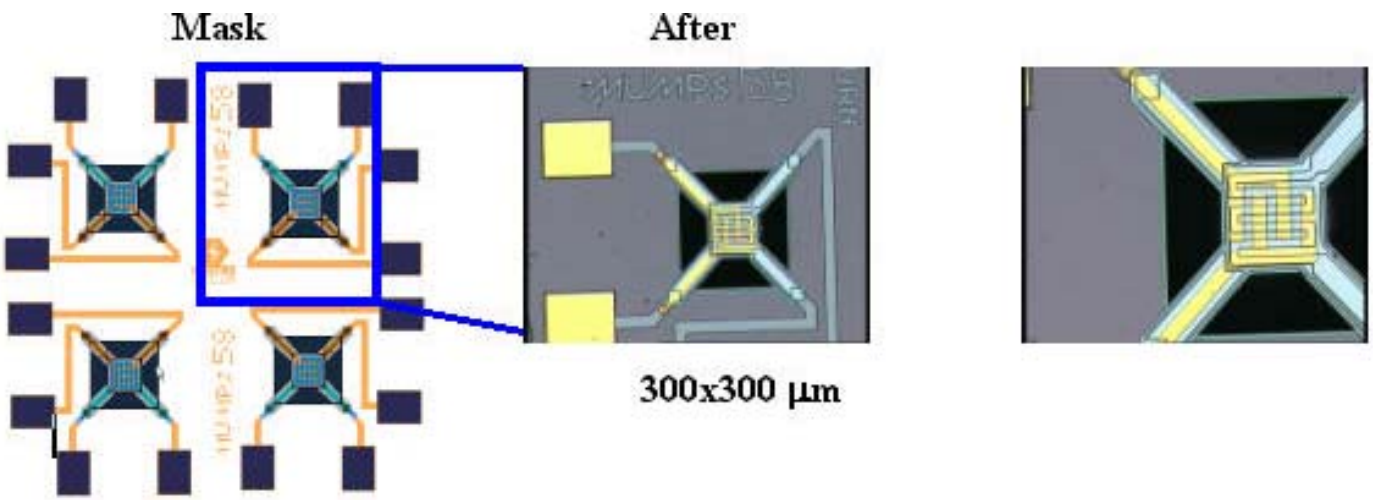
- Rinsing in a low flow rate of deionized water for 20 min.

- Bath of DI water for 8—12 hrs.

Test Pattern



Test pattern mask layout with pre-etching and post-etching using EDP solution.

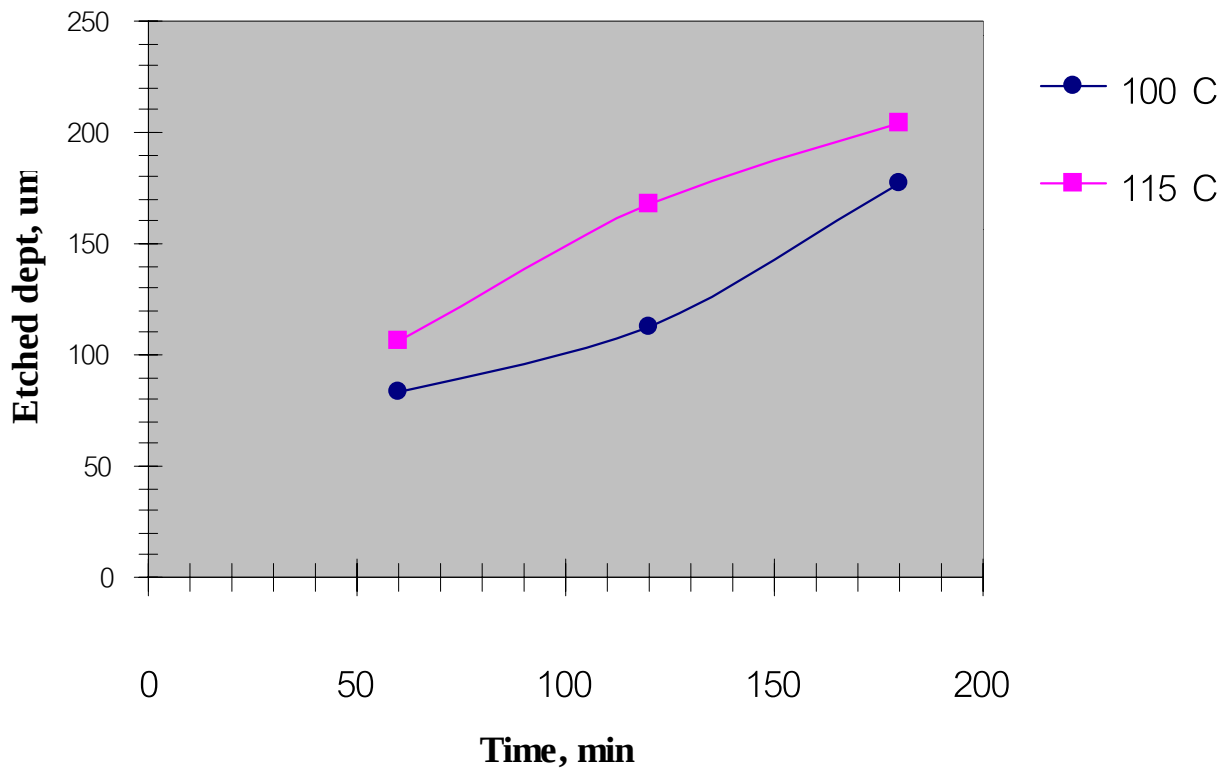


Experimental Results and Discussion

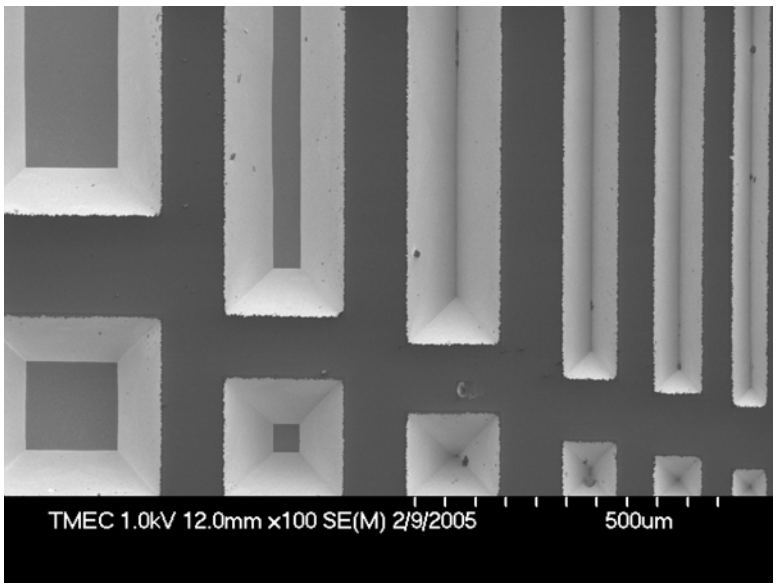
Experimental results : are shown

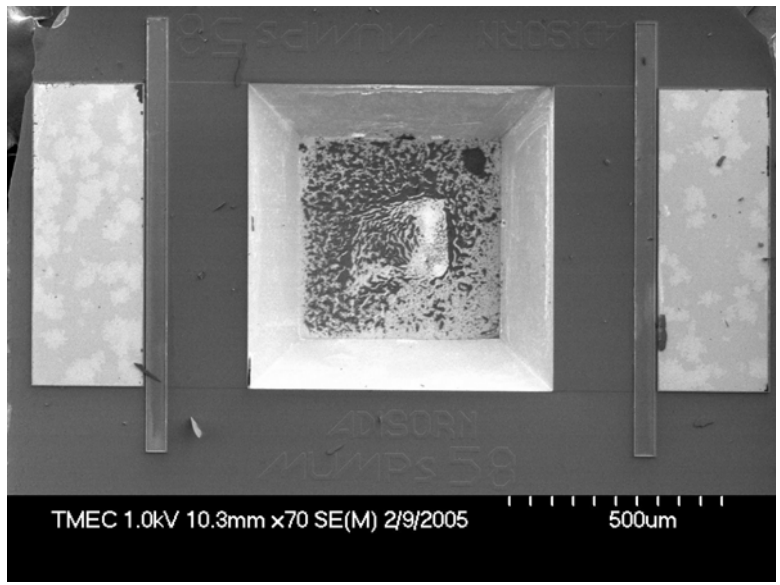
- The relation of etched dept and etching time at constant temperature and EDP concentration.
- The silicon substsrate etched dept in EDP steadily increases with increasing etching time. The etch rate is determined to be ~0.78 μm/min at 100 degree C and ~0.81 μm/min at 115 degree C.

Etched Dept Versus Etching Time at Constant EDP Concentration.



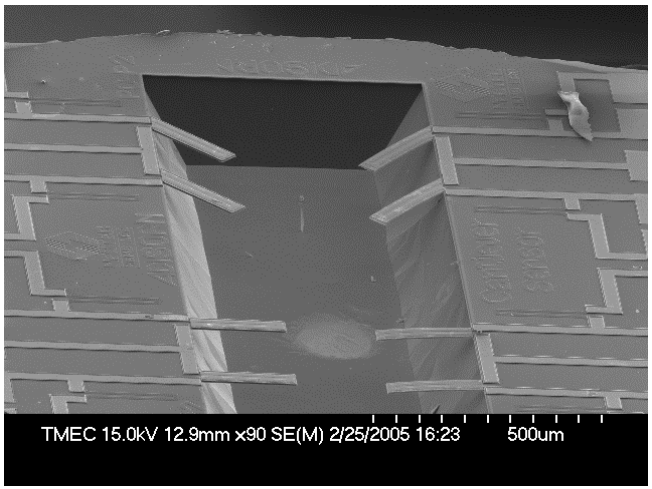
SEM Picture of Suspended MEMS Structures 1

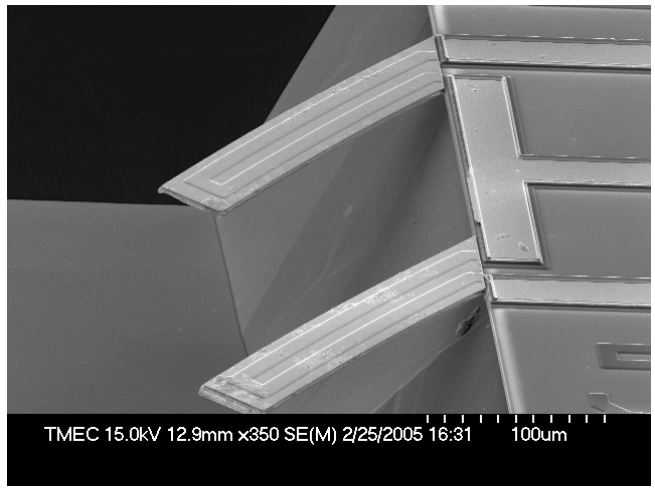


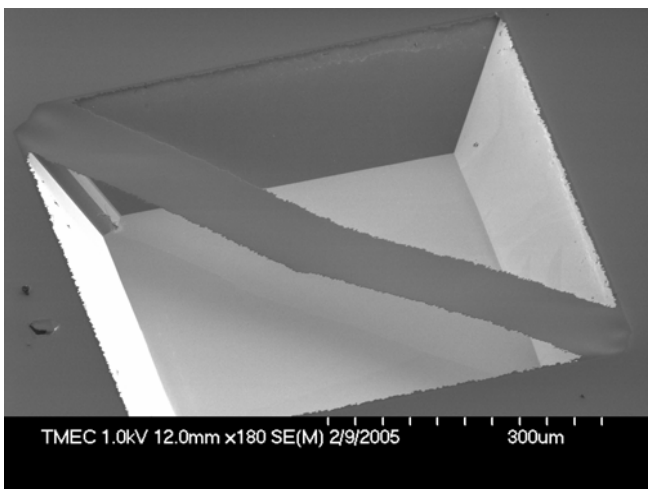


Square cavities

SEM Picture of Suspended MEMS Structures 2

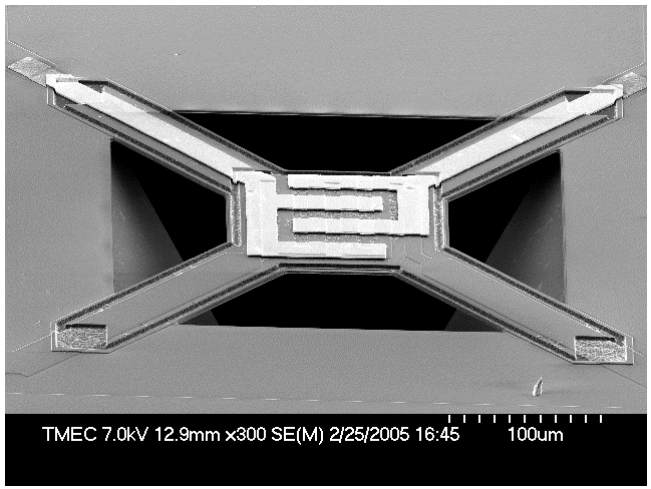


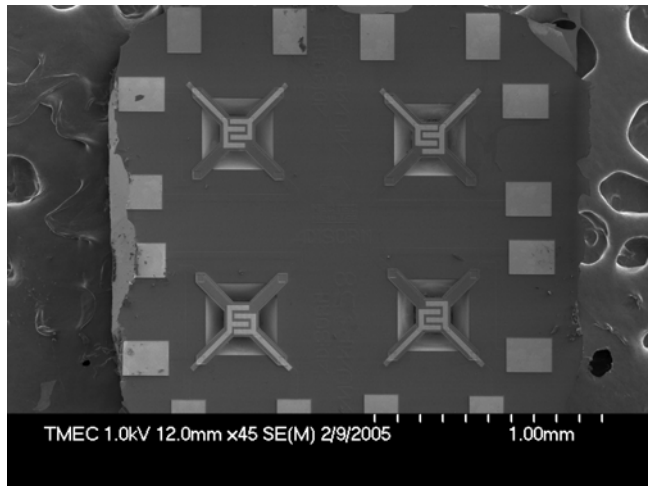


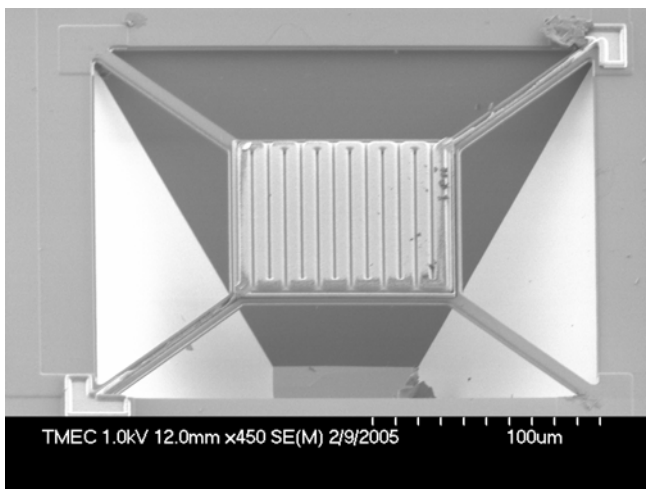


Micro-cantilever beam

SEM Picture of Suspended MEMS Structures 3







Trampoline-shape plate

Experimental Results and Discussion

- The microstructures were realized by a combination of MUMPs and bulk-micromachining by anisotropic etching using EDP solution.

- The advantages and disadvantages of this ethcant with respect to selectivity, reproducibility, and process compatibility are studied.

- Despite its toxicity, EDP is commonly used for bulk micromachining of silicon because it has moderately high etching rate suitable for a very deep trench formation under suspended MEMS structures and it has high etching selectivity over other materials.

Conclusions

- EDP was used to bulk-etch the 300x300 μm^2 cavity under trampoline-suspended structure and 620x1650 μm^2 cavity under cantilever beams.
- The etching dept is varied from 83 to 204 μm depending on etching time and increased with higher temperature.
- From this work, bulk etching by EDP is successfully applied to fabricate deep cavity under surface micromachined MEMS structures.

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