

A Piezoelectric MEMs Process with Thin Ferroelectric Film PZT

Joe T. Evans, Jr, Carl E. Montross, Gerald Salazar

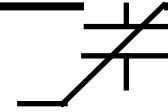
Radiant Technologies, Inc.

Johannes G. Smits

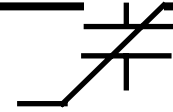
Scaldix

ISAF-ECAPD '10

Introduction



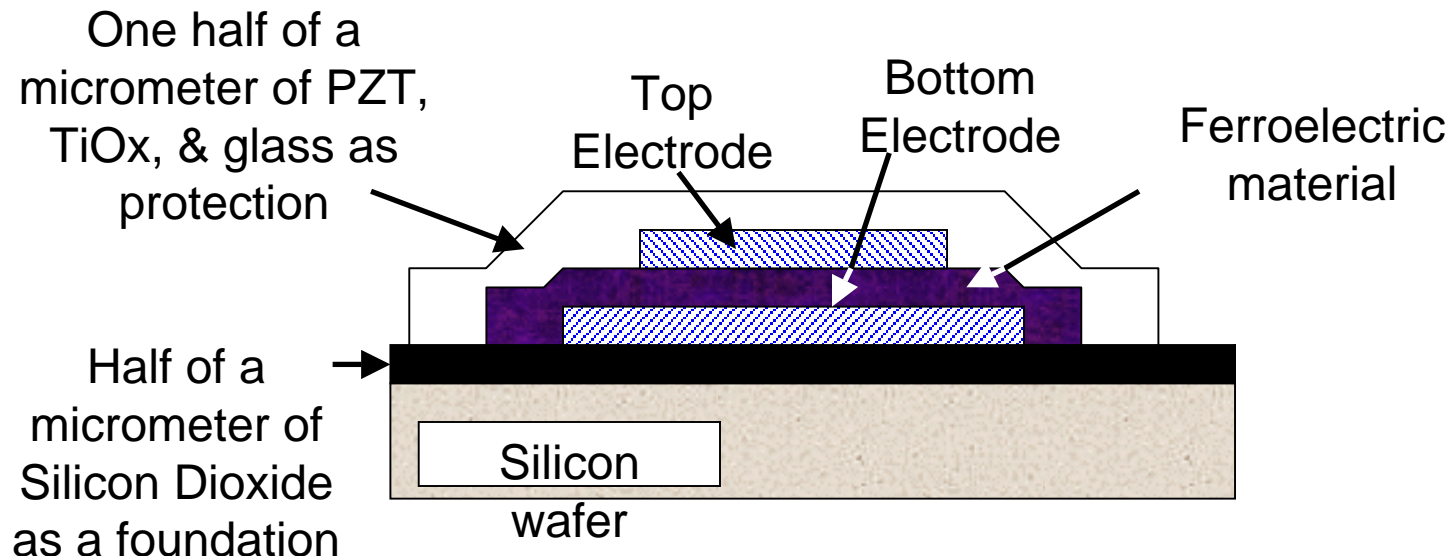
- Radiant has a long term effort to develop a repeatable piezoelectric MEMs process.
- Focus: The aim of the development is to create the infrastructure to support pMEMs processing. Optimization of piezoelectric materials will follow.
- Status: We are awaiting the DRIE etching steps to create the cantilever structures.
- Radiant will offer this process as a foundry service once the process is perfected.



Schedule

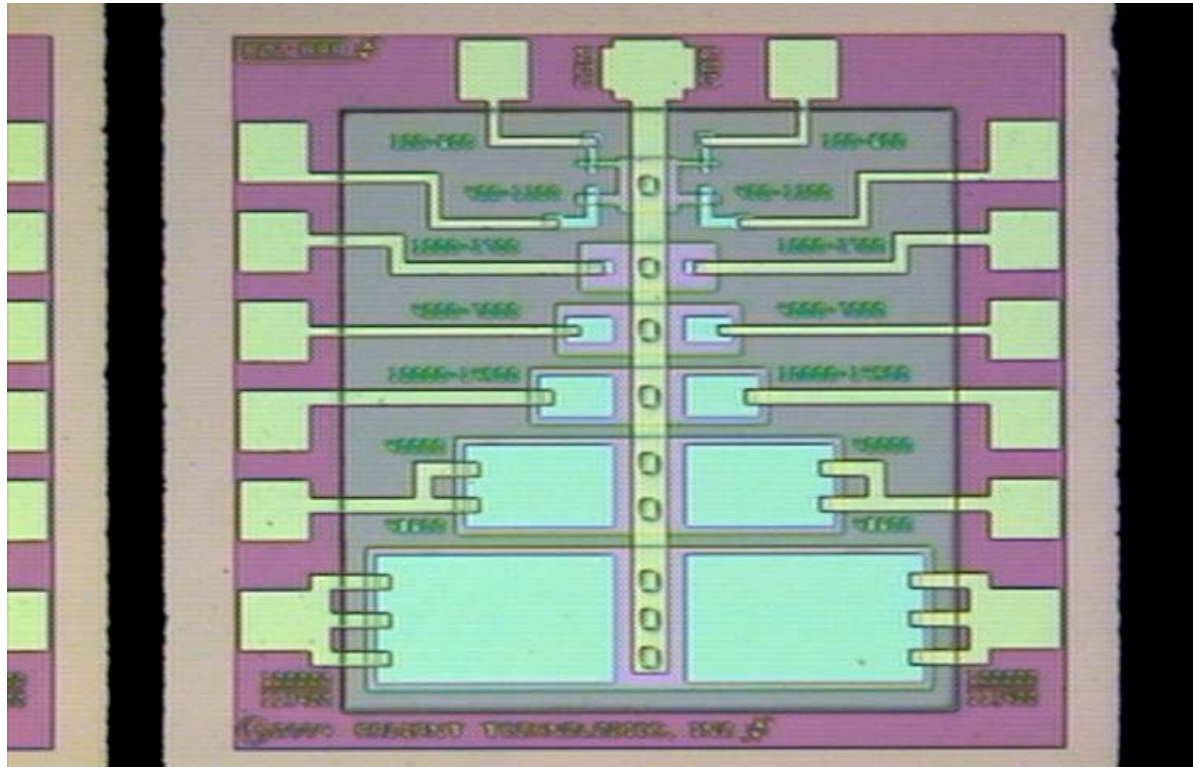
- The Foundation Process
- PZT Film Characteristics
- Additional Steps
- Example Device
- Device List
- Status
- Summary

Foundation Process



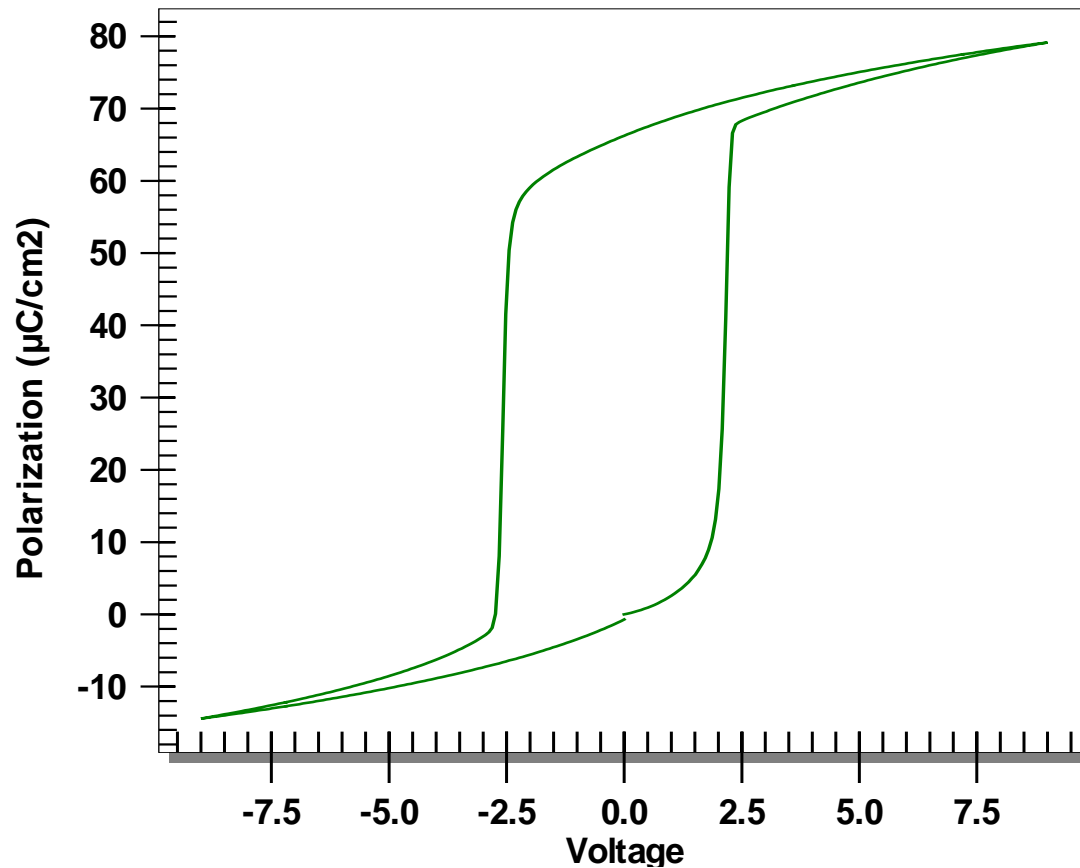
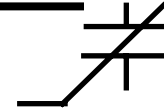
- Radiant has an established process for thin PZT film capacitors with platinum electrodes, top glass passivation, and chrome/gold metal interconnect (not shown).

Integrated PZT Capacitors



A Type AB PZT capacitor die before packaging. The process supports 0.26μ 20/80 PZT or 1.0μ 4/20/80 PNZT.

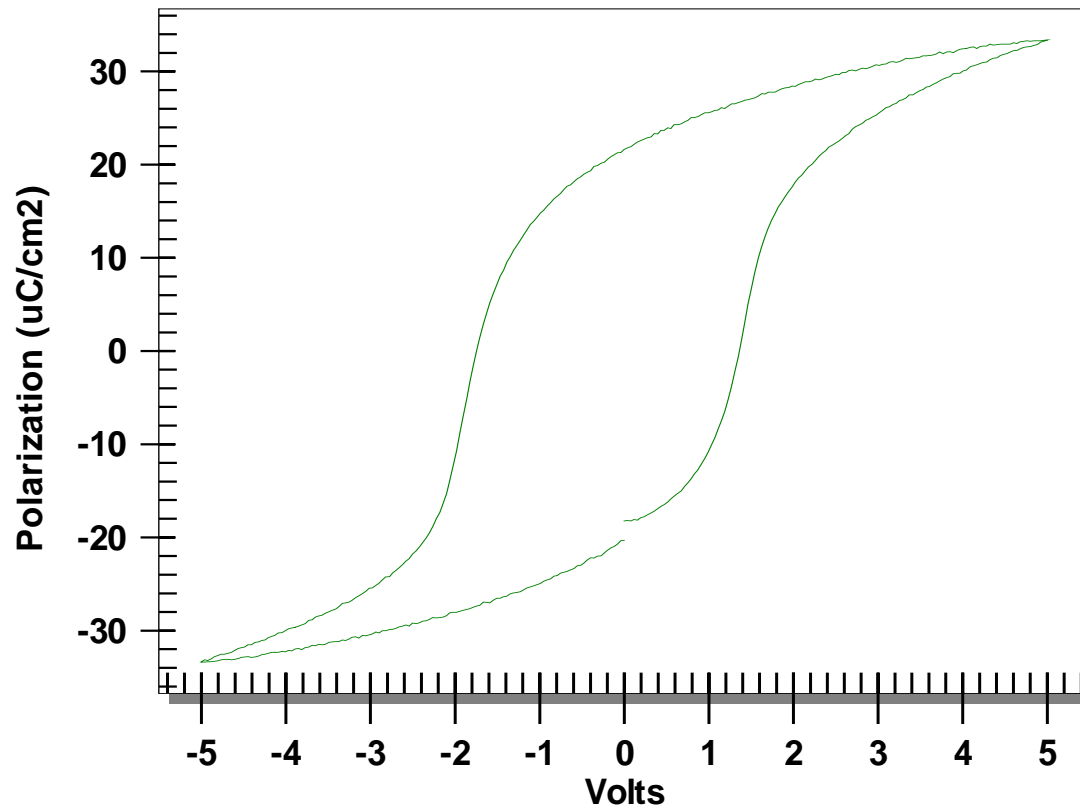
20/80 PZT



- Typical hysteresis loop for Radiant 0.26μ 20/80 PZT with platinum electrodes.

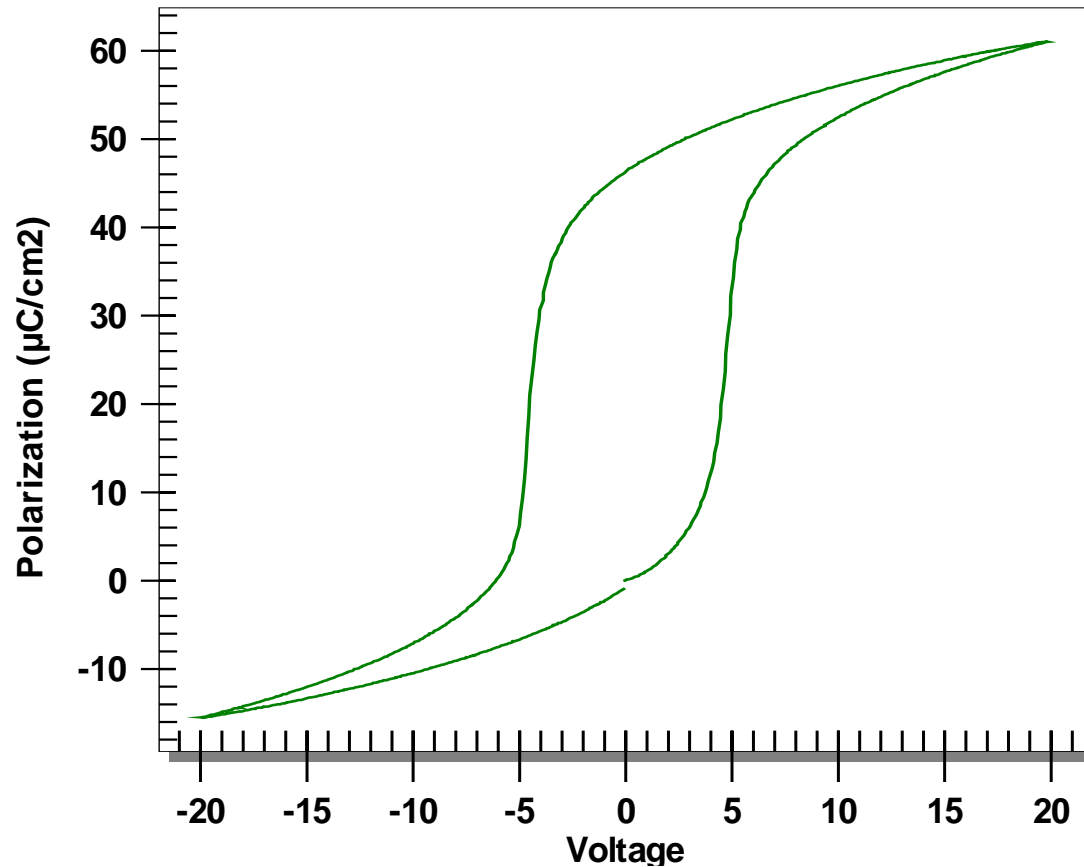
4/20/80 PNZT/LSCO

4/20/80 PNZT with LSCO Electrodes



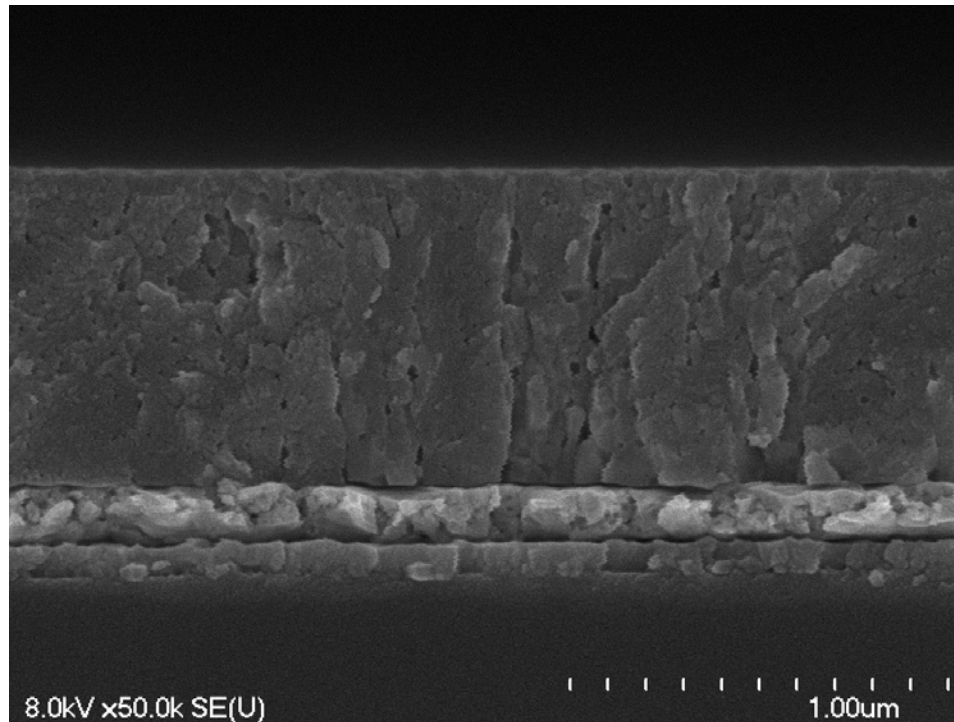
- Typical hysteresis loop for Radiant 0.26 μ 4% niobium doped 20/80 PZT with LSCO electrodes.

4/20/80 PNZT on Pt



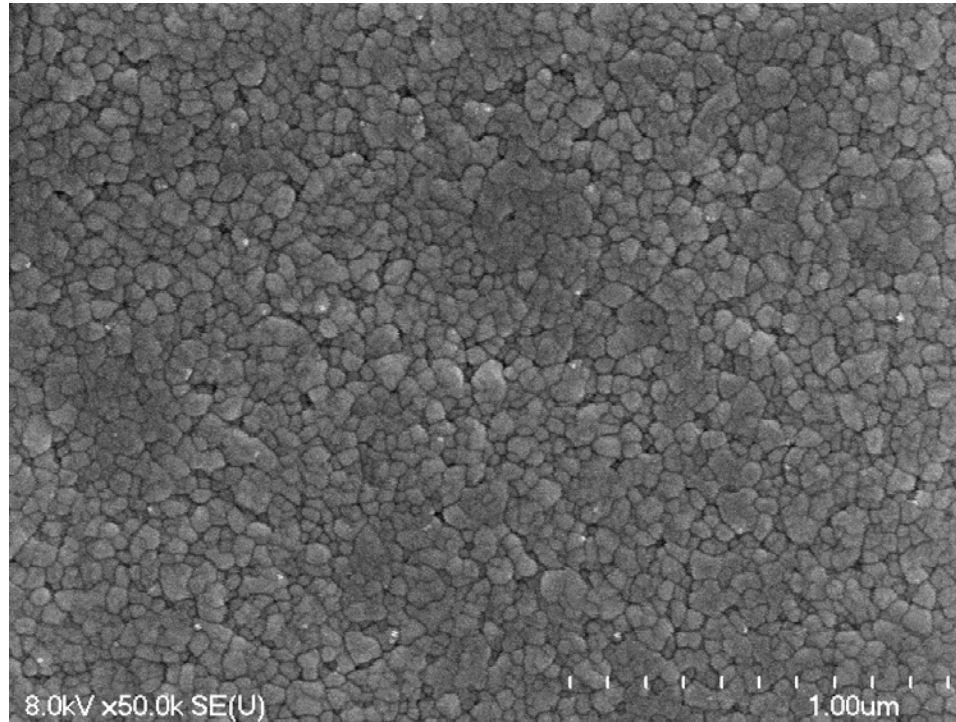
- Typical hysteresis loop for Radiant 1.0μ 4% niobium doped 20/80 PZT with platinum electrodes.

Integrated PZT Capacitors



SEM cross-section of 0.8μ 4/20/80 PNZT on platinum electrodes. Image courtesy of Dr. Jeff Cross of Tokyo Institute of Technology.

Integrated PZT Capacitors



Grains of the 20/80 PZT on platinum electrodes.

Image courtesy of Dr. Jeff Cross of Tokyo Institute of Technology.

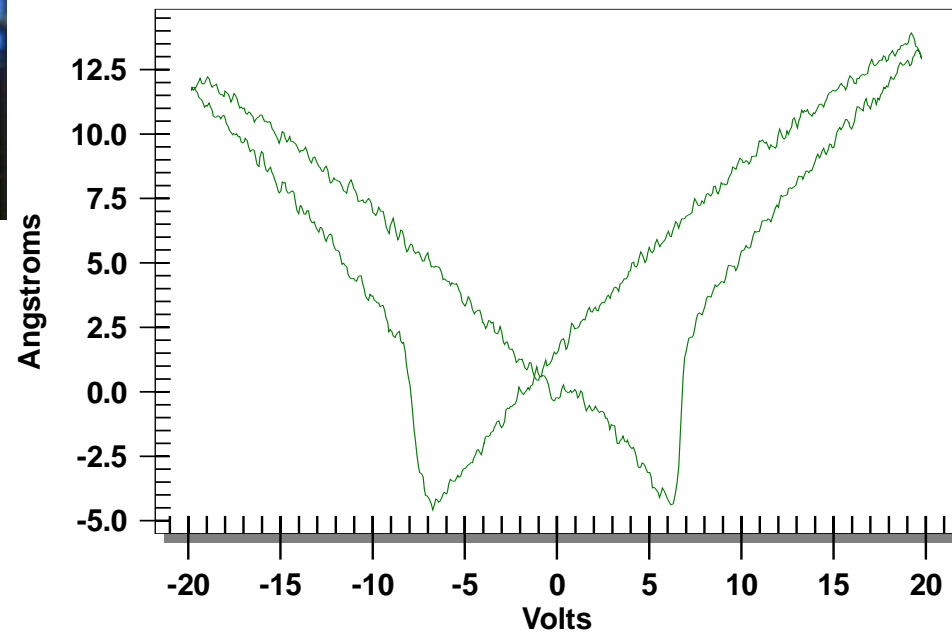
Radiant Technologies, Inc.

1 μ PNZT Displacement



Measured at 2 kHz
with a laser vibrometer.

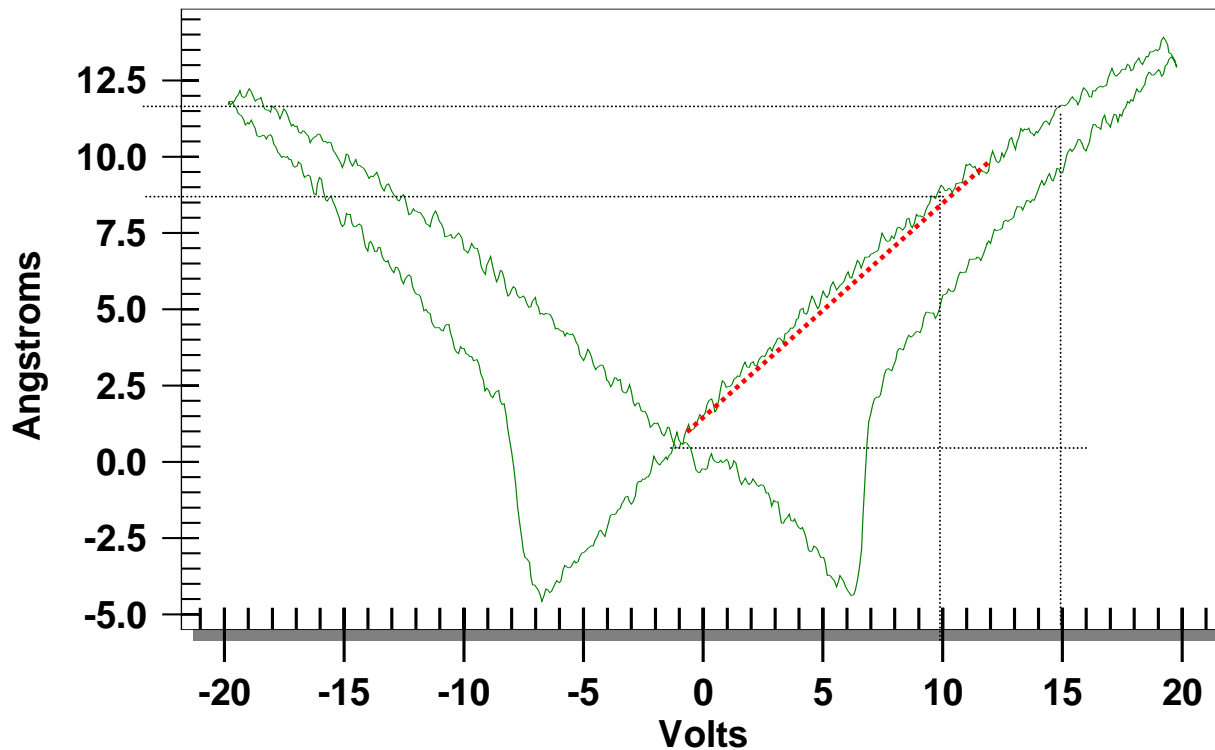
1 μ PNZT Piston
[Type AC WHITE]



Radiant Technologies, Inc.

4/20/80 PNZT d_{33}

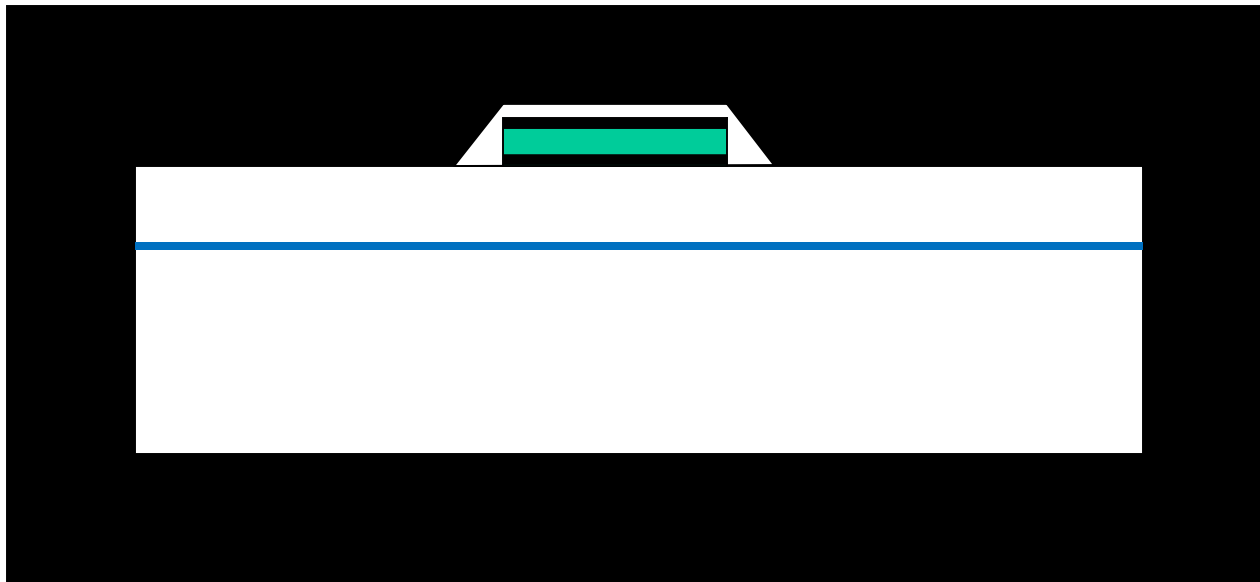
1 μ PNZT Piston
[Type AC WHITE]



- The d_{33} for Radiant's 1 μ 4/20/80 PNZT ranges from approximately 60pm/V to 80pm/V.

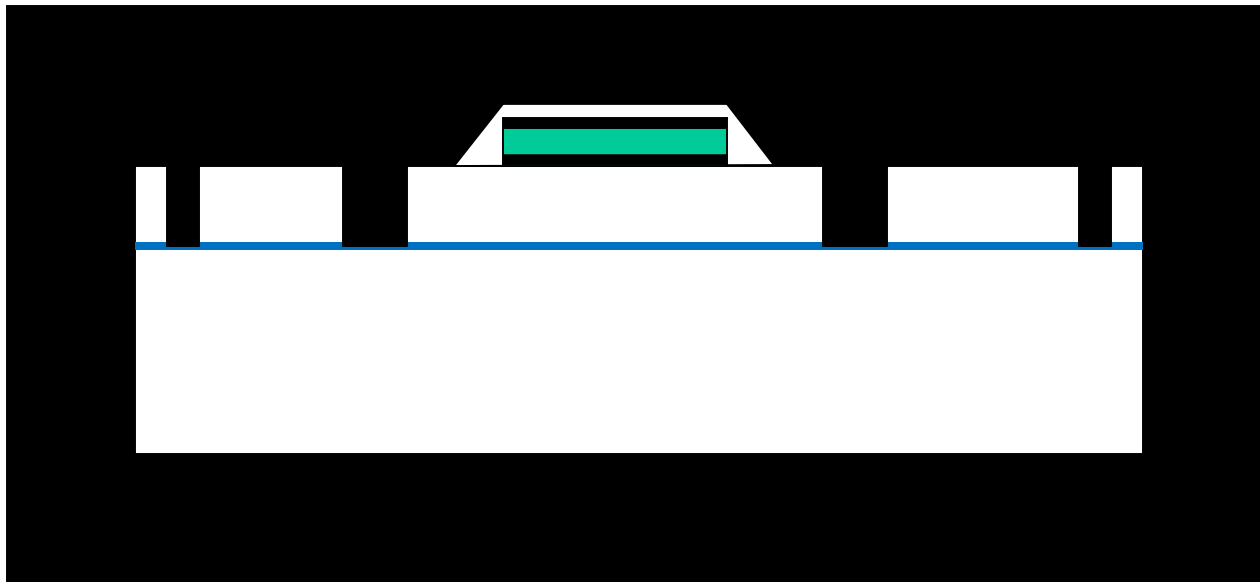
piezoMEMs Steps

- Build a standard capacitor on a Silicon-on-Insulator substrate.



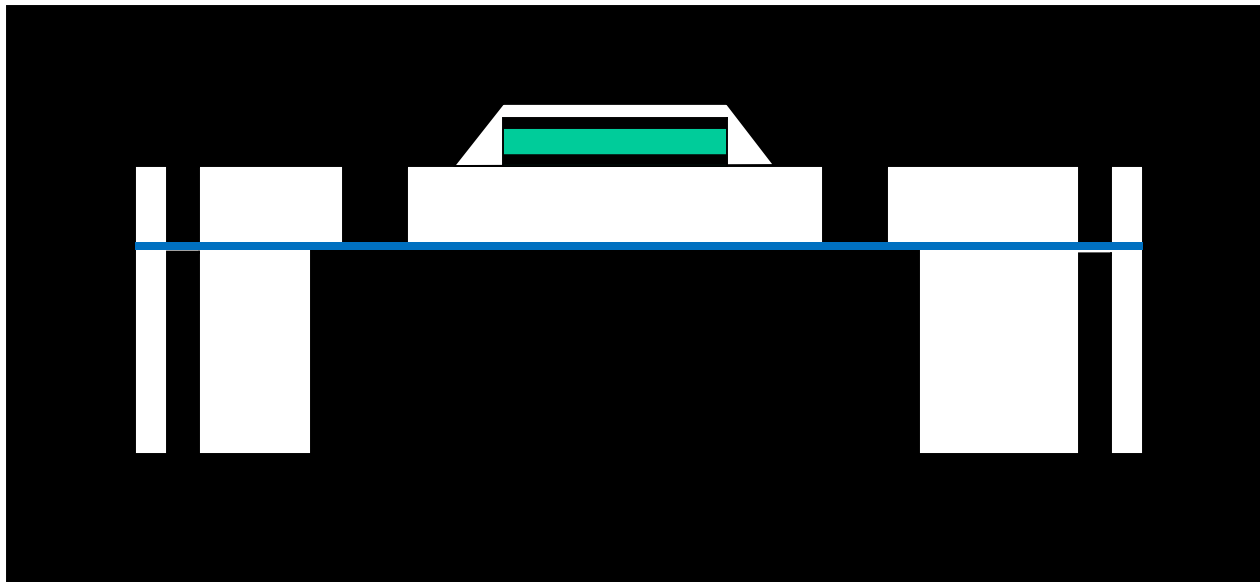
piezoMEMs Step

- Etch the top side of the wafer to the buried silicon dioxide layer.



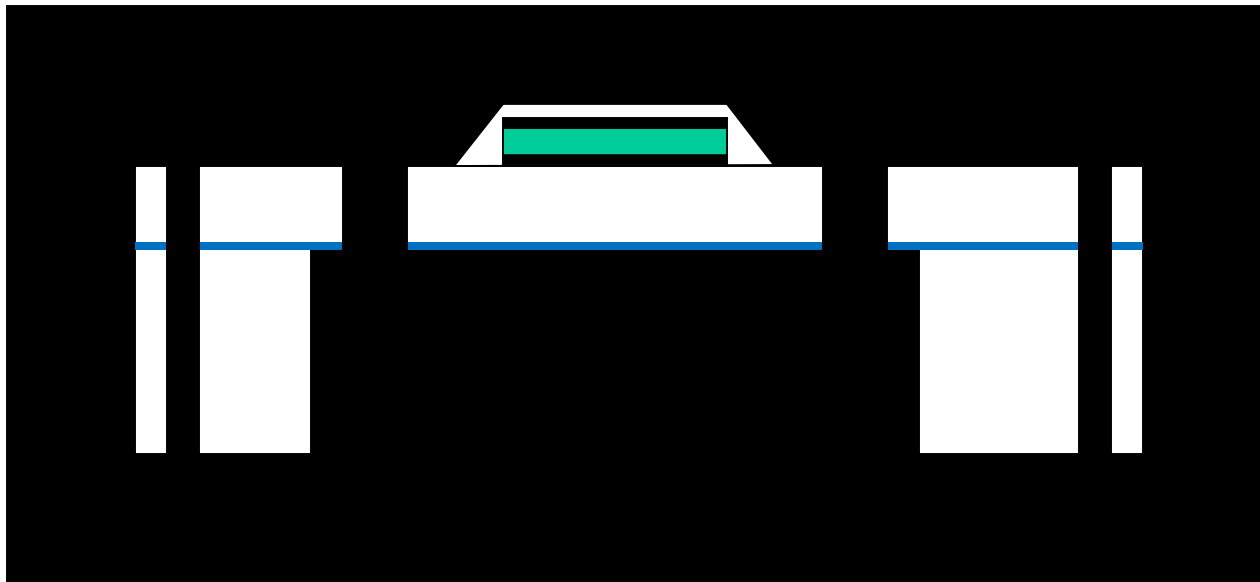
piezoMEMs Step

- Etch the back side of the wafer to the buried silicon dioxide layer.

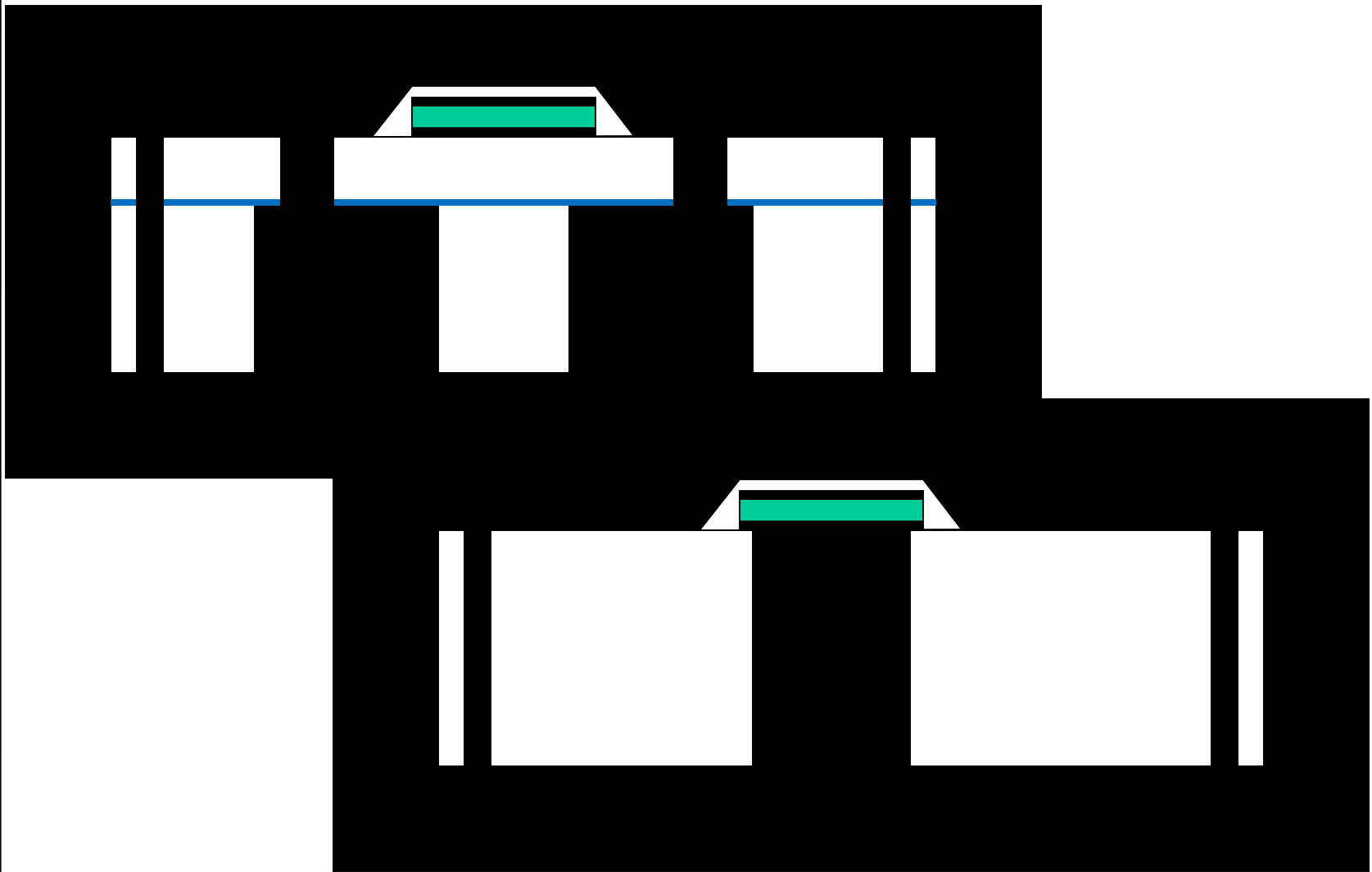


piezoMEMs Step

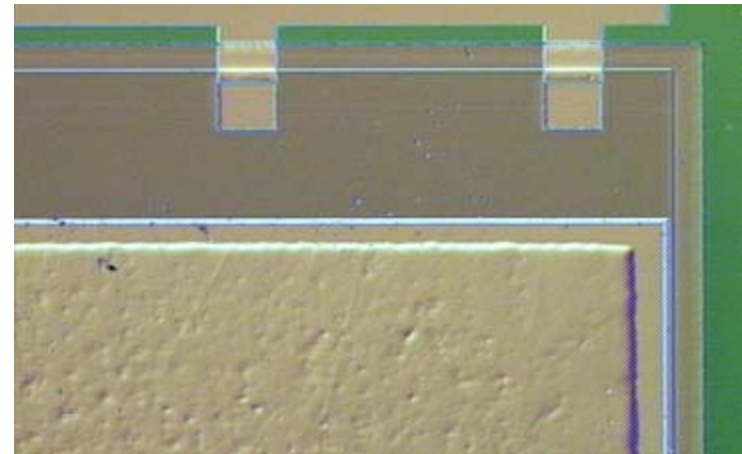
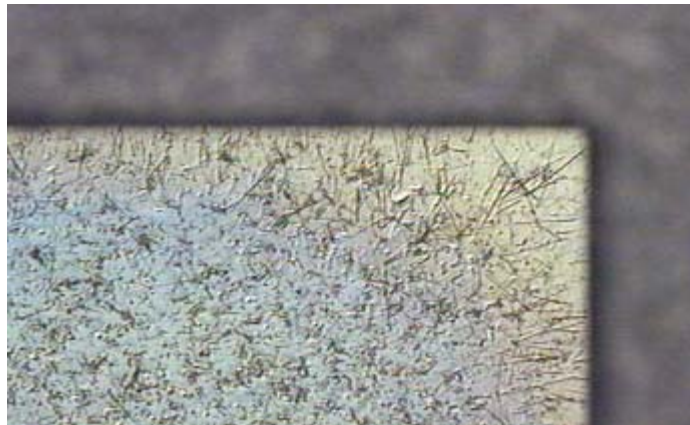
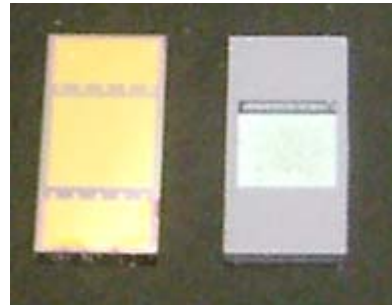
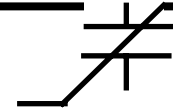
- Etch out the buried silicon dioxide. Note the self-dicing lanes.

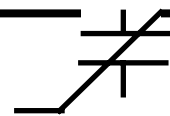


Alternative Structures

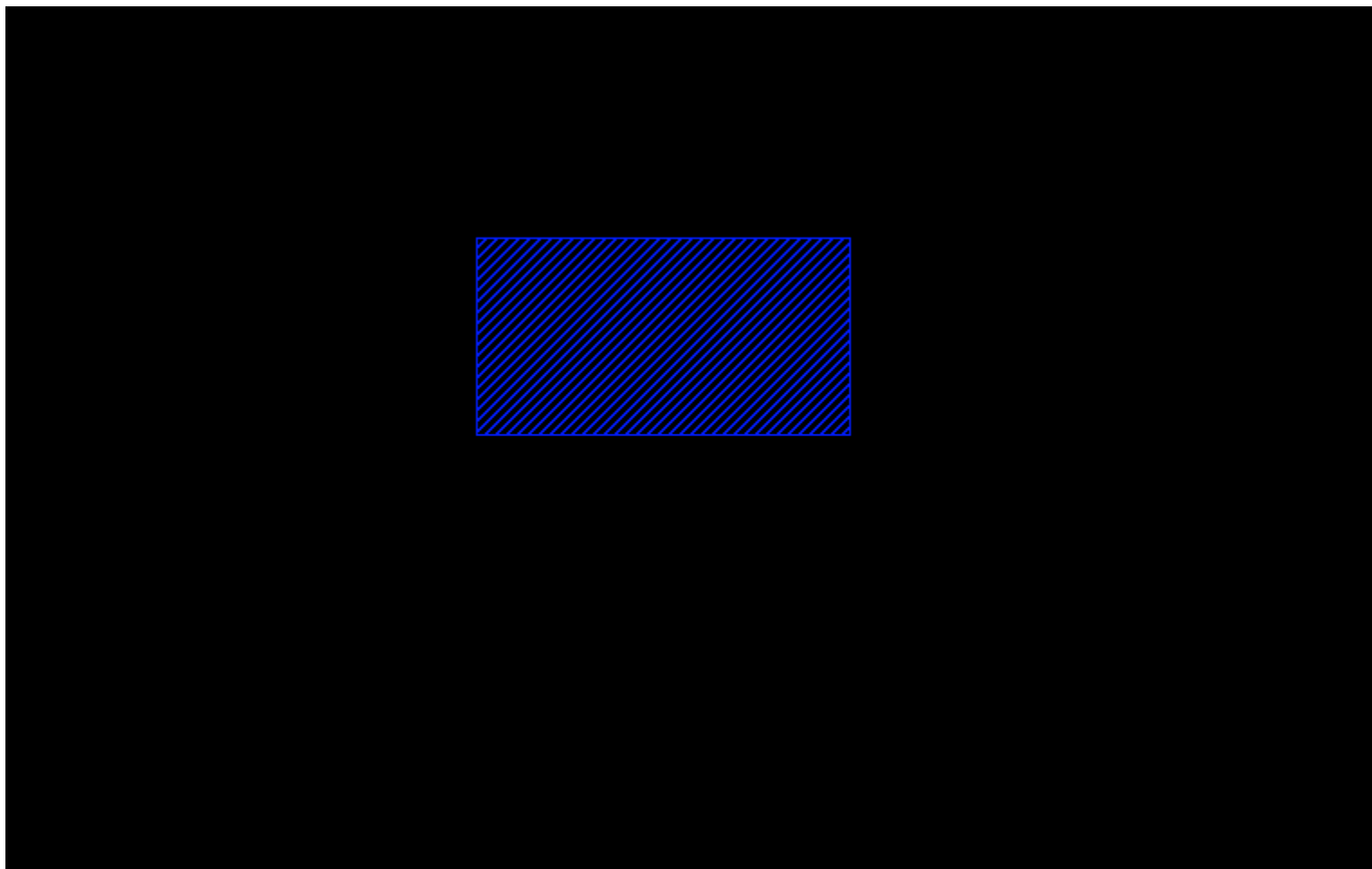


2 μ PNZT Membrane

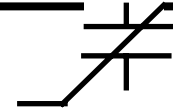




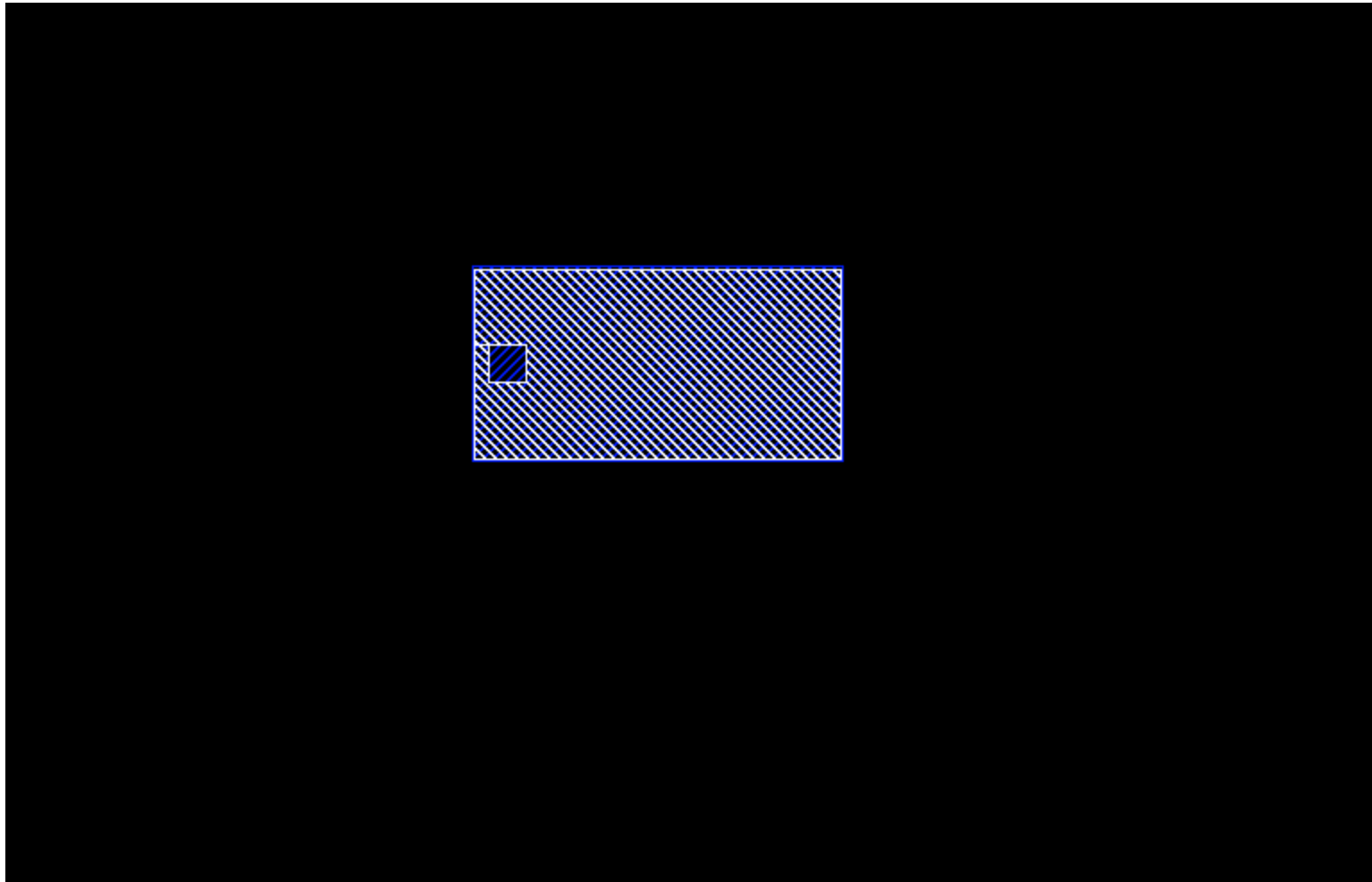
Step by Step



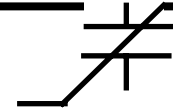
- Bottom electrode.



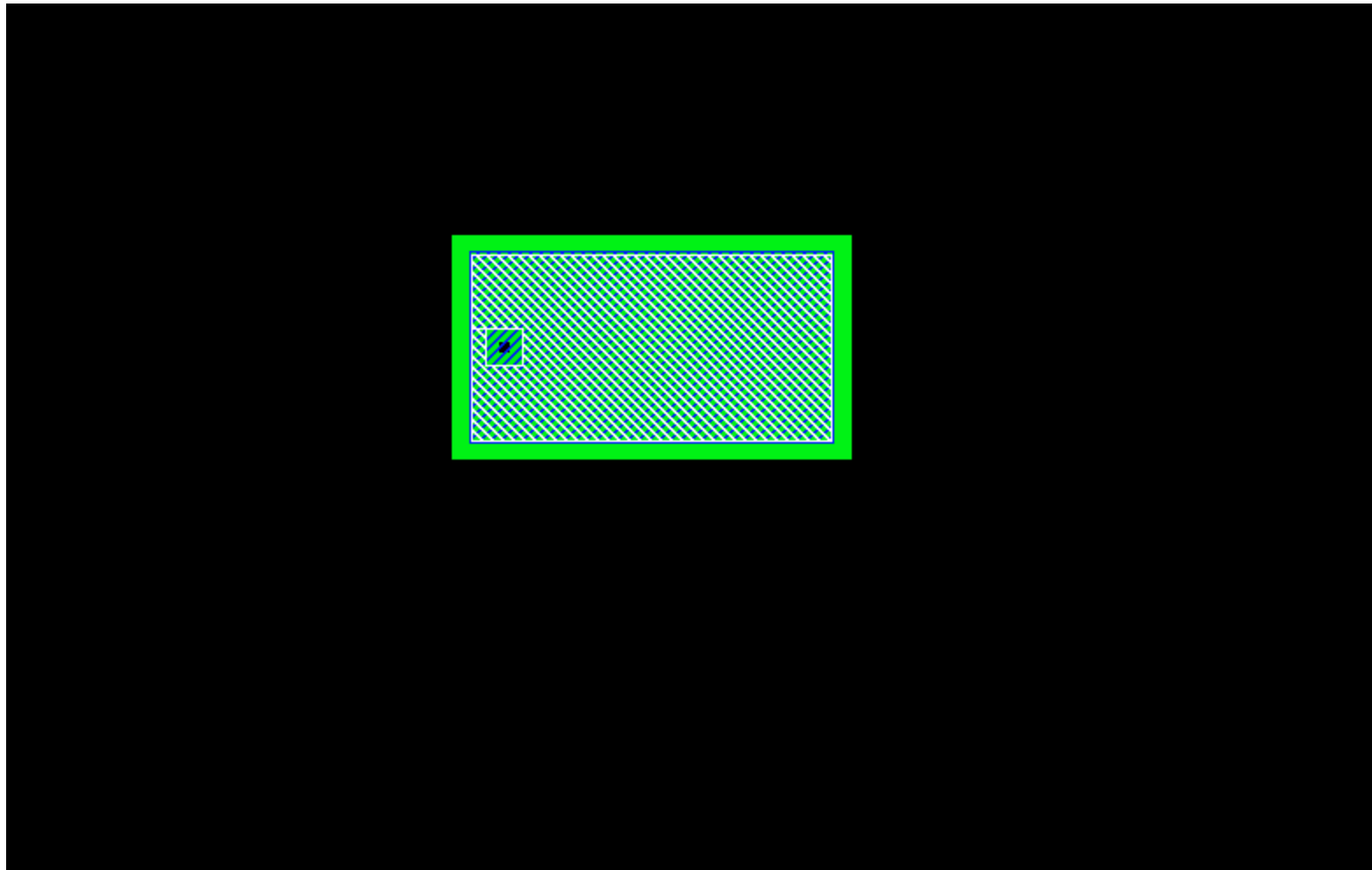
Step by Step



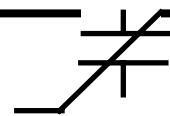
Top electrode. The PNZT is already deposited globally.



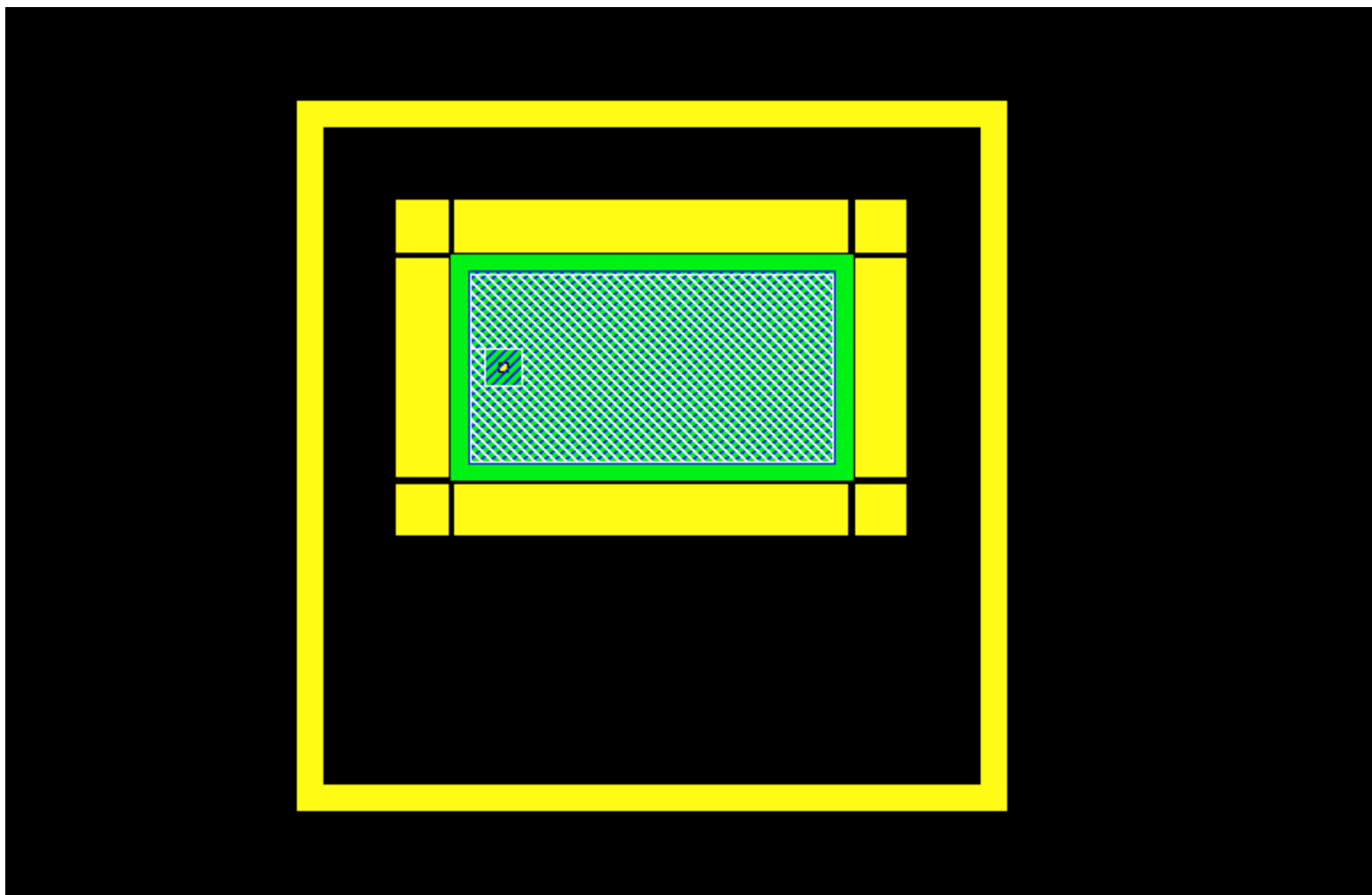
Step by Step



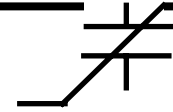
- Ferroelectric patterning.



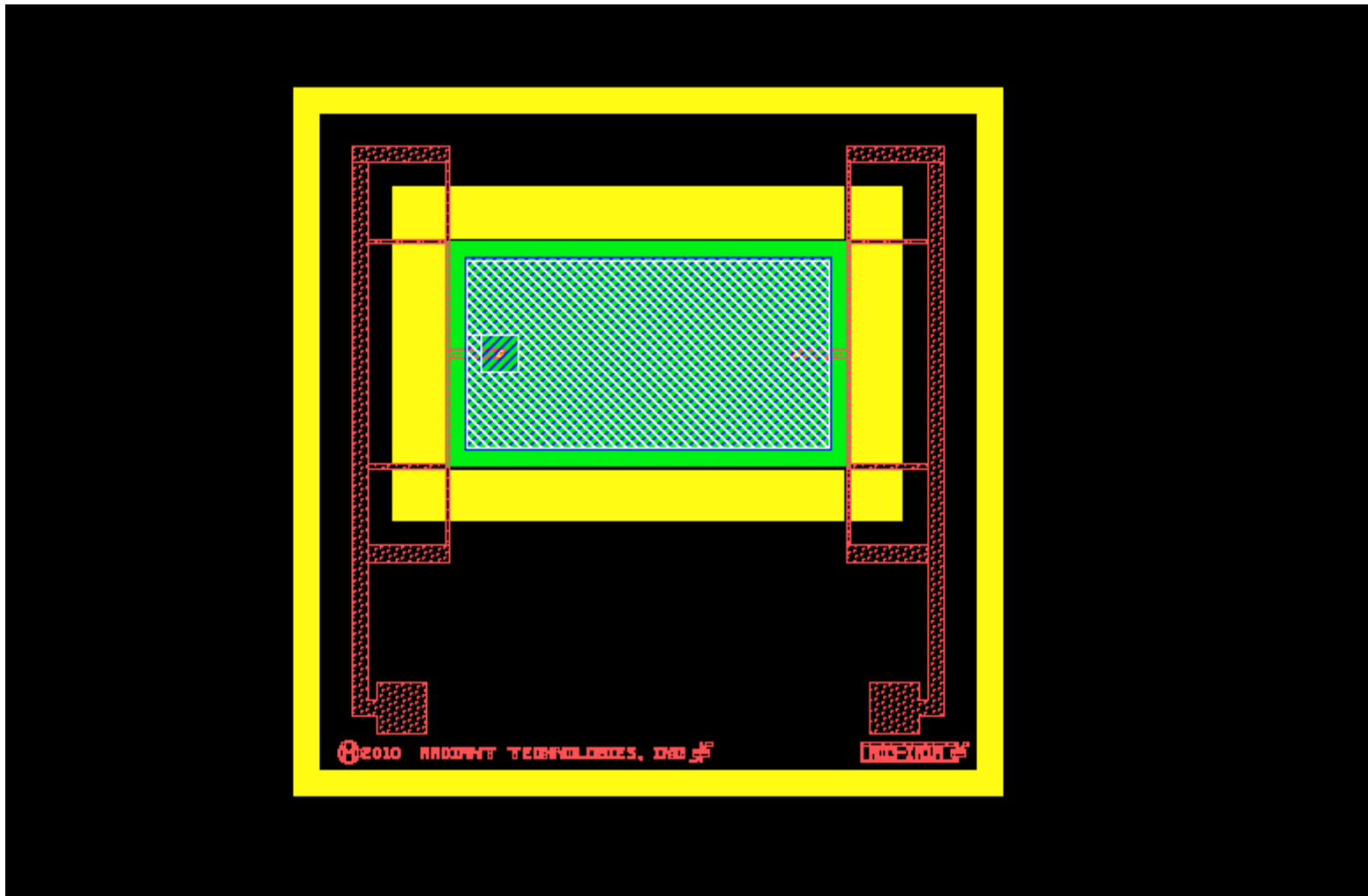
Step by Step



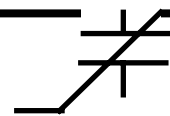
- Vias.



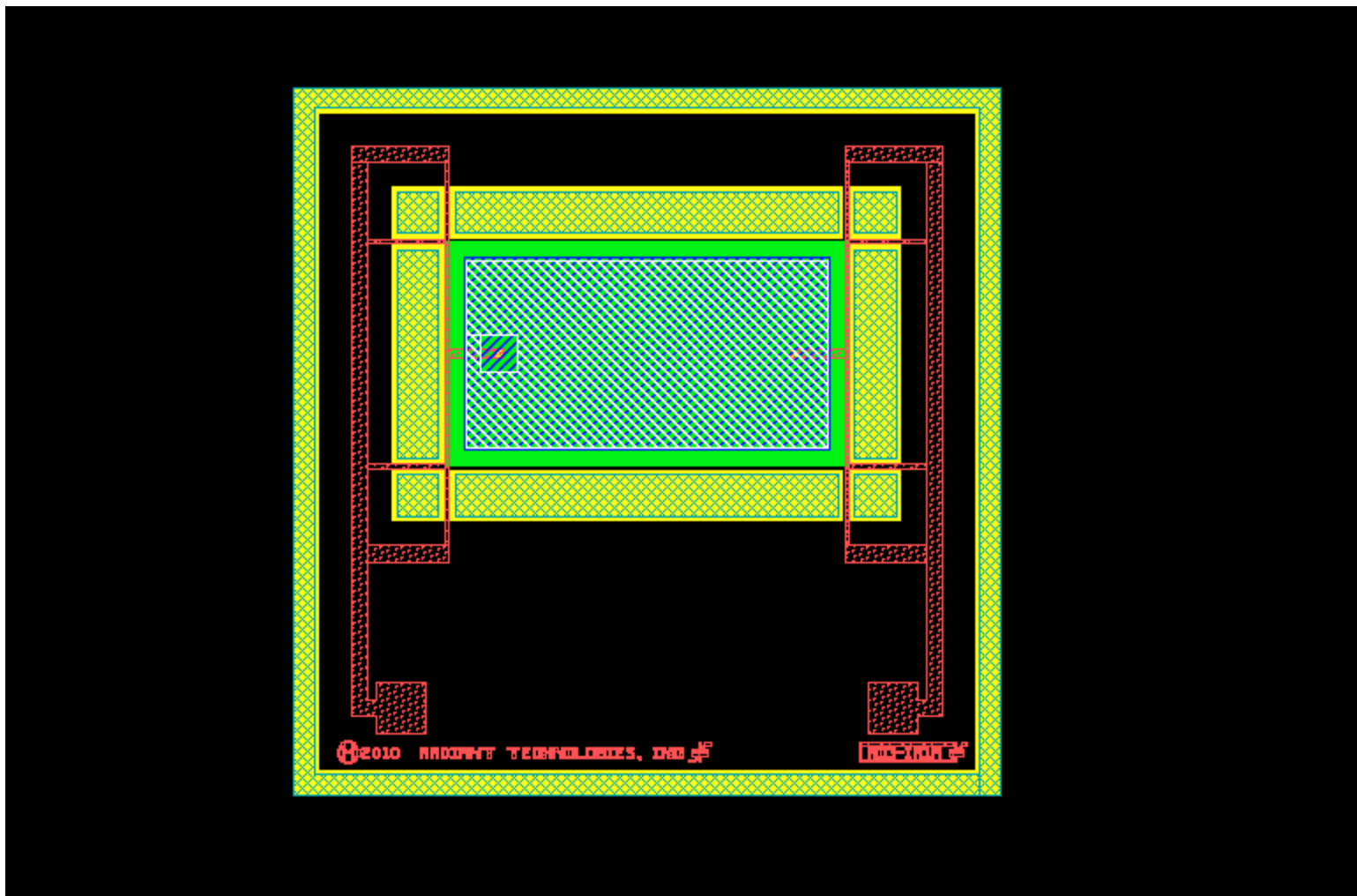
Step by Step



- Metal interconnect in chrome/gold.

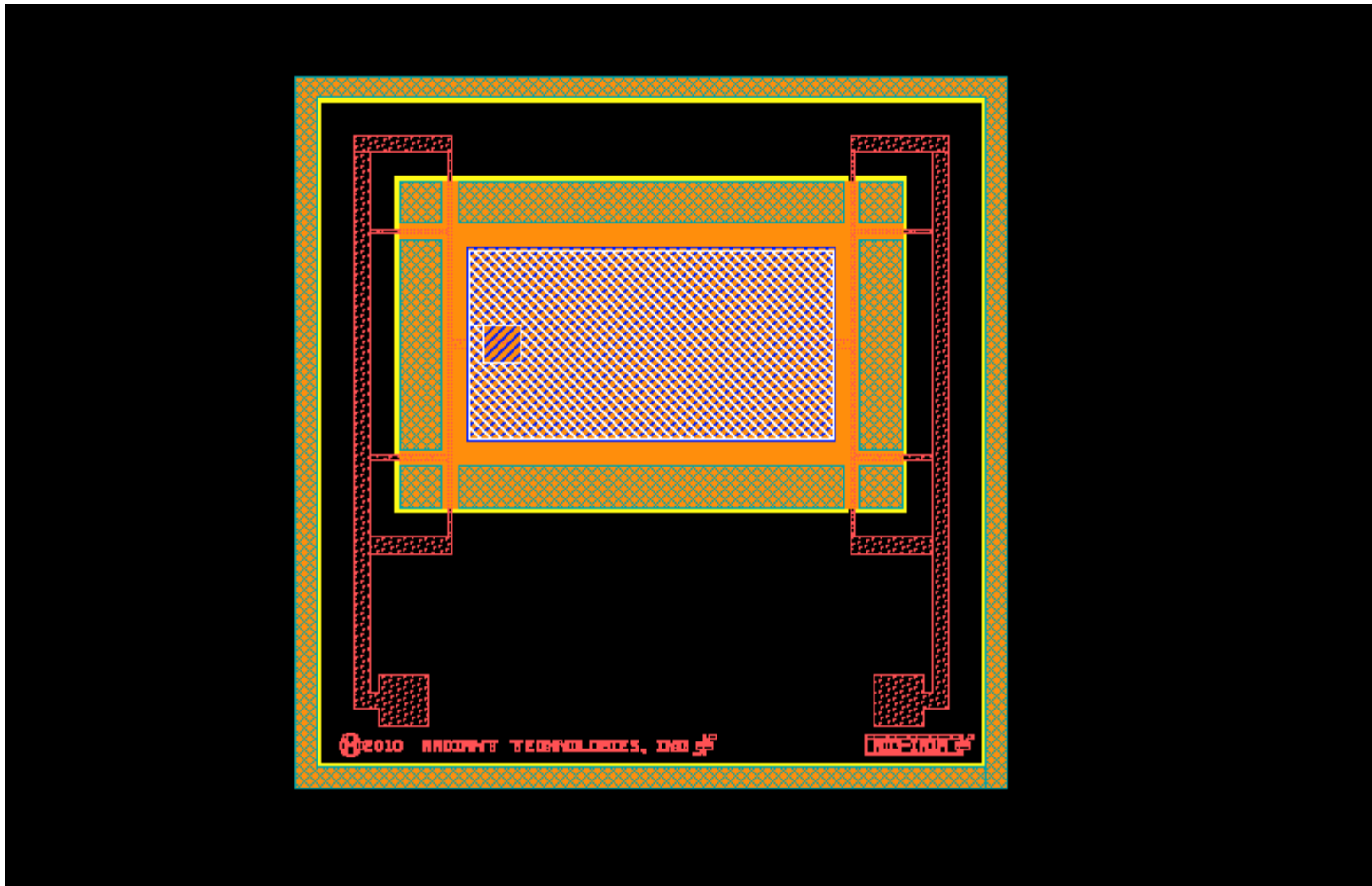
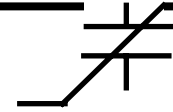


Step by Step



- Trench.

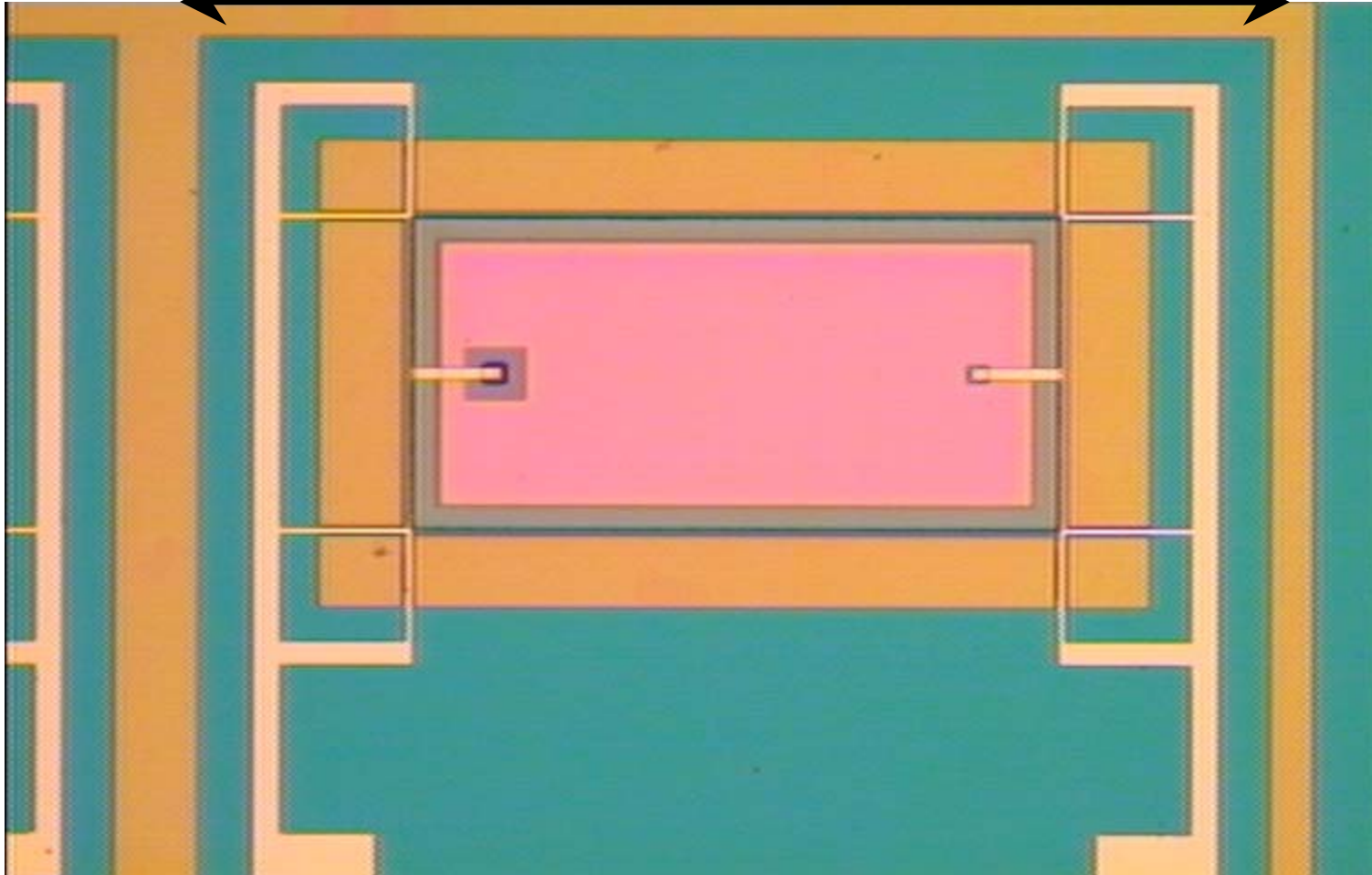
Step by Step



- Backside.

The Device on Wafer

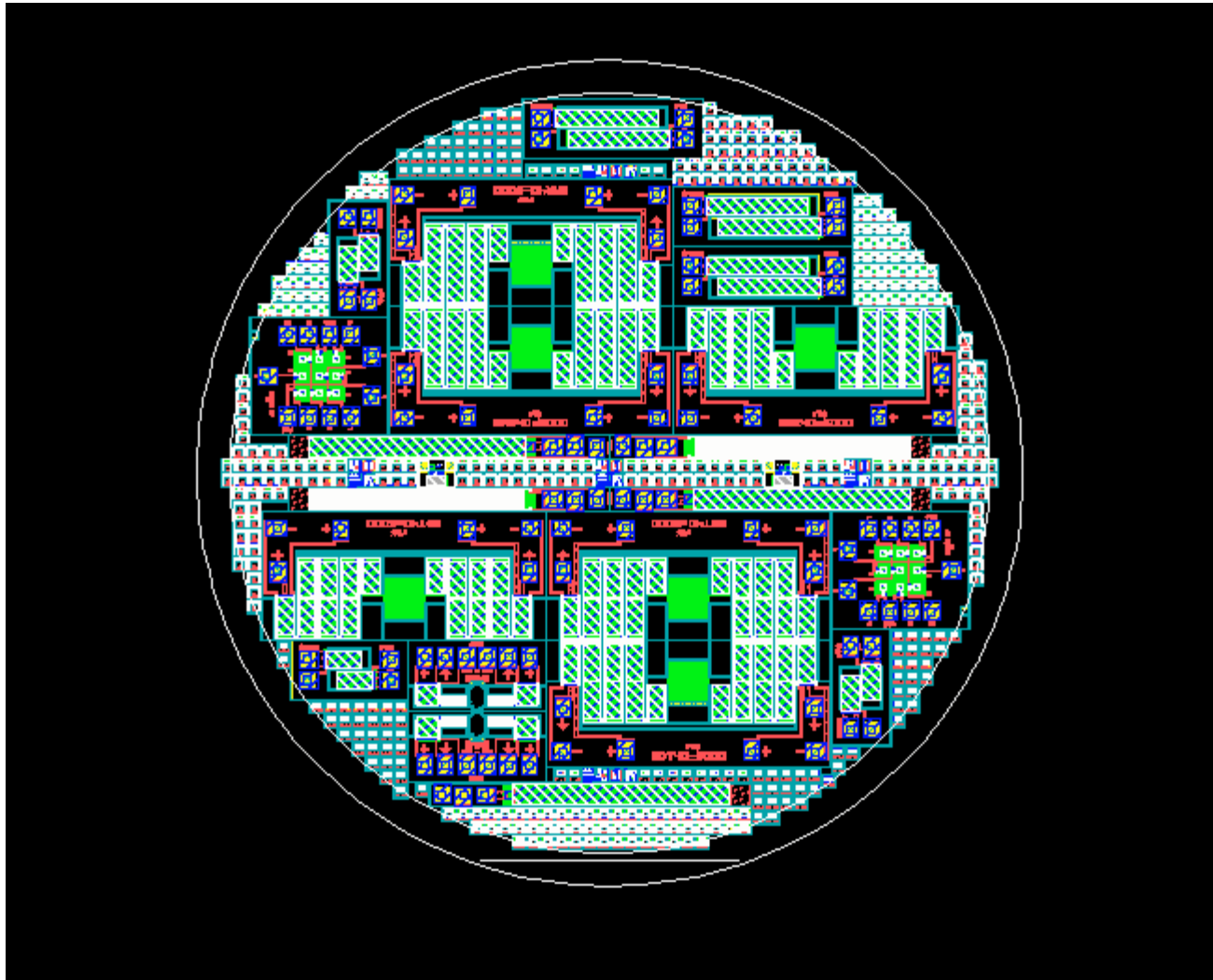
1.7mm



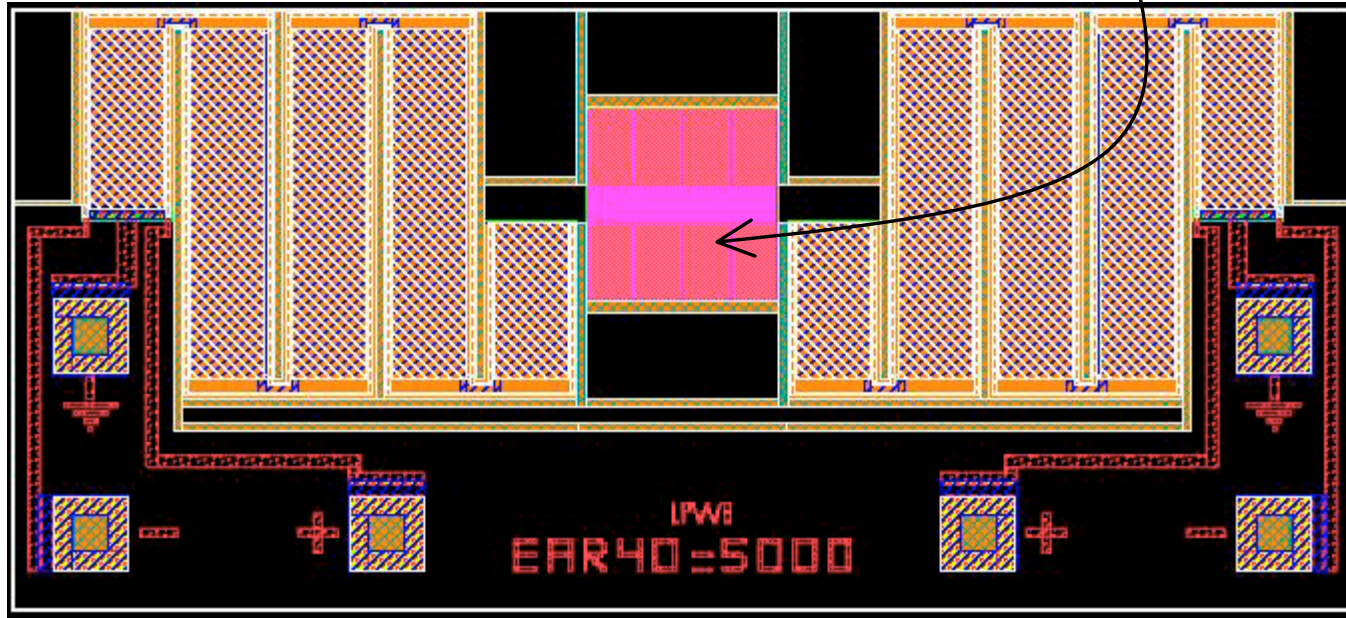
- This is the same device completed through metal interconnect. It is ready for Trench etch.

Radiant Technologies, Inc.

The Complete Wafer

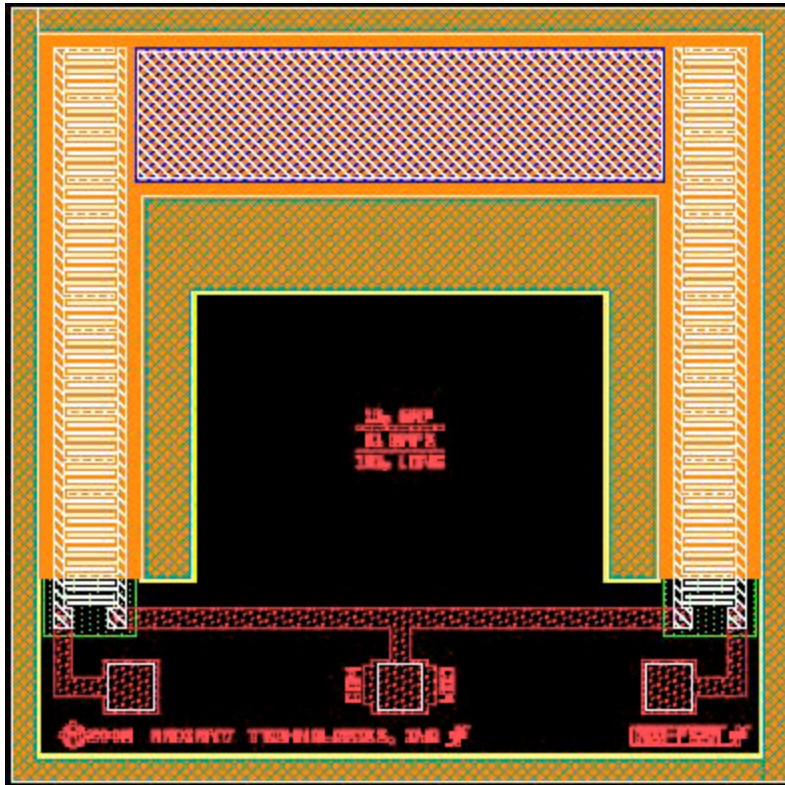


Scanning Mirror



- A large area scanning mirror designed by Dr. Smits of Scaldix called an Eight Alpha Rotator.
 - Note the through-hole mounting points.
 - Orange areas are the 40μ SOI layer of the wafer.
 - Brown areas are holes through the wafer.

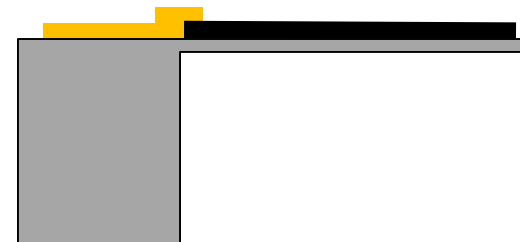
2mm² Vibration Sensor



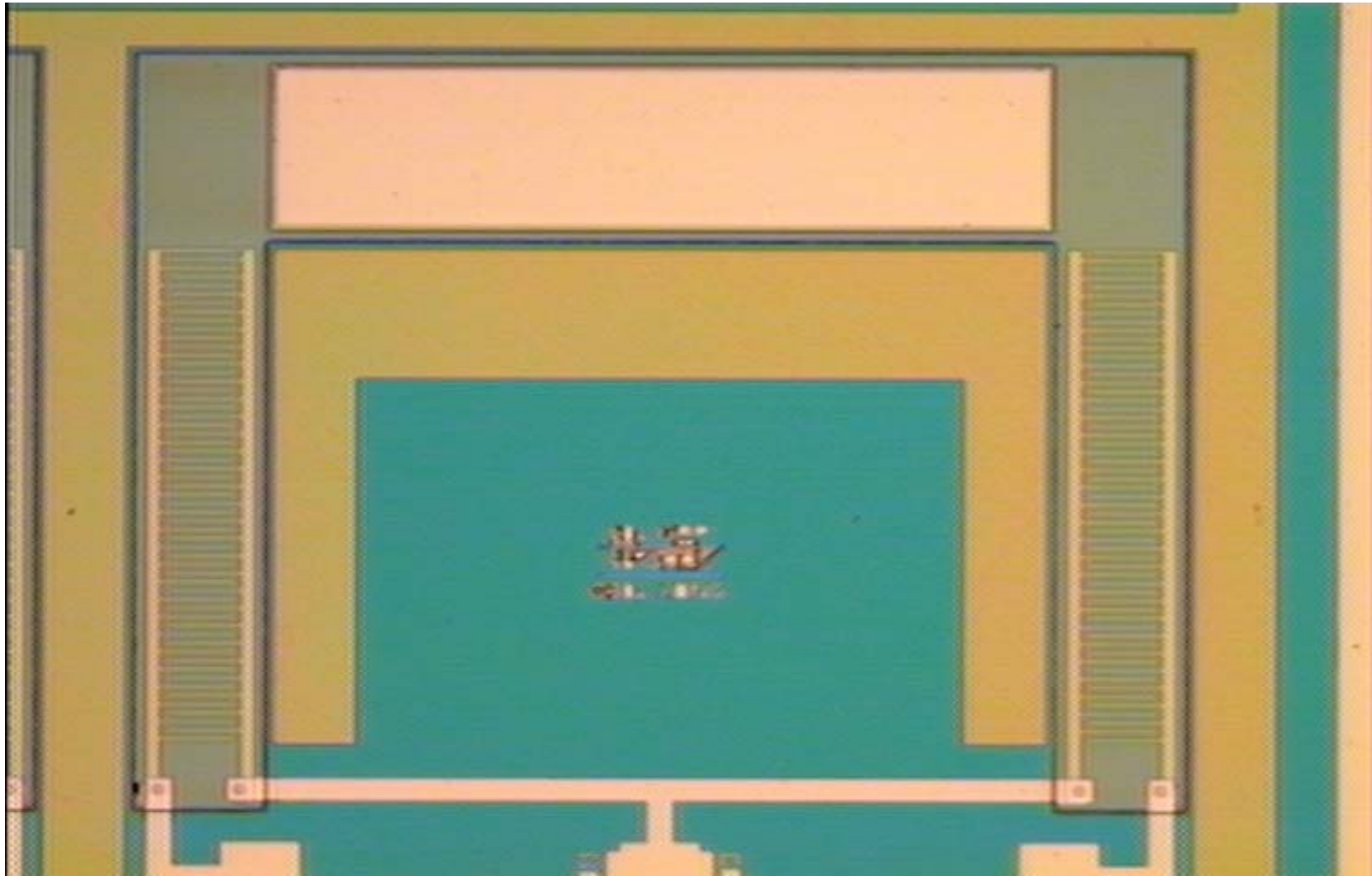
TO-18 Can

A vibration sensor with a 40 μ -thick cantilever that will fit in a small TO-18 transistor can.

The two 10 μ -gap interdigitated electrode capacitors require 200V to pole but will generate large voltage signals when deflected and can drive a high impedance input.

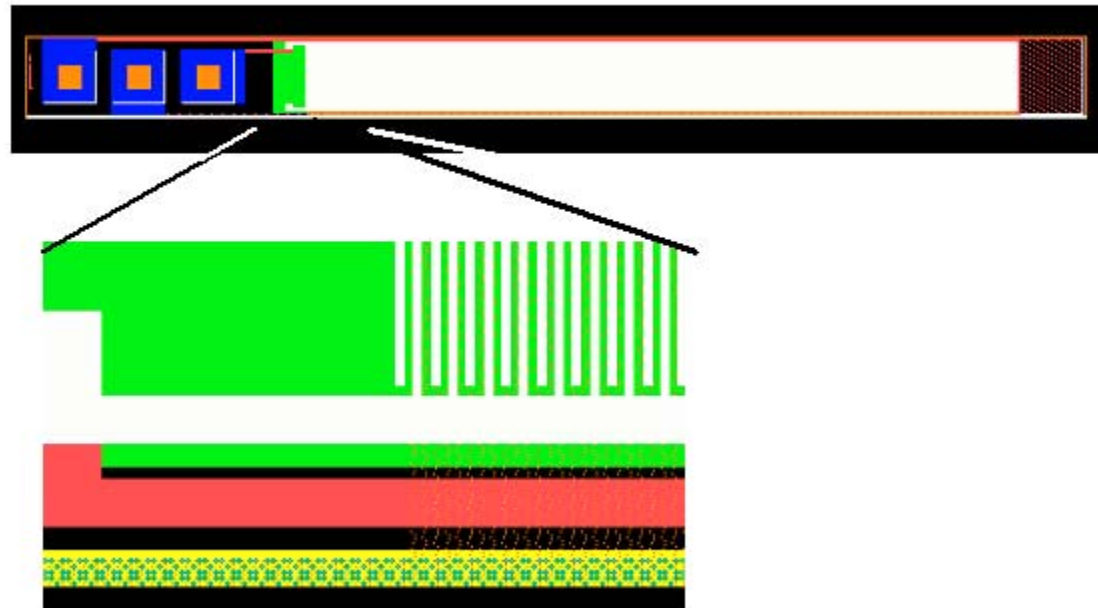


2mm² Vibration Sensor



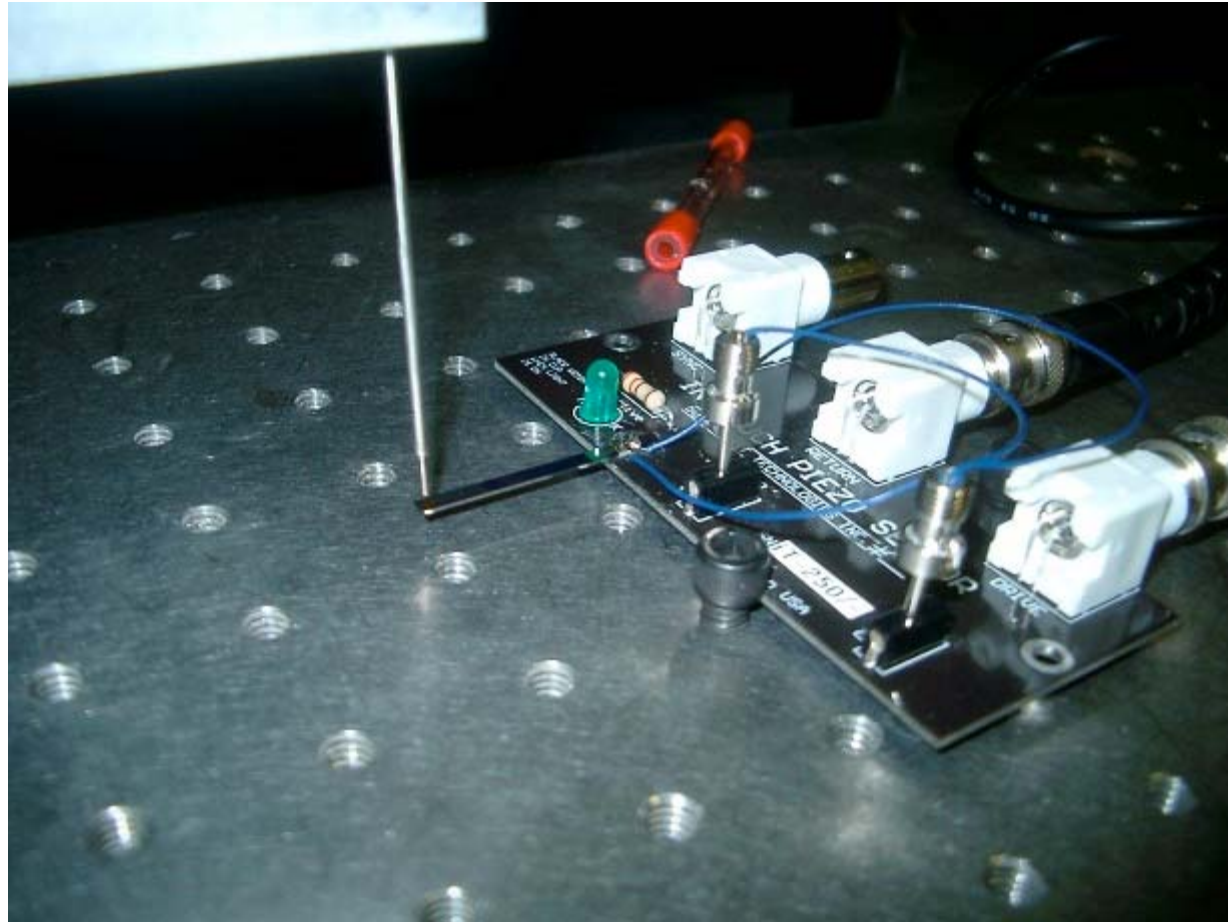
Radiant Technologies, Inc.

IDE Cantilever



- A 2.9-centimeter long vibration sensor or energy scavenger designed by Radiant.
 - 15μ gaps on the interdigitated electrodes makes this a voltage generator sensor.

Parallel-Plate Cantilever

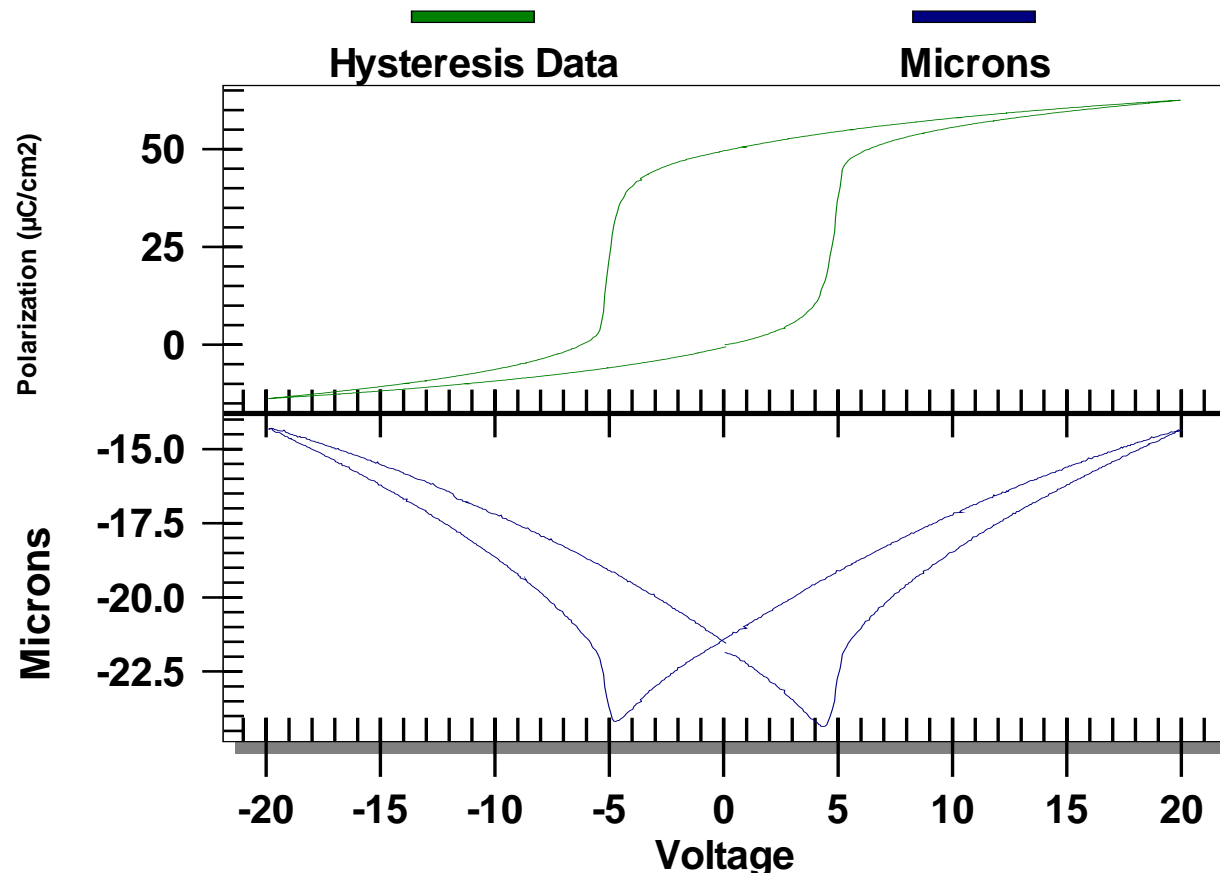


- The cousin to the IDE cantilever with a single 2.9cm long, 1μ -thick parallel plate PNZT capacitor.

Tip Displacement

PA1A Cantilever

[pMEMs-1002]

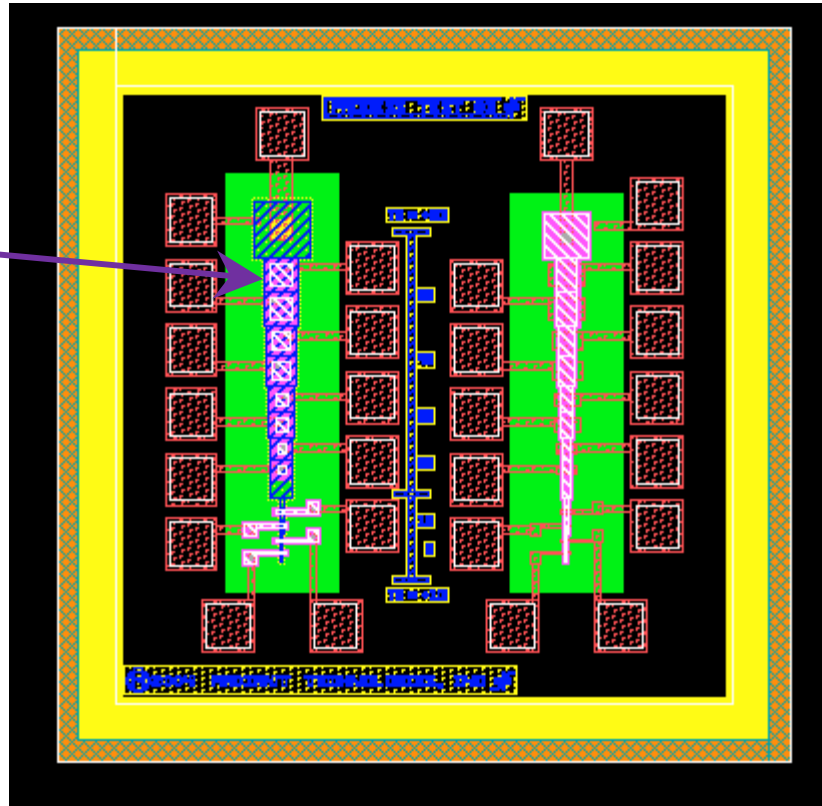


Measured with a Precision Premier II connected to an MTI2000 using a 2032RX displacement sensor module. Cantilever thickness = 550μ .

Radiant Technologies, Inc.

Hysteresis Performance

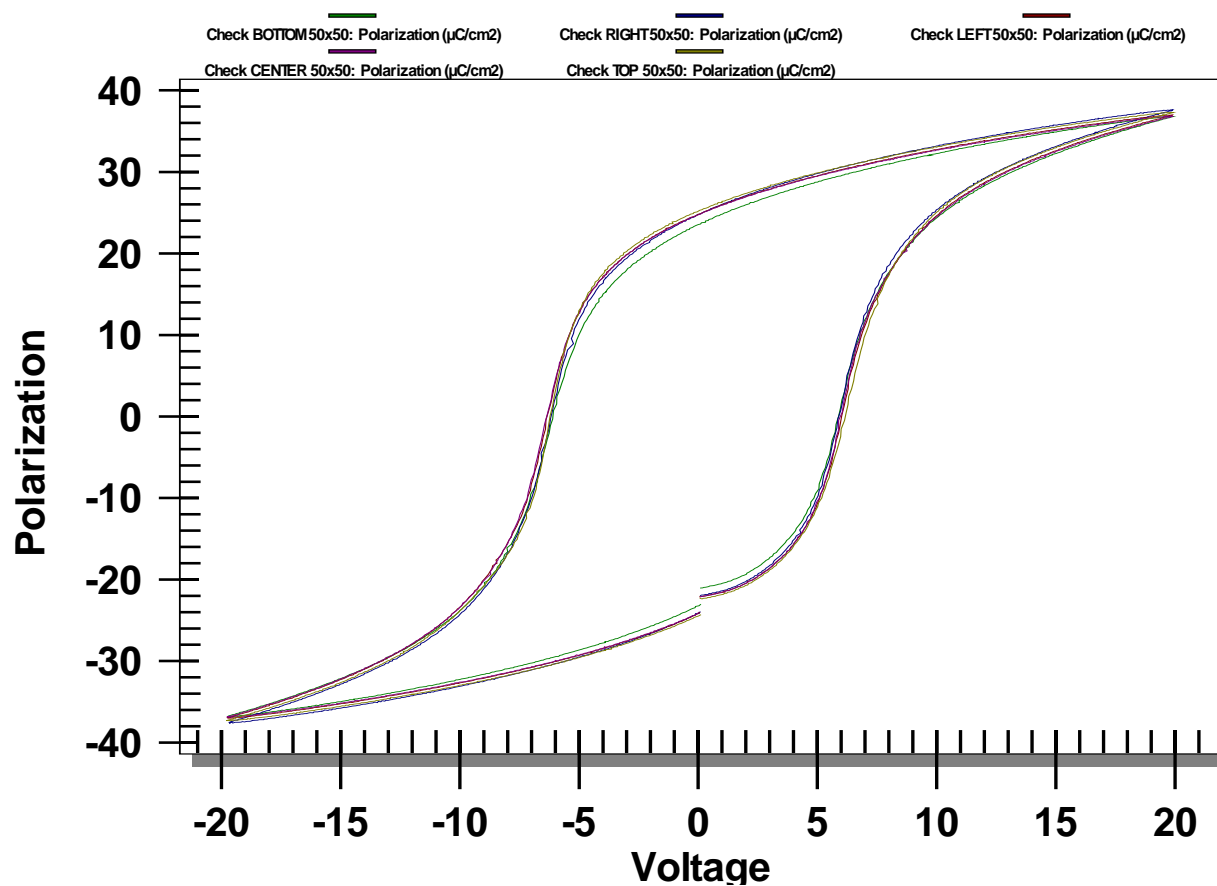
50 μ x50 μ
Capacitor



- There are **five** test die located at the cardinal points of each pMEMS wafer.

Hysteresis Performance

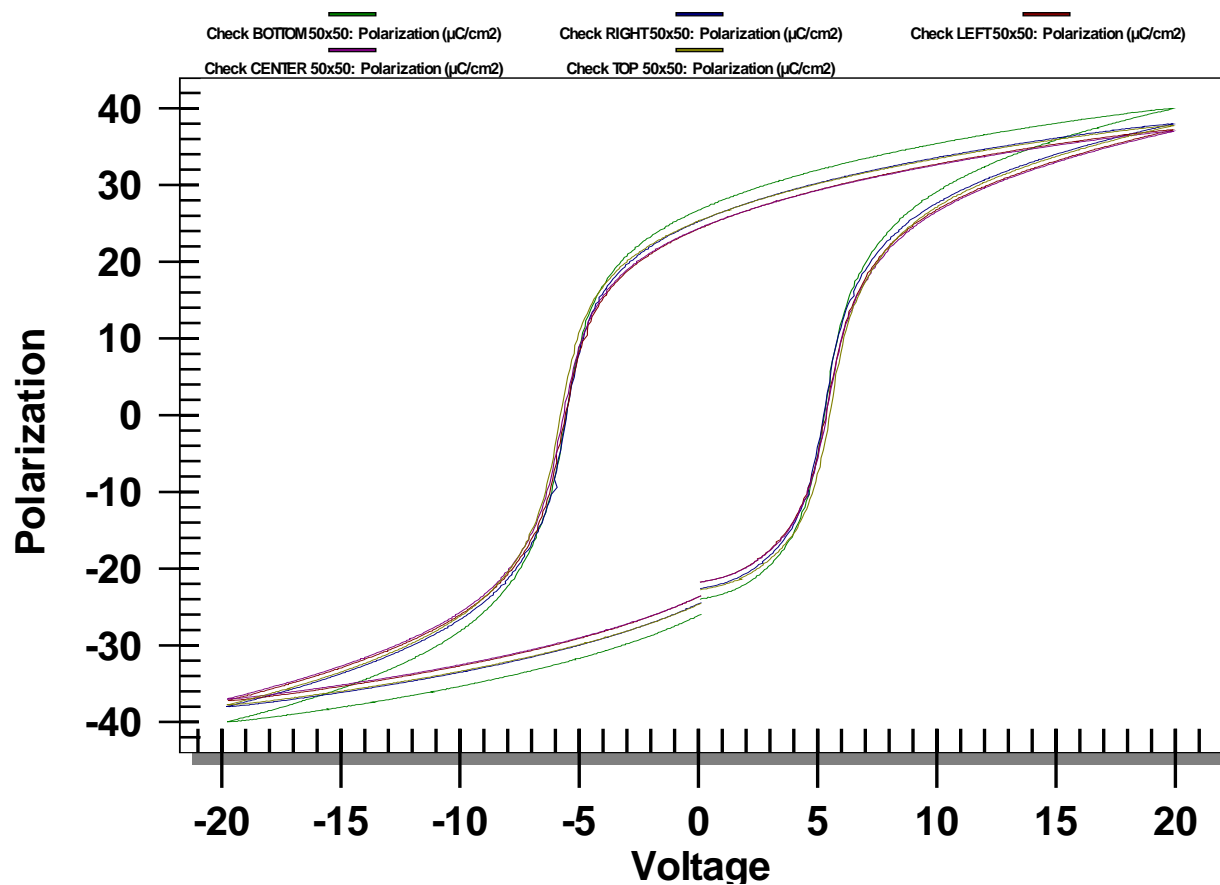
50x50 Test Caps [pMEMs-1003 Wafer 2]



- pMEMs Wafer 2.

Hysteresis Performance

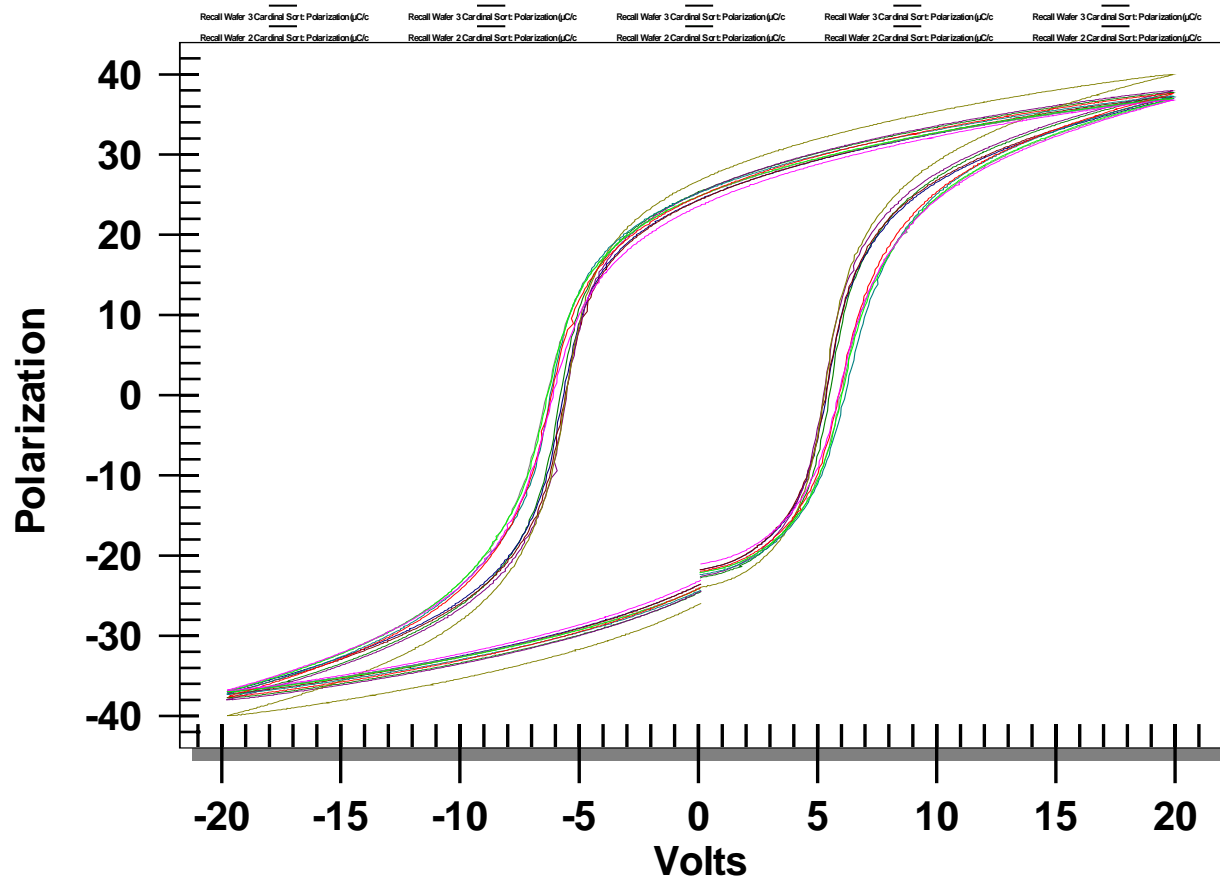
50x50 Test Caps
[pMEMs-1003 Wafer 3]



- pMEMs Wafer 3.

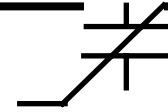
Hysteresis Performance

Wafer 2 and Wafer 3 Cardinal Sort [pMEMs-1003]

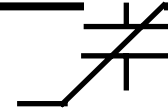


- Both wafers.

Status



- Wafers are at Trench etch.
- Issue : the DRIE etch rate using an Alcatel deep RIE etcher at the University of New Mexico stops half way through the wafer.
 - UNM and Tegal are working with Radiant to improve this performance.
 - The DRIE Trench and Backside etches are the last remaining steps to finish the piezoMEMs dice.



The Future

- Once the process is dependable, Radiant will explore various piezoMEMs device designs that might have commercial value.
- Radiant intends to offer a piezoMEMs fabrication package to universities starting this fall.
 - Students and researchers can lay out their own designs using Radiant's 5 μ design rules.
 - Radiant will acquire the mask set and fabricate the devices.
- Radiant is creating a family of microprocessor-based platforms derived from the EDU to drive and test these pMEMs devices.