Piezoelectric MEMs with Thin Ferroelectric Film PZT

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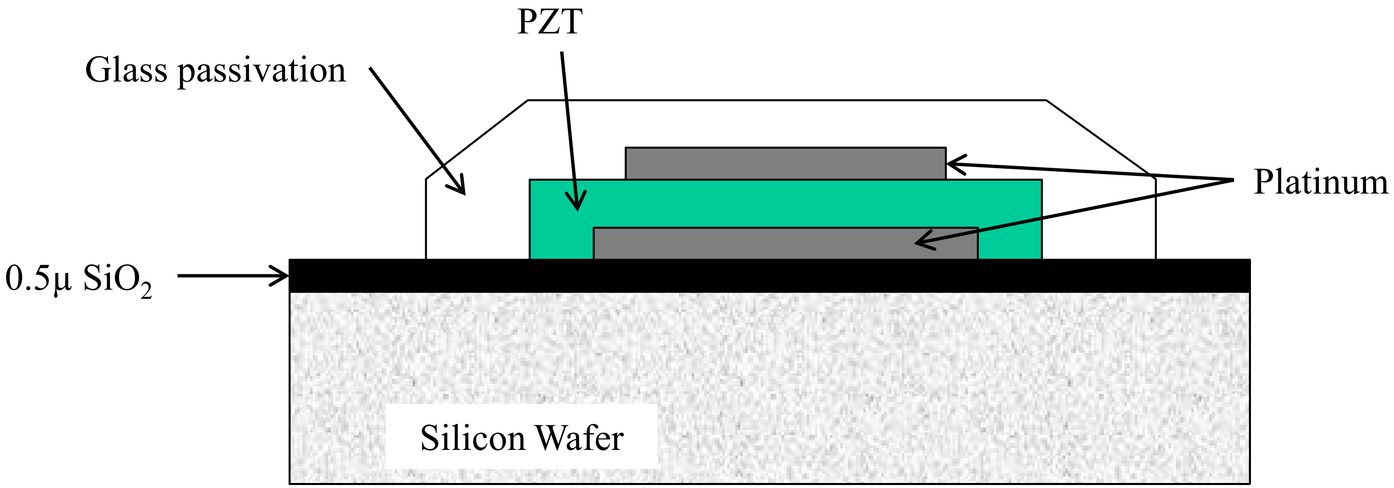
Abstract

Fabricating piezoelectrically-driven micromachines (pMEMs) presents unique problems not faced by the traditional silicon-based MEMs community. When the bottom electrode is deposited globally followed by the piezoelectric or ferroelectric film, the ceramic material is prevented by the bottom electrode from reacting with the substrate surface, leaving a clean surface for deep etching by xenon difluoride or DRIE. The drawback is that this global stack of ceramic material and bottom electrode must be etched aggressively with RIE or ion-milling to remove the unnecessary materials and expose the substrate surface. A less expensive patterning approach uses lift-off for the noble metal bottom electrode but this leaves the majority of the substrate surface exposed to the piezoelectric or ferroelectric ceramic material during high temperature annealing steps. Difficulty arises in removing the ceramic film from the surface trench areas and the scribe lanes for those devices that will self-disarticulate.

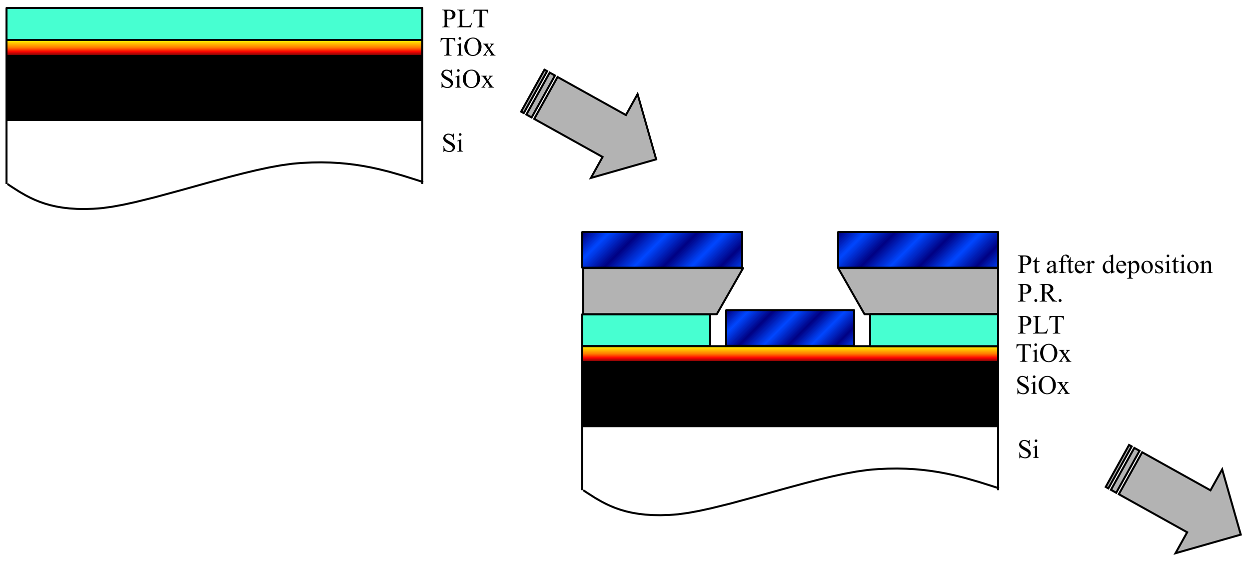
Radiant uses a unique barrier layer in the field to mediate this issue. The barrier layer is deposited prior to the bottom electrode metal. Wells are etched in the barrier layer into which the bottom electrode is deposited. The barrier prevents the formation of unetchable layers under the piezoelectric or ferroelectric material where trenches or scribe lanes are to be placed. The entire stack of substrate oxide, barrier layer, and ceramic may be cleanly removed prior to surface DRIE steps.

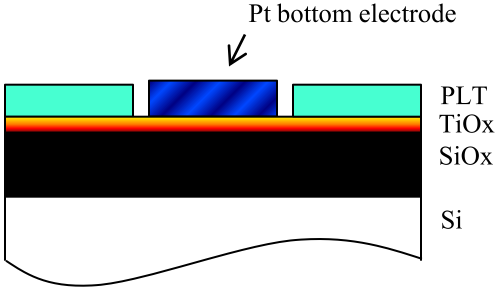
Integrated PZT Capacitor Structure



- The thin PZT film capacitors have platinum electrodes, top glass passivation, and chrome/gold metal interconnect (not shown).
- The platinum is patterned by lift-off photolithography.
- PZT is wet etched.

BE Lift-off Process



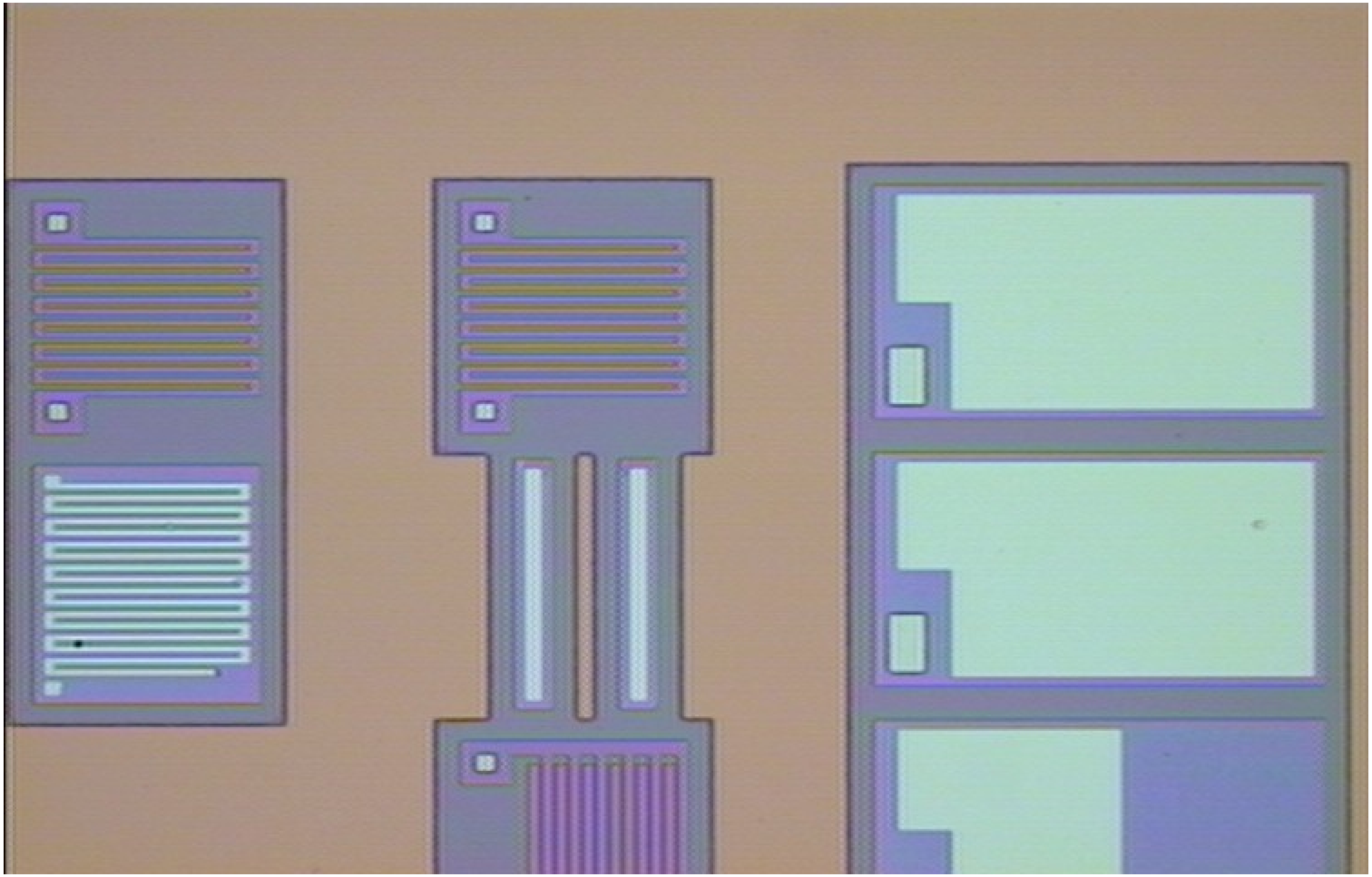


Process:

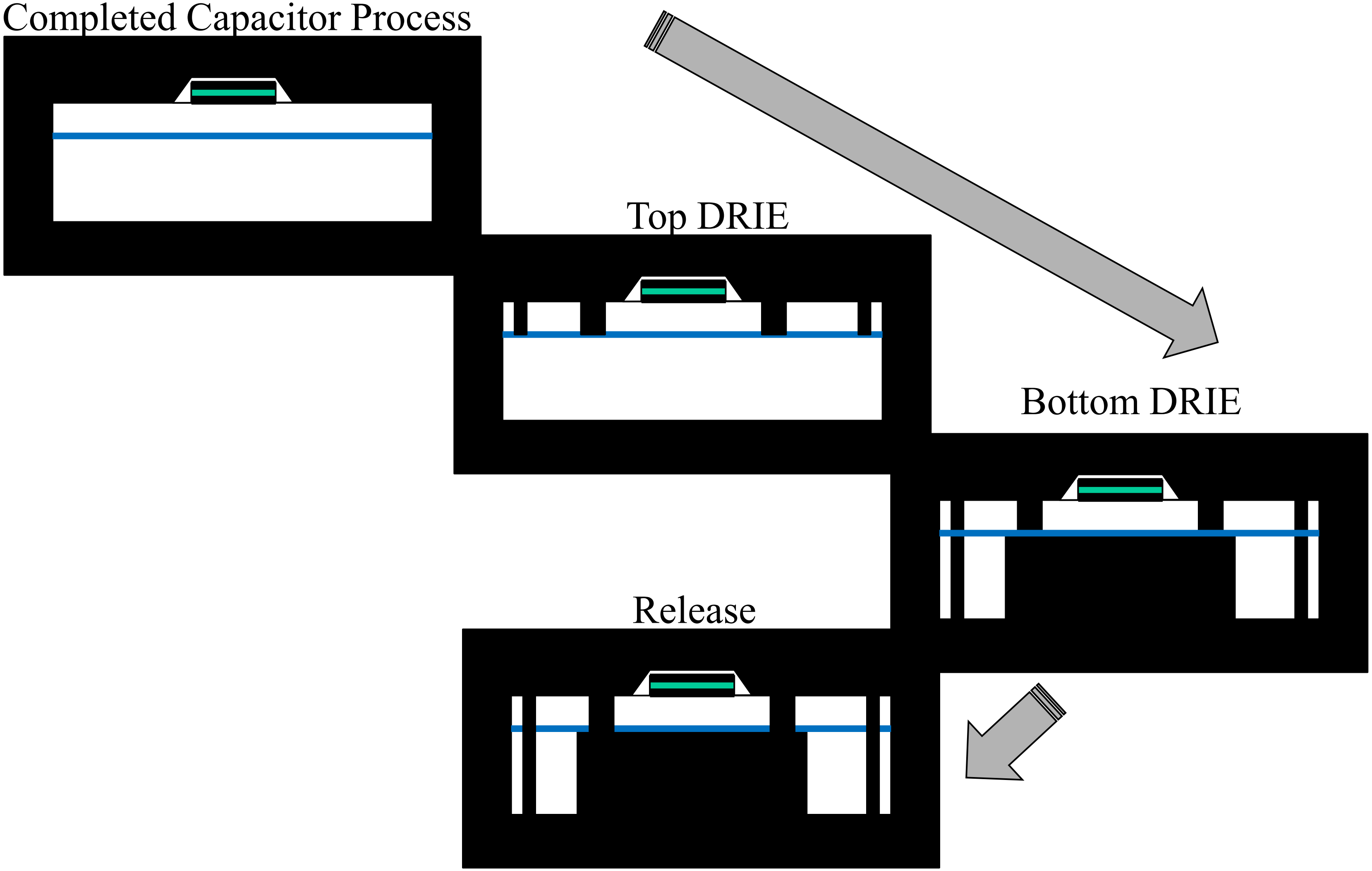
1. Coat SiO_2 with TiO_2.
2. Coat TiO_2 with Lead Lanthanate Titanate (PLT).
3. Coat photoresist and pattern for BE lift-off.
4. Etch PLT.
5. Deposit platinum and lift-off.

BE Patterns

(under PZT with TE)



pMEMs Fabrication



Completed Capacitor Process

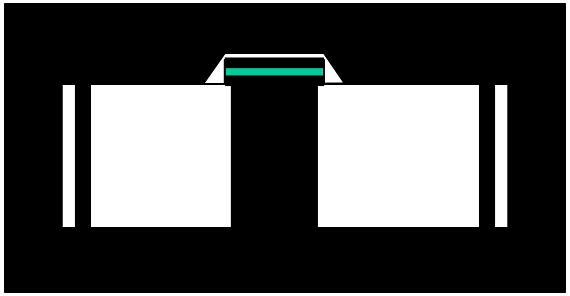
Top DRIE

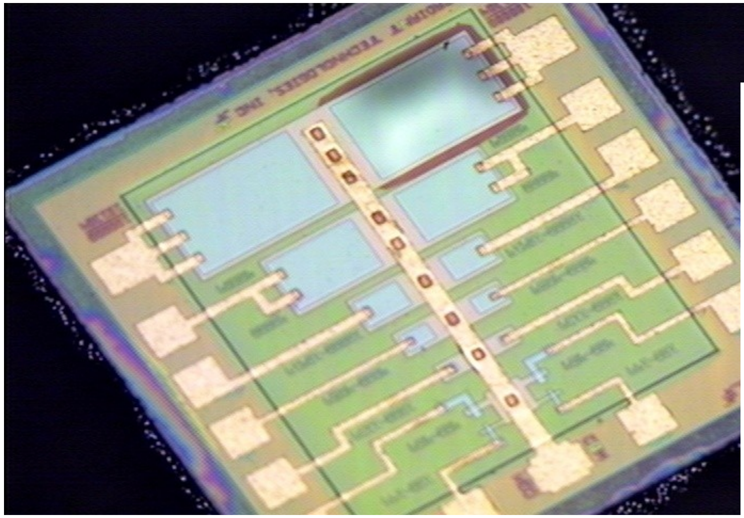
Bottom DRIE

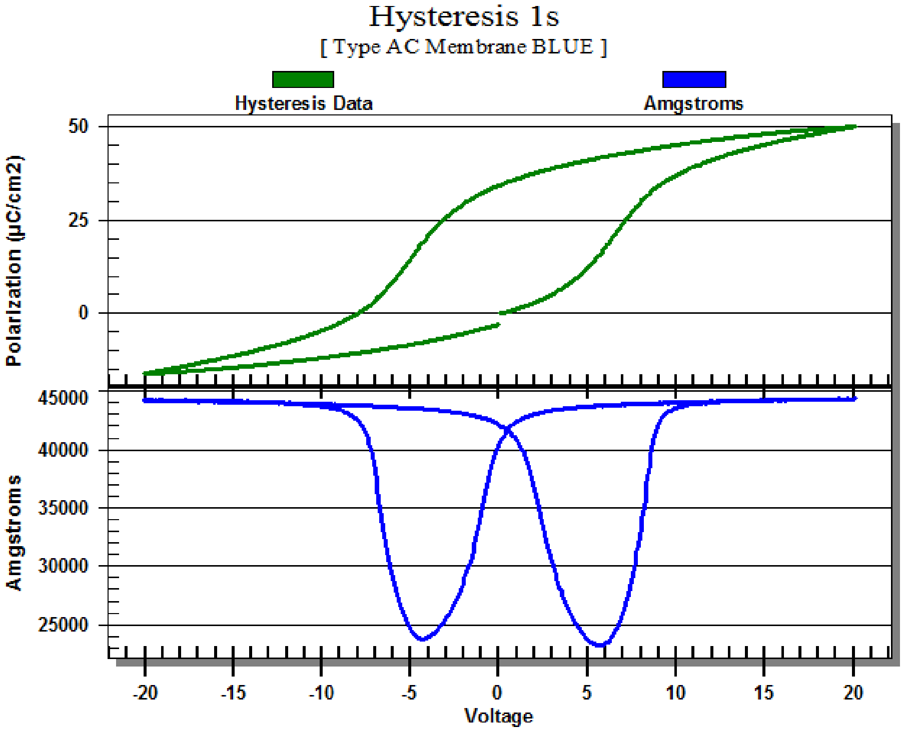
Release

Piezoelectric Membrane

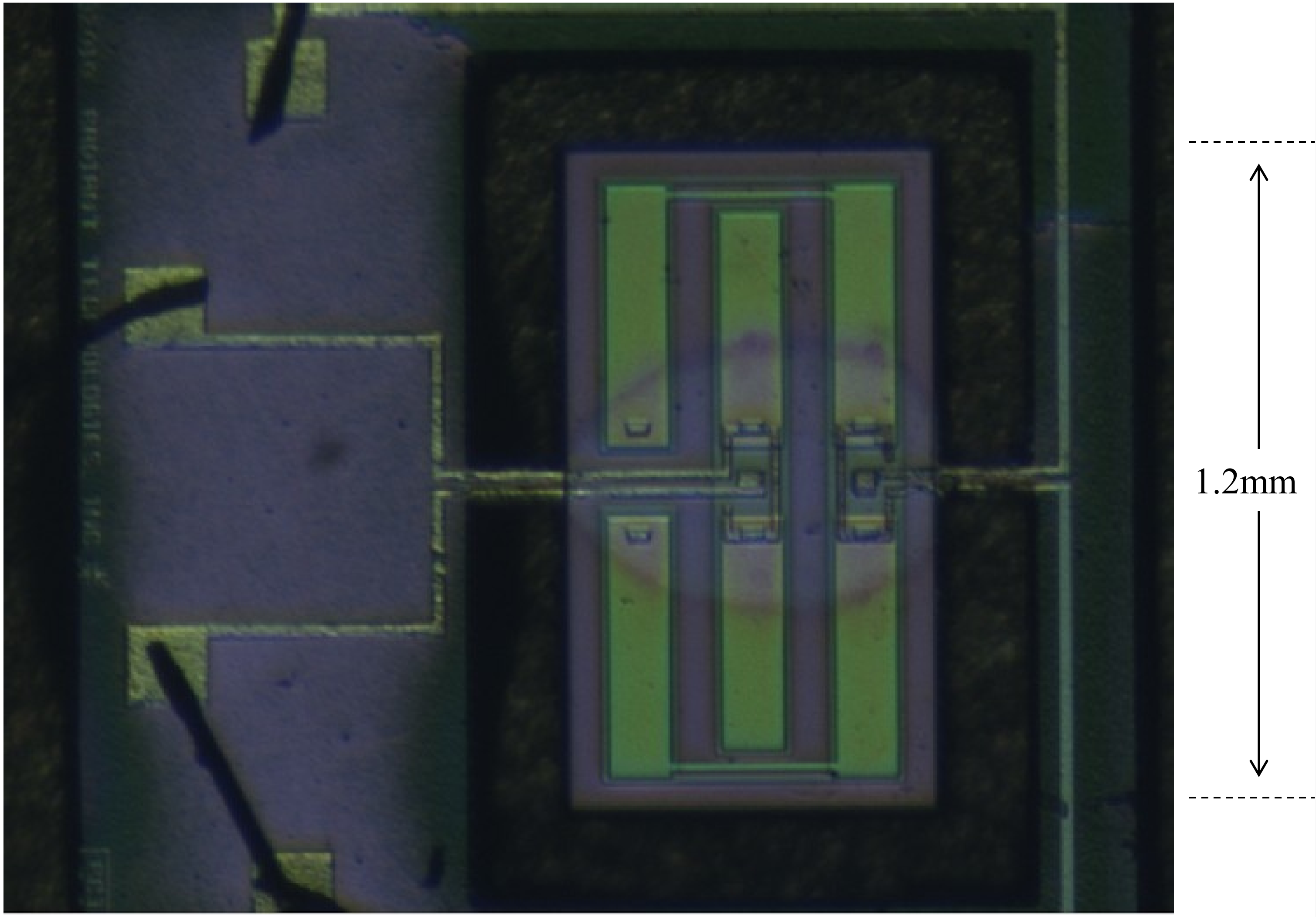
2μ-thick PNZT/Pt/Glass membrane.



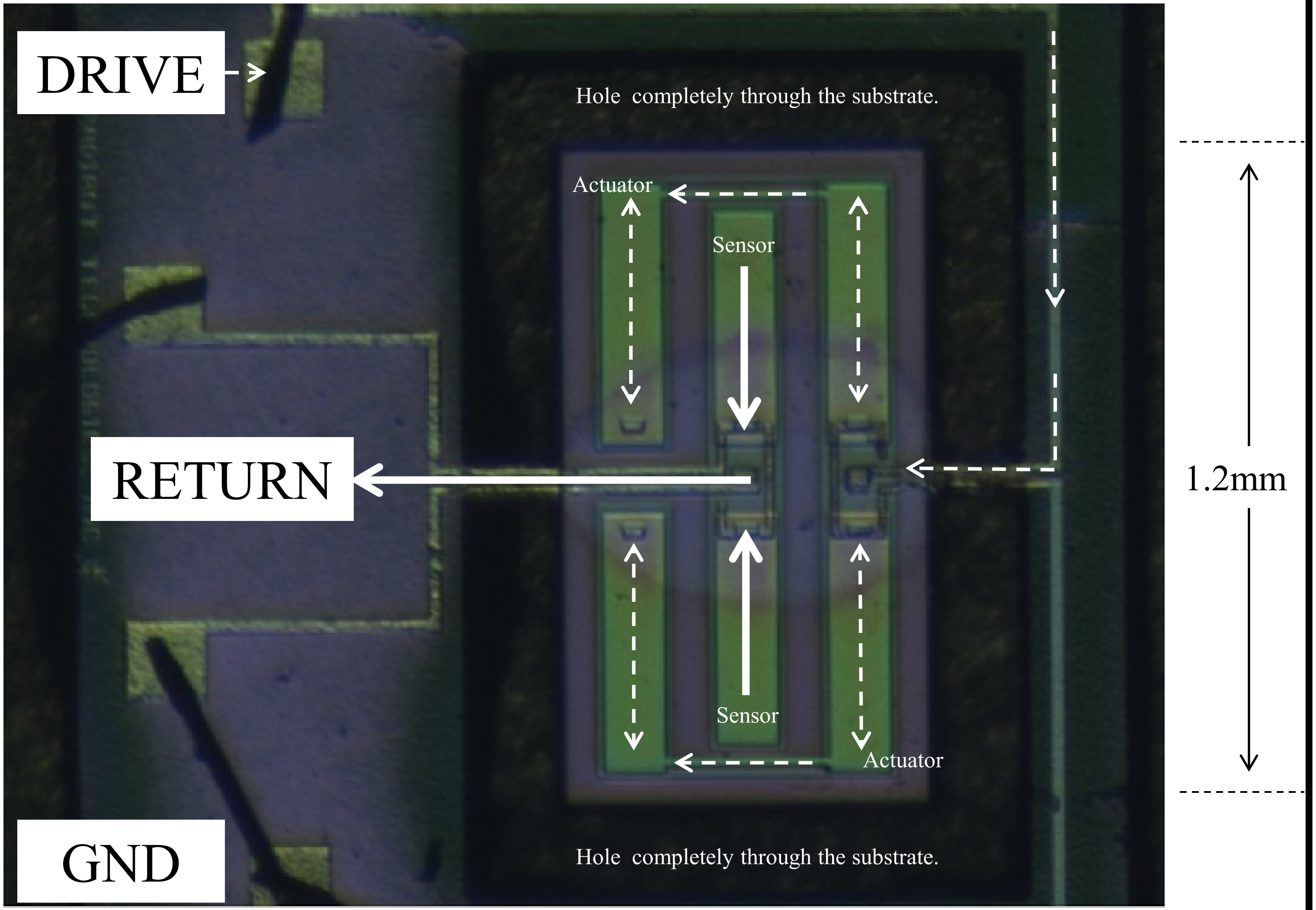




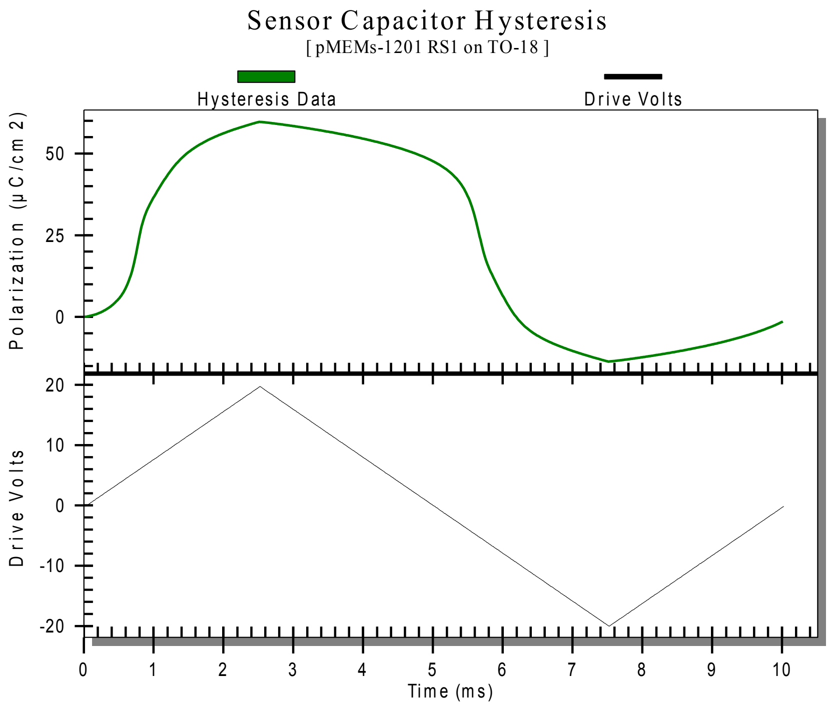
Mechanically Coupled Capacitors



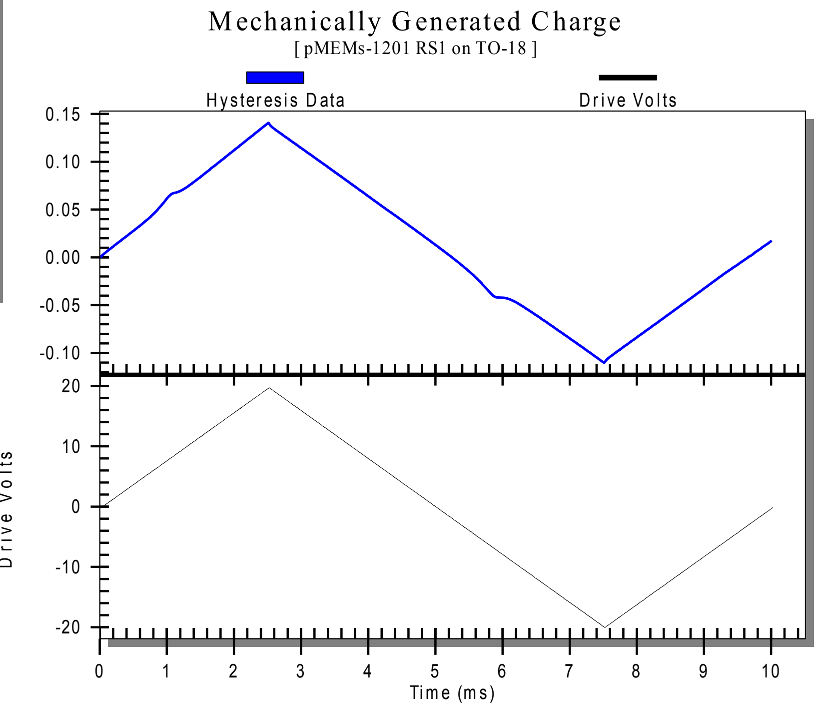
Mechanically Coupled Capacitors



Mechanically Coupled Capacitors

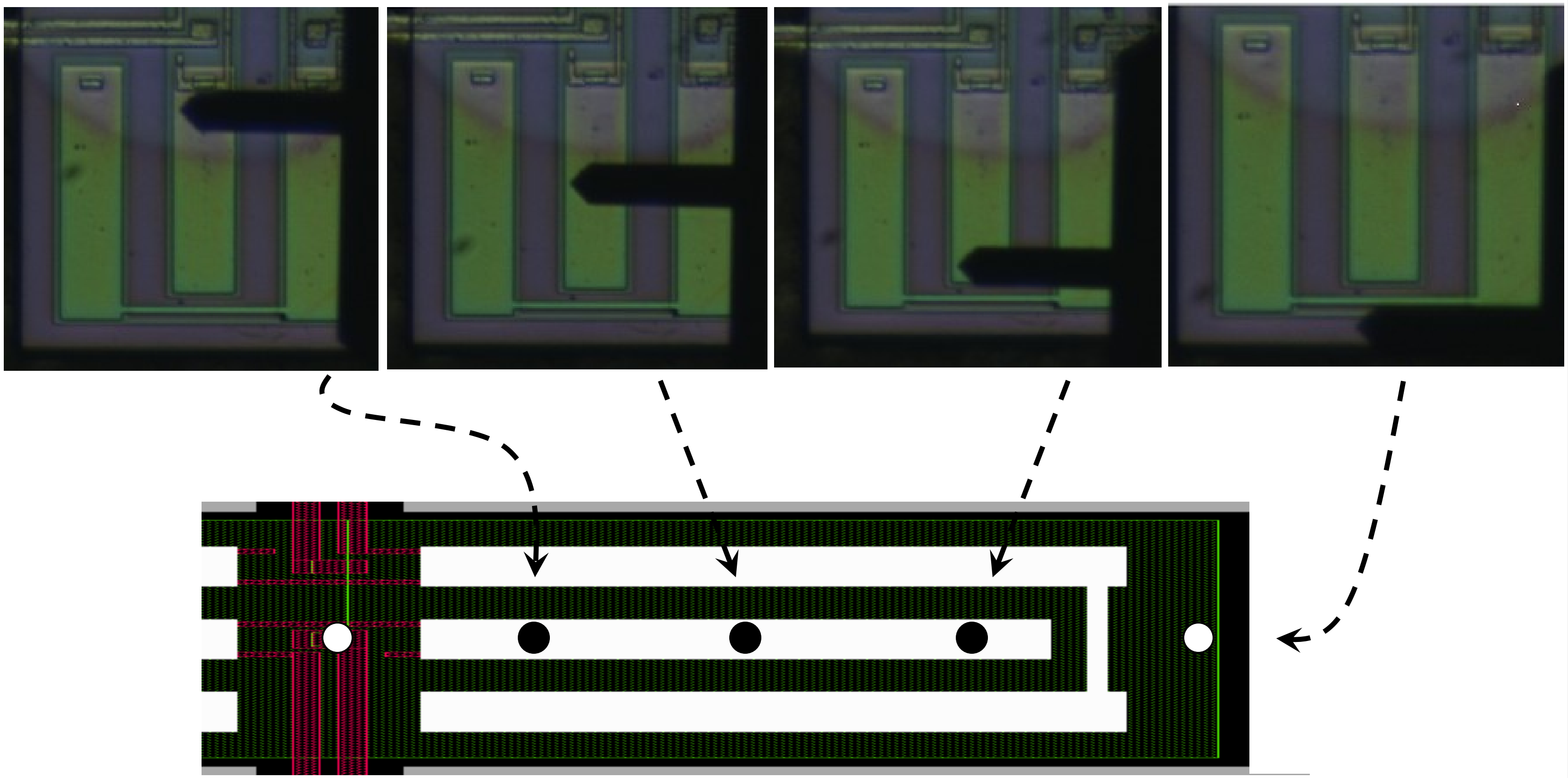


Mechanically generated charge arises by executing a hysteresis loop on the actuator capacitors while measuring the charge produced by the sensor capacitors with zero volts across them.



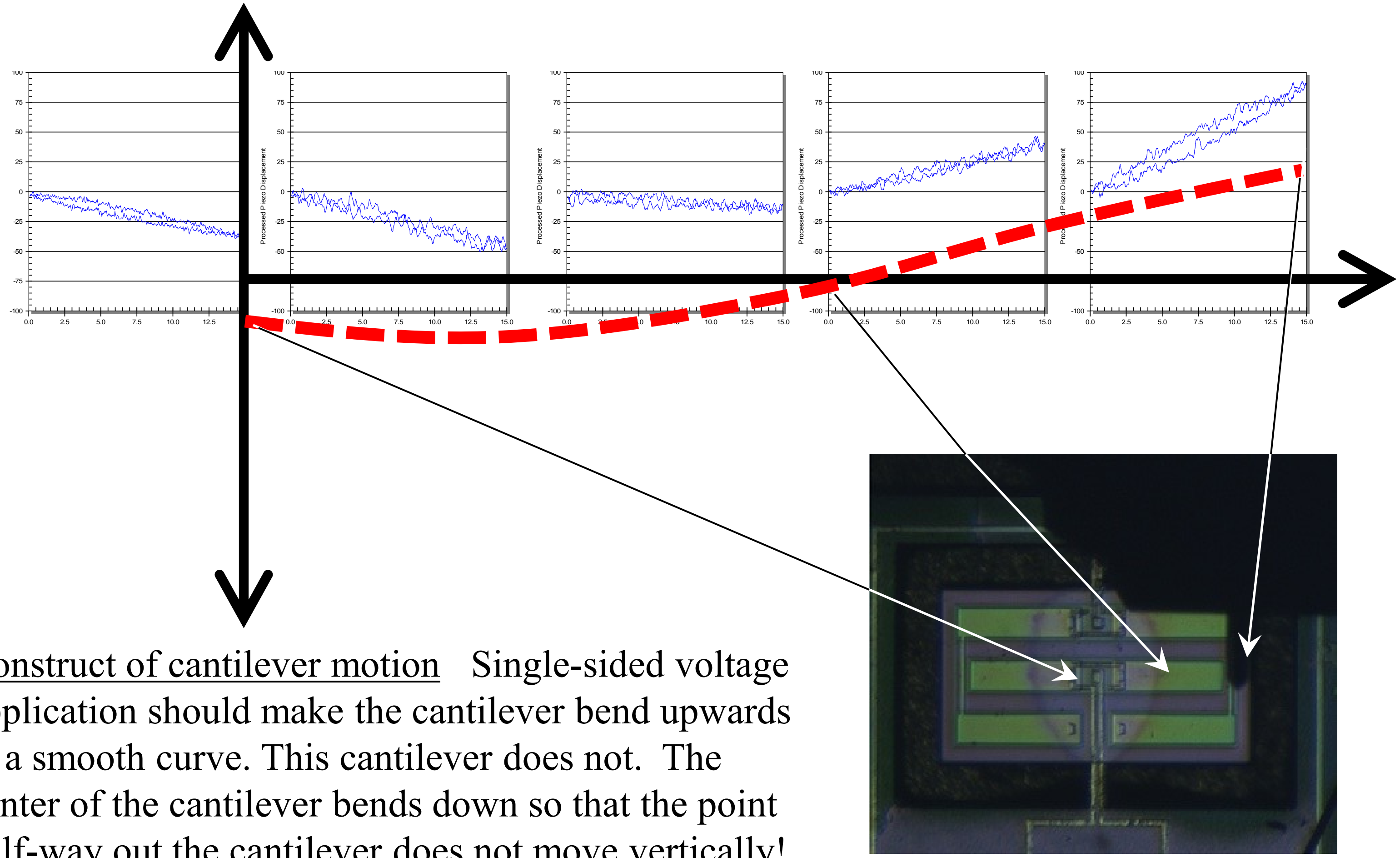
~1:400 coupling coefficient

Complex Cantilever Motion



By measuring at different parts of the resonator as it is flexed in pseudo-static piezoelectric motion, complex behavior is revealed.

Complex Cantilever Motion



<u>Construct of cantilever motion</u> Single-sided voltage application should make the cantilever bend upwards in a smooth curve. This cantilever does not. The center of the cantilever bends down so that the point half-way out the cantilever does not move vertically!