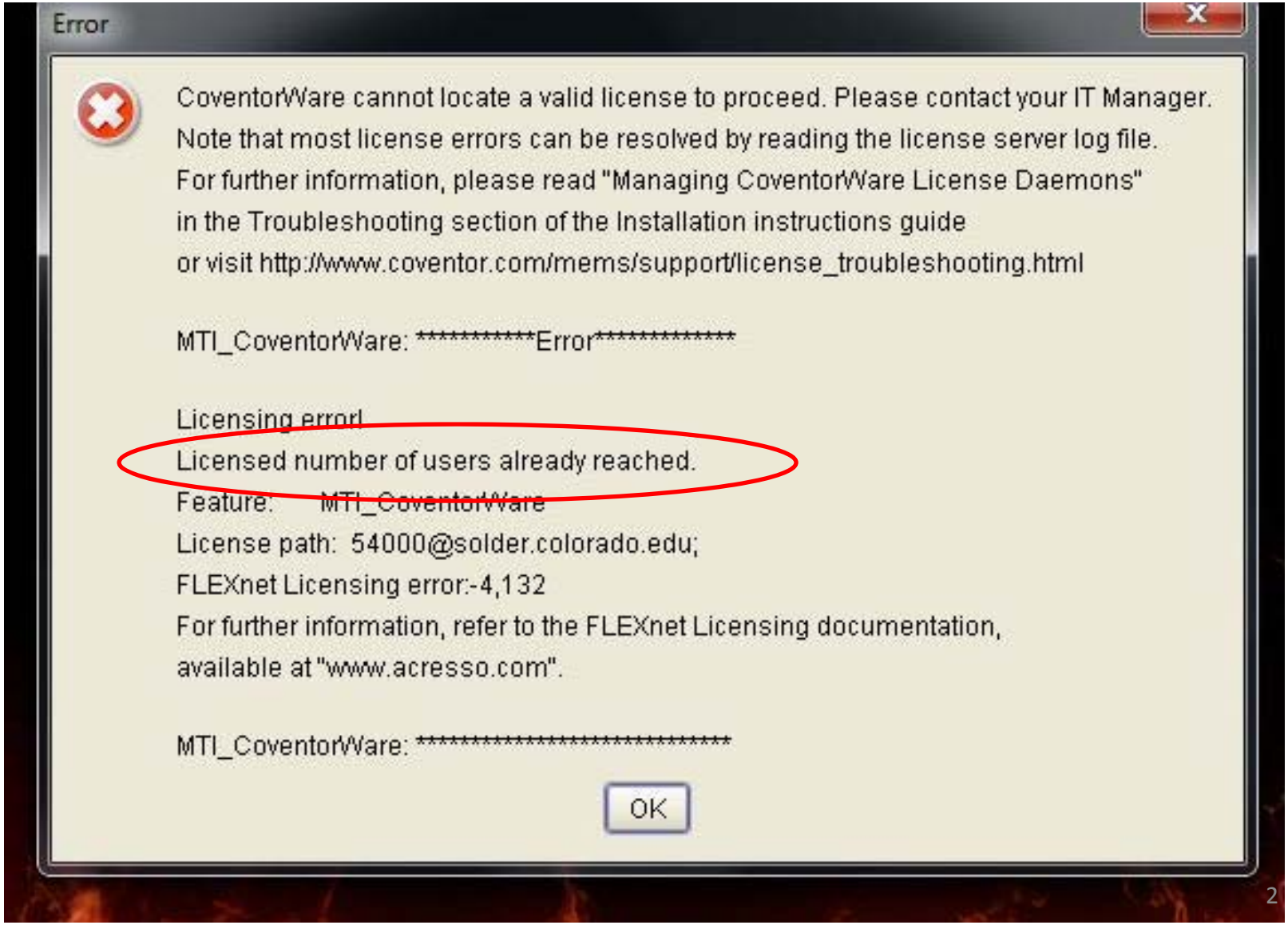
MEMS II: February 8, 2012

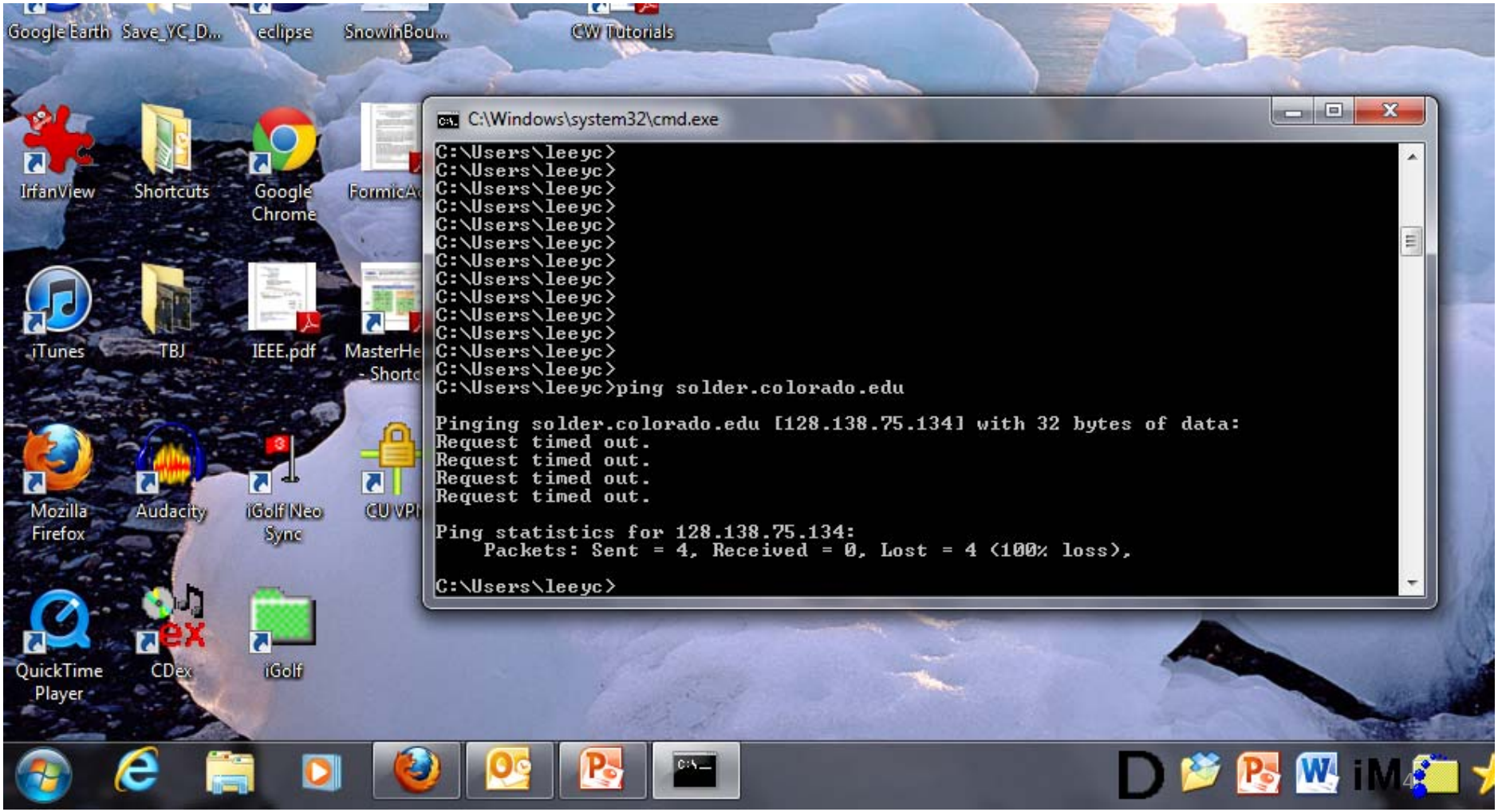
- Licensing problem again?
- Supplementary meshing slides
- Literature Review: Design of RF MEMS

Error Message

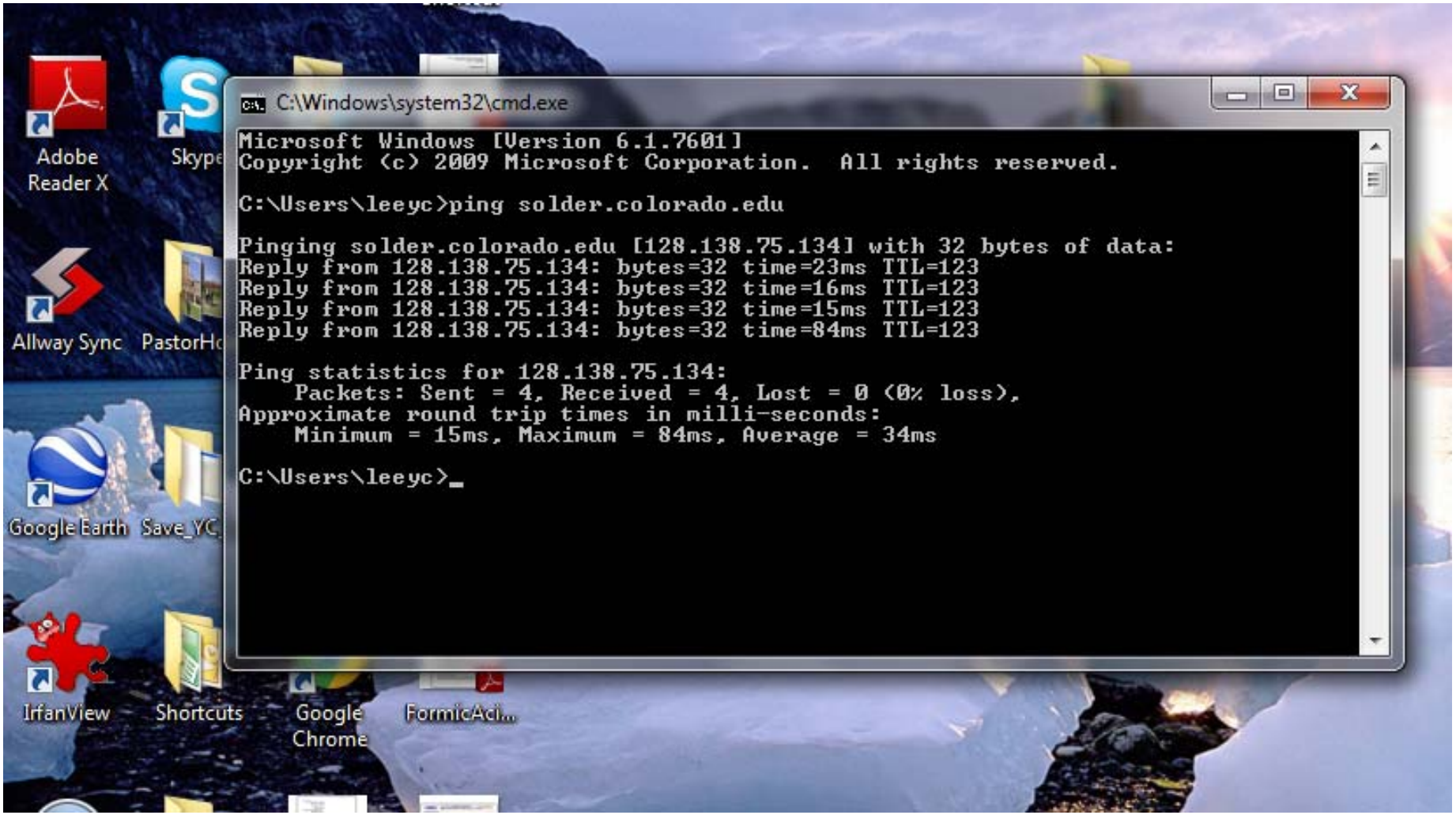


Connection to solder.colorado.edu?

Bad Connection



Good Connection



Solutions

- Check the error message. If the connection is not good, check your VPN connection using ping solder.colorado.edu.
- If your connection to solder.colorado.edu is good, and you receive the error message as shown, you may have the licensing problem again. Email leeyc@colorado.edu or call (303)492-3393 and you will reach my cell phone.
- YC will re-start the solder.colorado.edu PC in the DLC office.

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Deposition

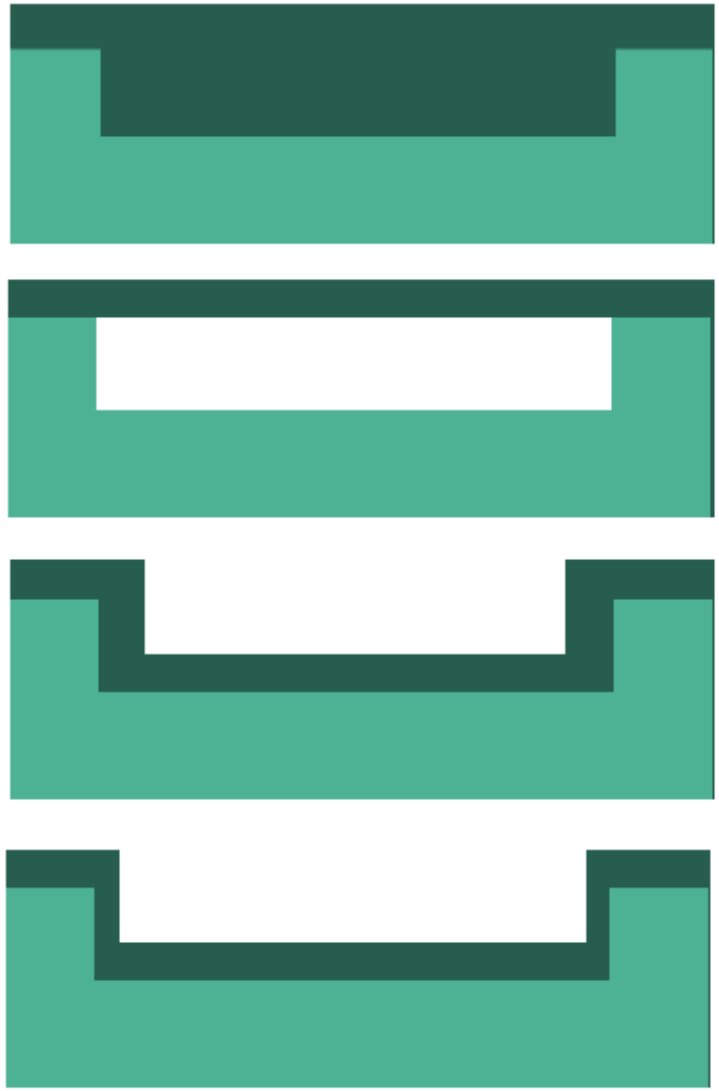
Planar Fill

Stacked

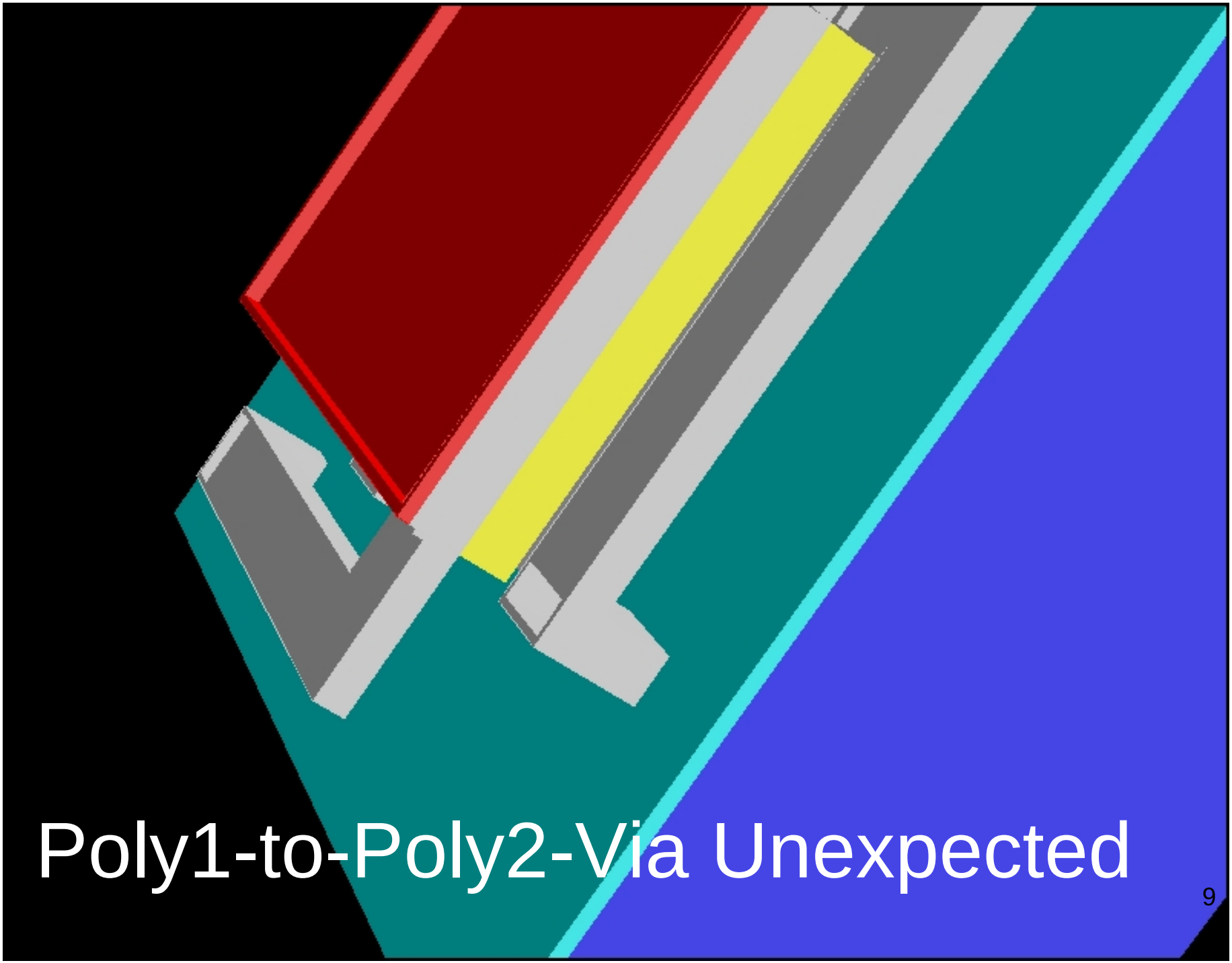
SCF = 1

Conformal Shell

SCF = 0.5



SCF: Surface Conformality Factor



Poly1-to-Poly2-Via Unexpected

Revised Process File with Offset for P12via

0	Base		Substrate	SILICON	20.0	blue	GND				
1	Deposit	Stacked	Nitride	SI3N4	0.6	cyan					
2	Deposit	Stacked	Poly0	POLYSILICON	0.5	white					
3	Etch	Front, Last L...				cyan	poly0	+	0.5	0.0	0.0
4	Deposit	Conformal	Oxide1_1	PSG	1.25 S...	blue					
5	Etch	Front, Last L...				white	anchor1	-	1.25	0.0	0.0
6	Etch	Front, Last L...				blue	anchor2	-	1.25	0.0	0.0
7	Deposit	Conformal	Oxide1_2	PSG	0.75 S...	oran...					
8	Etch	Front, Last L...				oran...	dimple	-	0.75	0.0	0.0
9	Etch	Front, Last L...				yello...	anchor1	-	0.75	0.0	0.0
10	Etch	Front, Last L...				gray	anchor2	-	0.75	0.0	0.0
11	Deposit	Conformal	Poly1	POLYSILICON	2.0 S...	yello...					
12	Etch	Front, Last L...				light...	poly1	+	2.0	0.0	0.0
13	Etch	Front, Last L...				red	hole1	-	2.0	0.0	0.0
14	Etch	Front, Last L...				pink	anchor2	-	2.0	0.0	0.0
15	Deposit	Conformal	Oxide2	PSG	0.75 S...	gray					
16	Etch	Front, Last L...				green	p12via	-	0.75	3.0	0.0
17	Etch	Front, Last L...				mag...	anchor2	-	0.75	0.0	0.0
18	Deposit	Conformal	Poly2	POLYSILICON	1.5 S...	light...					
19	Etch	Front, Last L...				cyan	poly2	+	1.5	0.0	0.0
20	Etch	Front, Last L...				white	hole2	-	1.5	0.0	0.0
21	Deposit	Conformal	Metal	GOLD	0.5 S...	red					
22	Etch	Front, Last L...				blue	metal	+	0.5	0.0	0.0
23	Sacri...			PSG							

Poly1=Poly2=P12via=Metal

Poly1=Poly2=P12via+>0.75um=Metal

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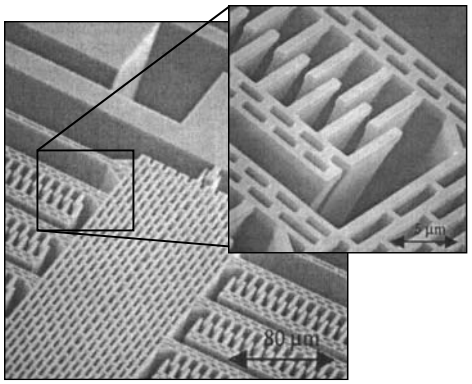
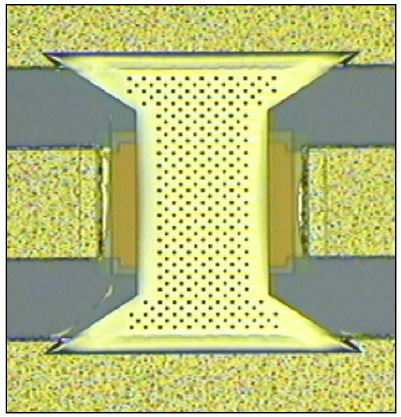
A STRESS-TOLERANT TEMPERATURE-STABLE RF MEMS SWITCHED CAPACITOR

I. Reines1, B. Pillans2, and G.M. Rebeiz1
1University of California San Diego, La Jolla, California, USA
2Raytheon Systems Co. Dallas, Texas, USA

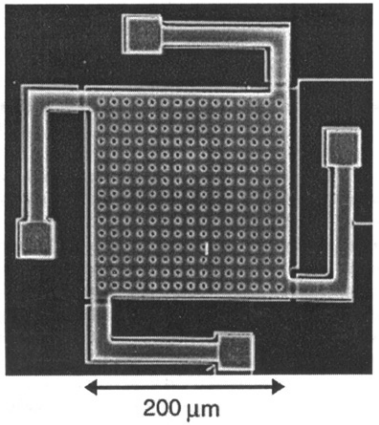
RF MEMS



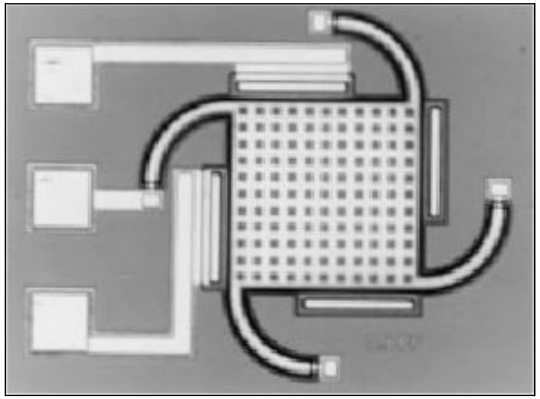
Area Tuned Variable Capacitors



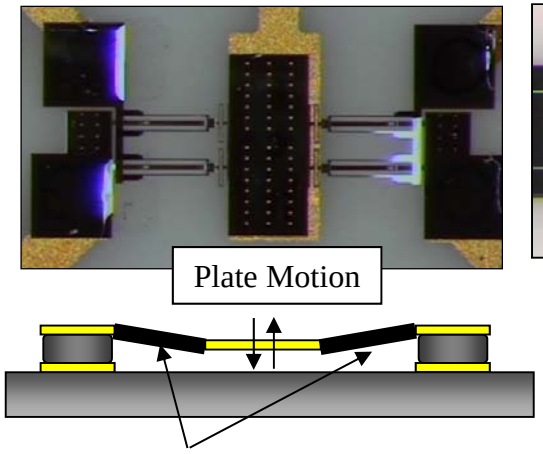
Raytheon Switch



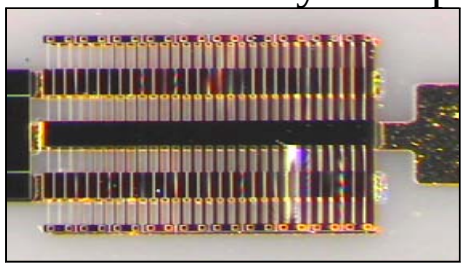
On-chip Variable Capacitor
Berkeley Group



On-Chip MUMPS Variable Capacitor
Columbia Univ.

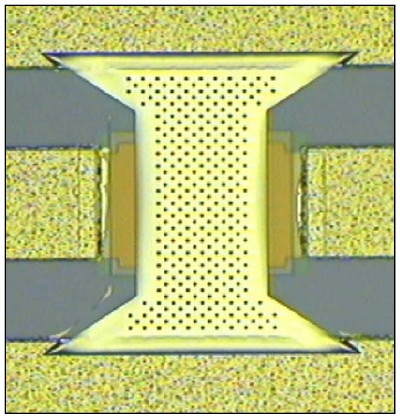


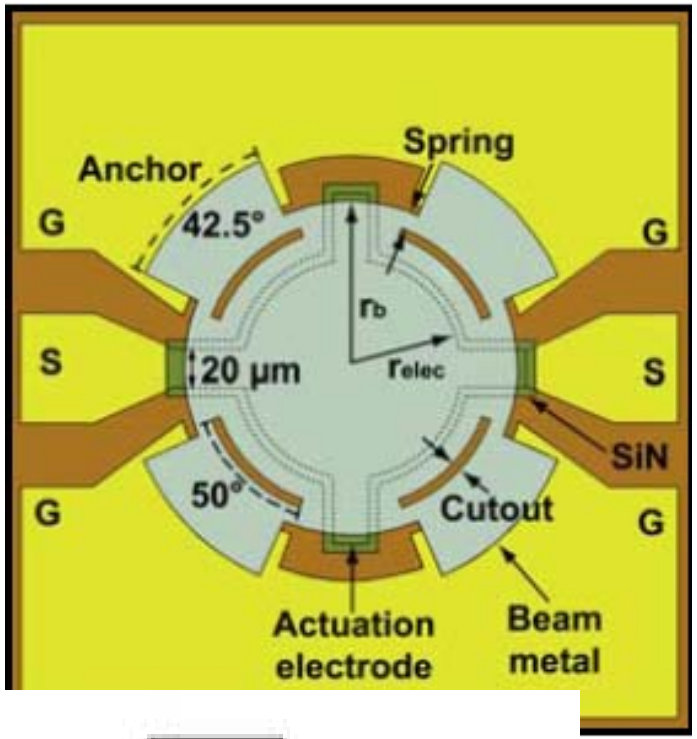
CU Variable Capacitor
(thermal actuation)



CU Variable Capacitor
Electrostatic (1-D)

RF MEMS Switch





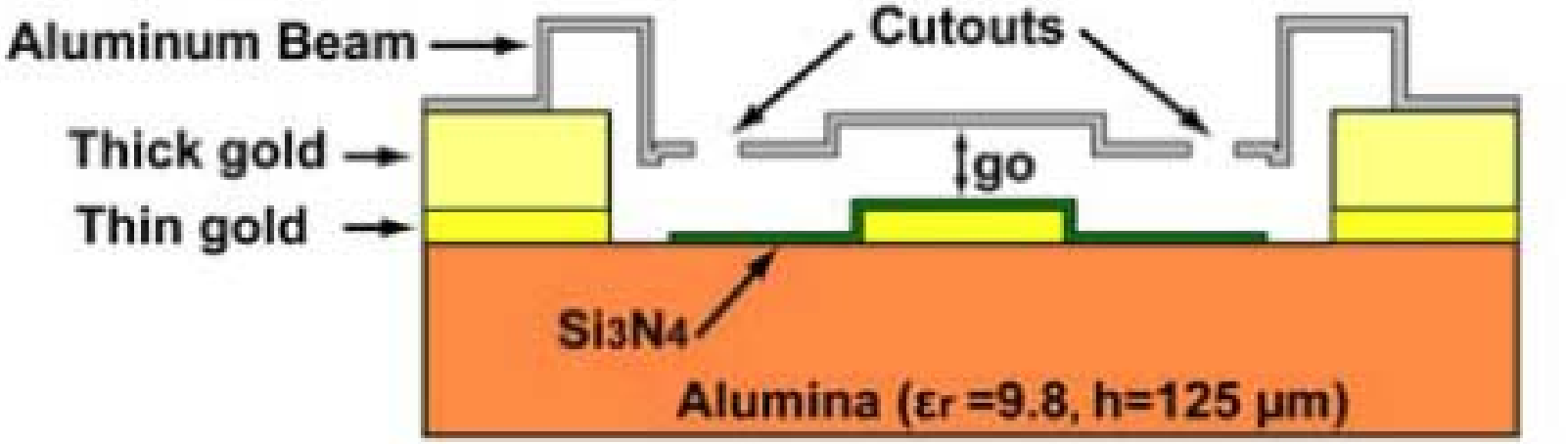
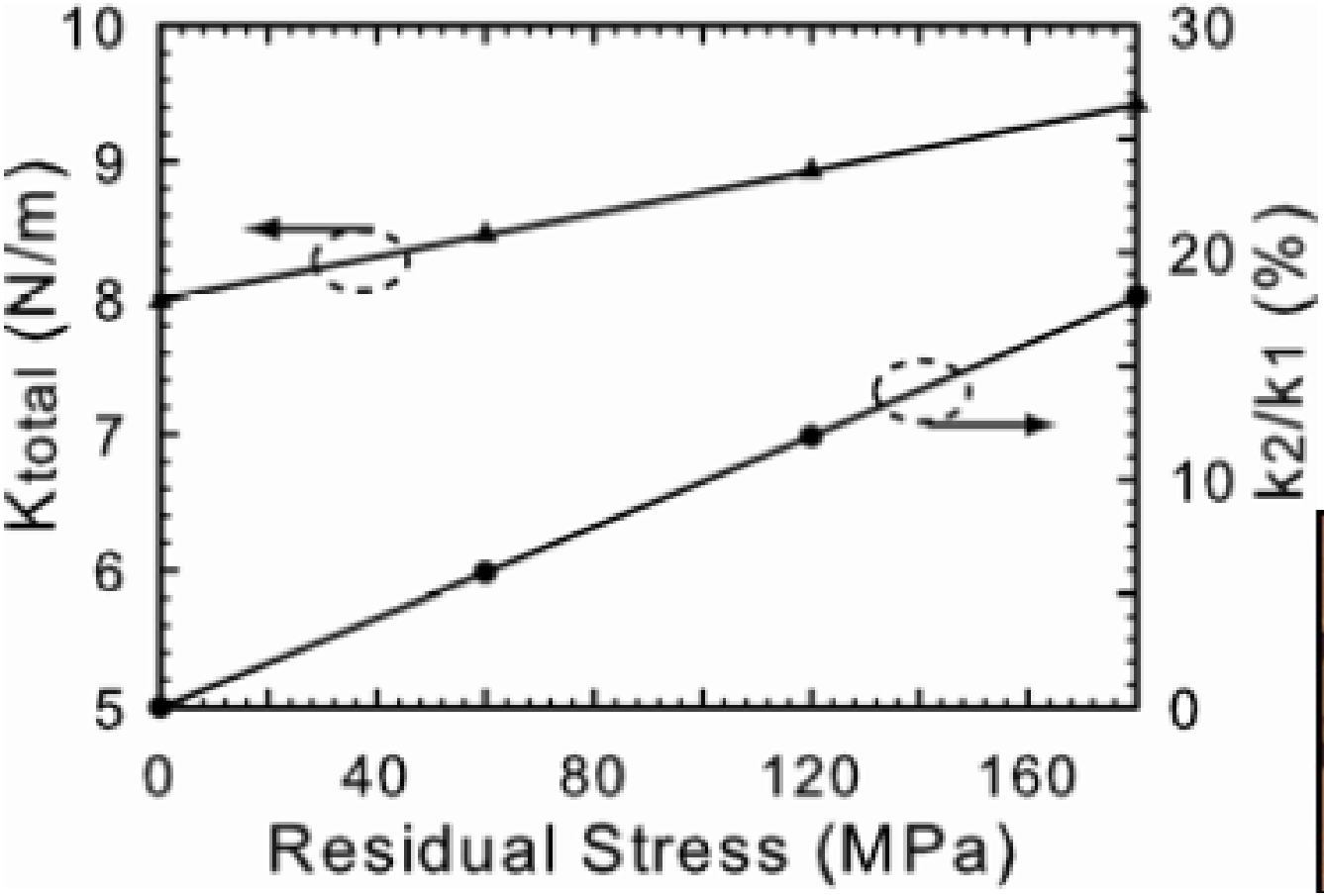


Figure 1: Circular MEMS switched capacitor, (top) layout, (bottom) cross-section.

Table 1: Mechanical parameters of the switched capacitor.

Parameter	Value
Effective area: A (μm^2)	13923
Beam radius: r_b (μm)	97
Electrode radius: r_{elec} (μm)	60
Spring width: w_s (μm)	10
Cutout width: w_c (μm)	5
Beam height: g_o (μm)	3.5
Spring constant[1]: k (N/m)	8.46
Pull-down voltage: V_p (V)	25.9
Resonant frequency[1]: f_o (kHz)	123

[1]simulated using CoventorWare assuming $\sigma_{res} = 60$ MPa



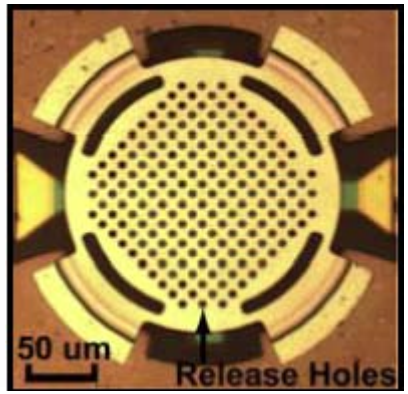
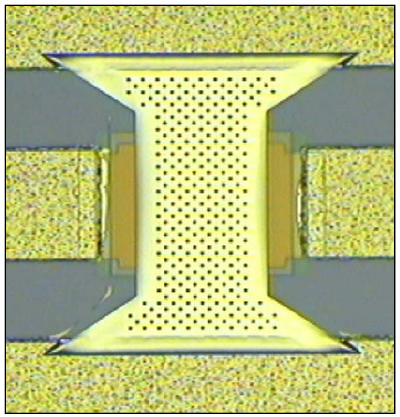


Figure 2: Simulated circular beam stiffness and k_2/k_1 for a varying in-plane residual stress.

The spring constant of fixed-fixed beams is given by $k_{total} = k_1+k_2$, where the k_1 portion is due to the stiffness of the bridge which is determined by material characteristics such as Young's modulus and the moment of inertia. The k_2 portion is due to residual biaxial stress in the beam and is controlled by the fabrication process. A symmetric



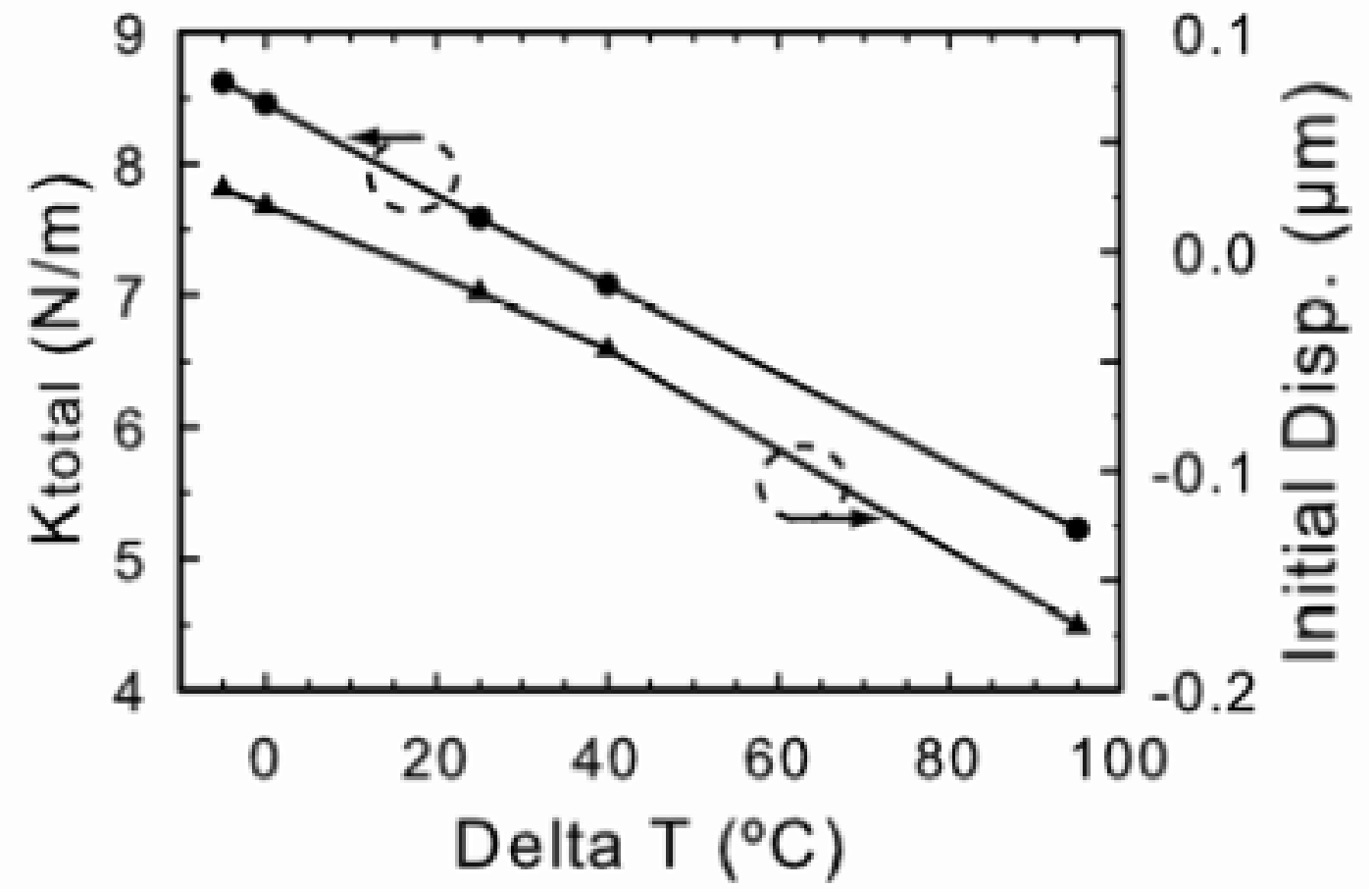


Figure 3: Simulated circular beam stiffness and maximum initial beam displacement (σ_{res} = 60 MPa, $\alpha_{substrate}$= 0 ppm/°C).

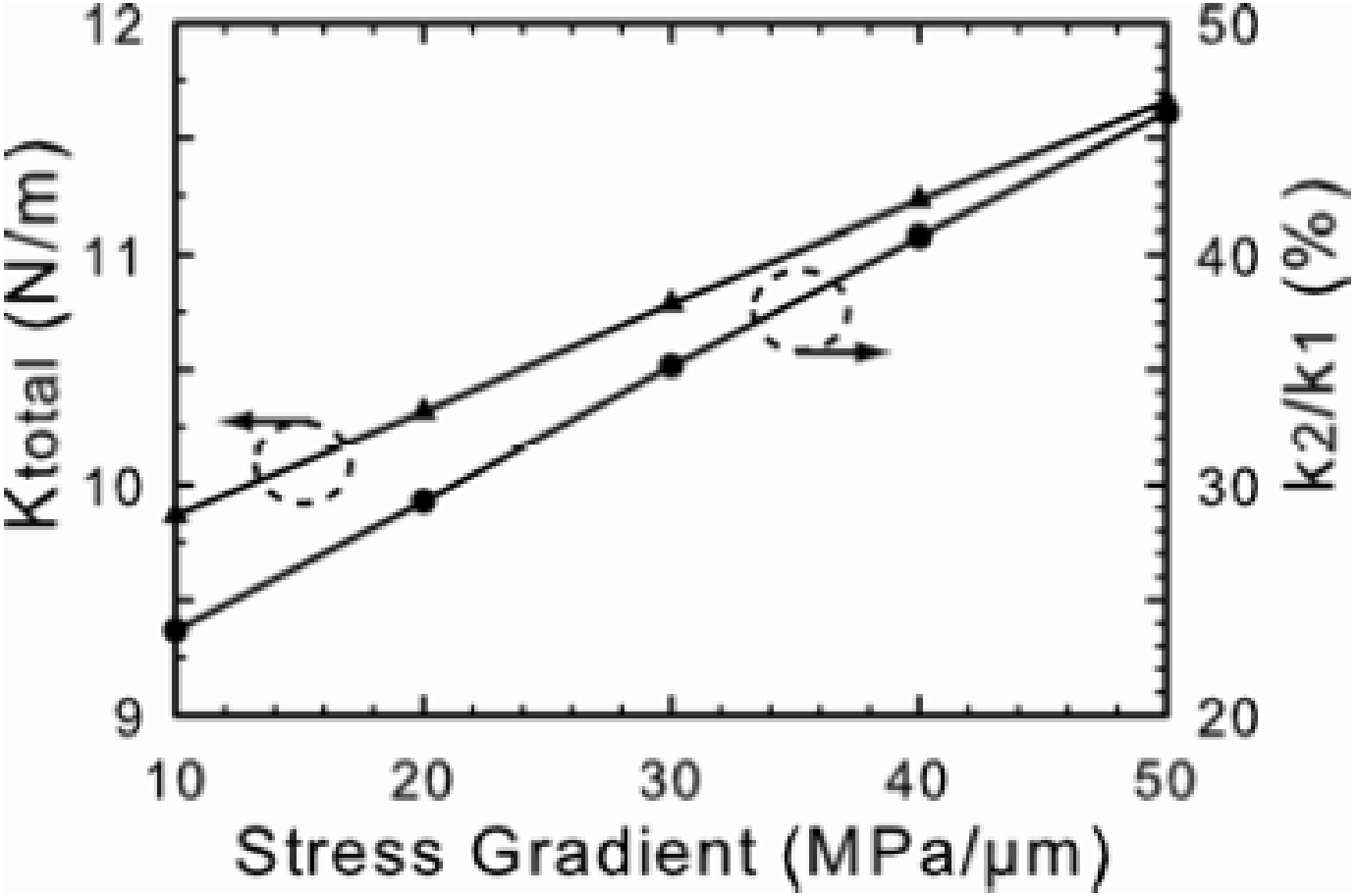


Figure 4: Simulated circular beam stiffness and ratio of k_2/k_1 for a varying vertical stress gradient.

The switched capacitor was also simulated versus varying vertical stress gradients. To approximate a stress gradient in Coventorware, the beam was divided into two equal-thickness layers that were assigned different average in-plane stress values while keeping the total average beam stress fixed at 60 MPa. As shown in Fig. 4,

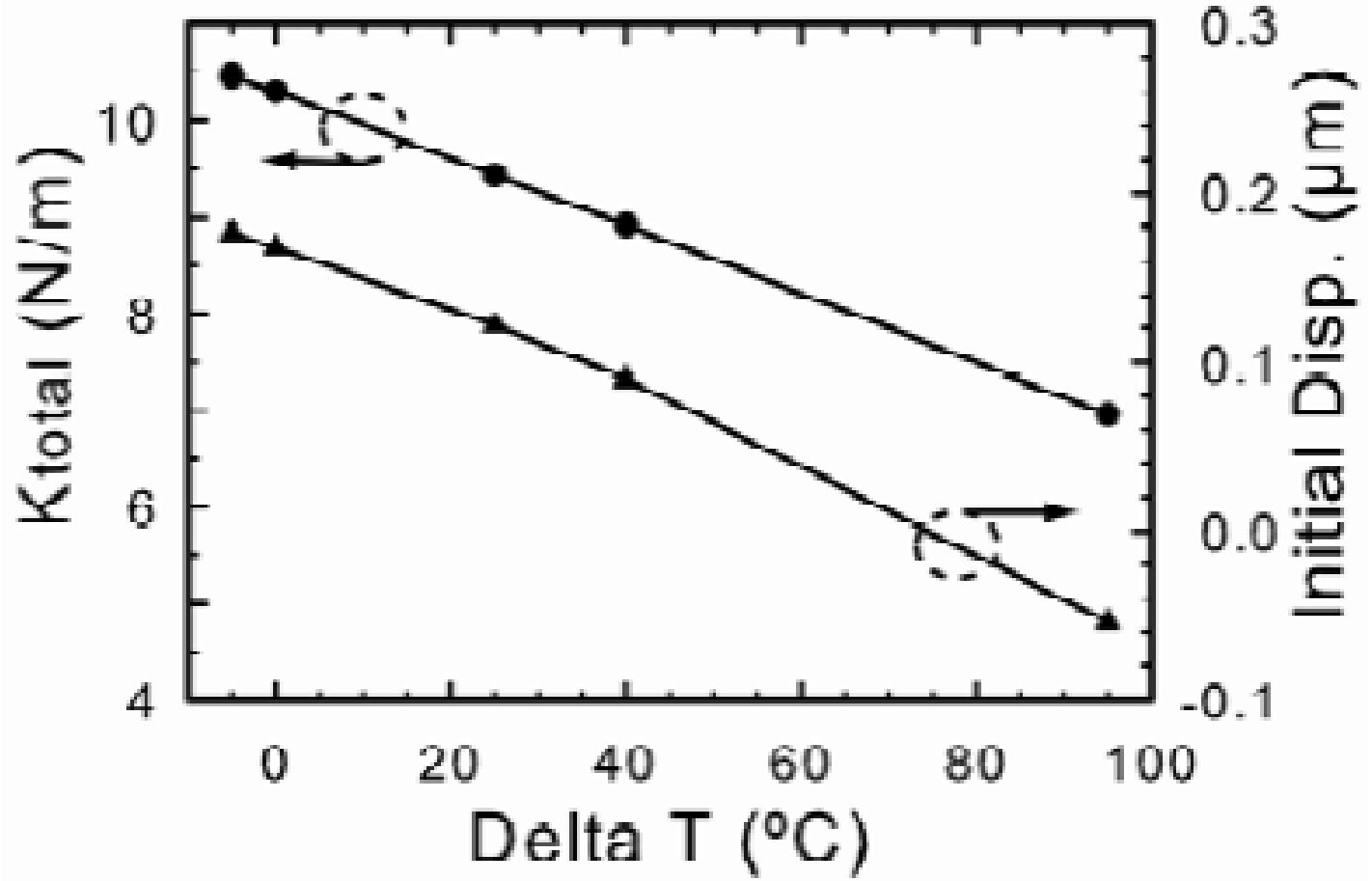


Figure 5: Simulated circular beam stiffness and maximum initial displacement ($\Delta\sigma_{grad}$ = 20 MPa/μm, $\alpha_{substrate}$ = 0 ppm/°C).

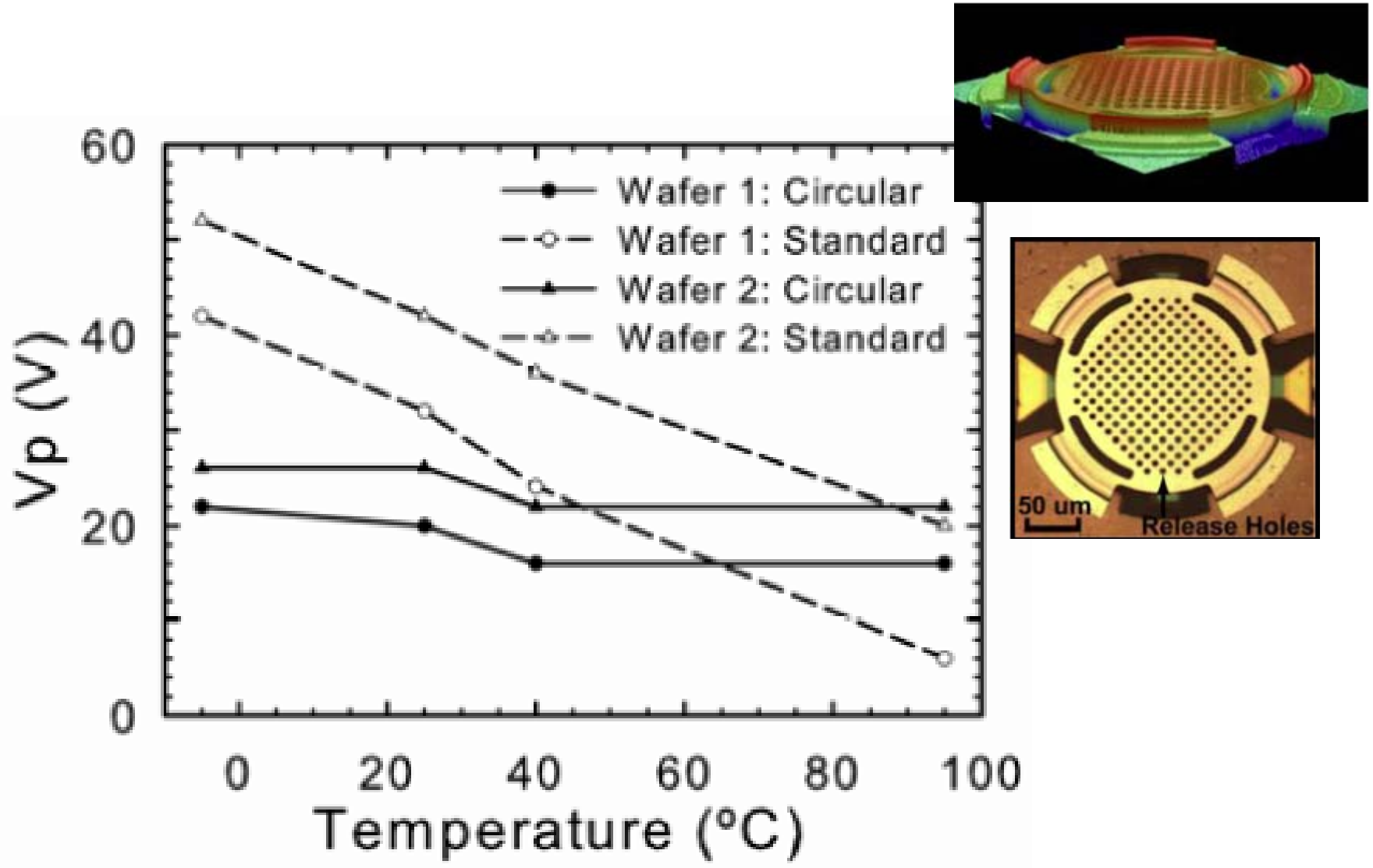


Figure 8: Measured pull-in voltage vs. temperature for both circular and standard switched capacitors from 2 wafer lots.

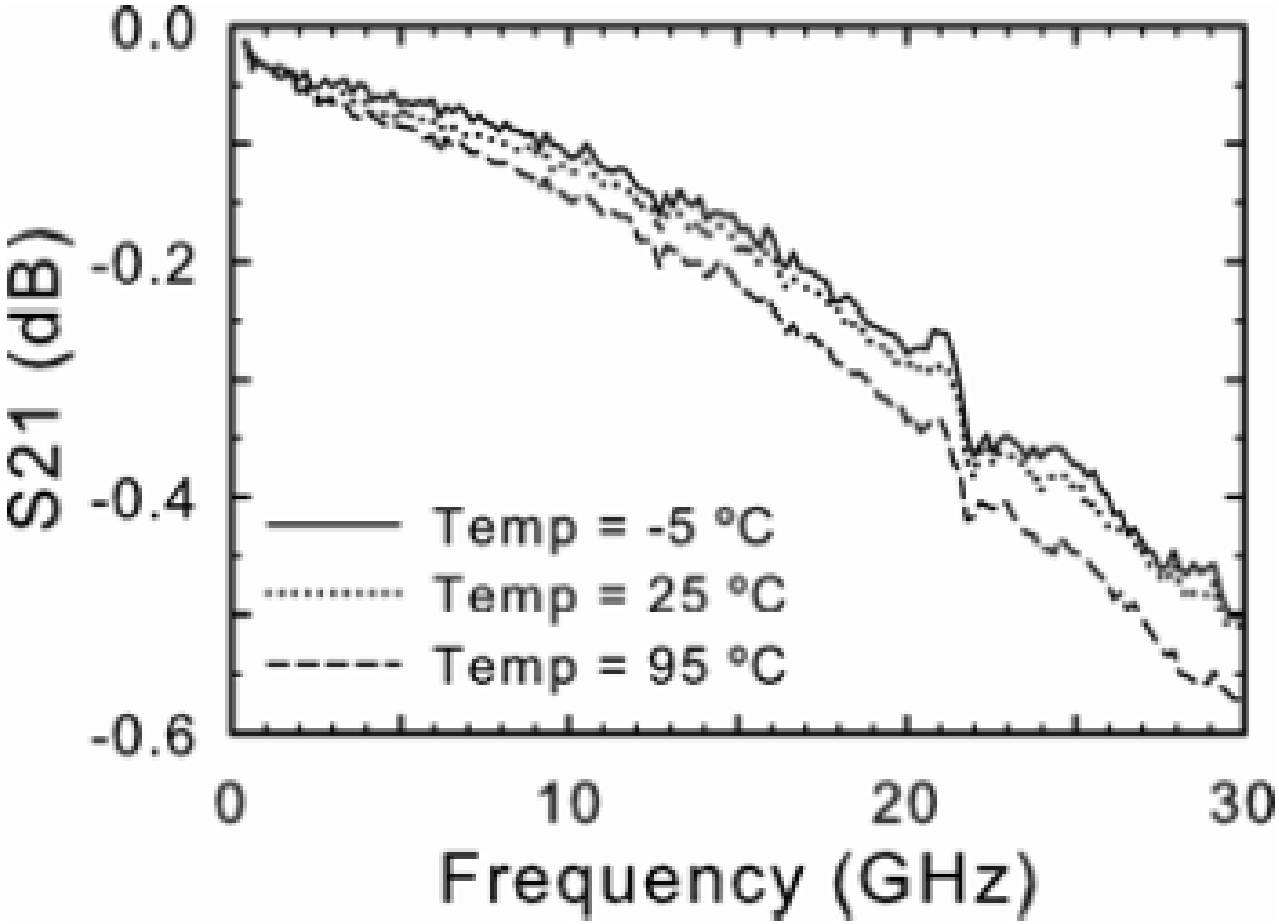


Figure 9: Up-state insertion loss of the switched capacitor from -5 °C to 95 °C (C_{bridge}=55.5 fF +/- 2.5 fF).

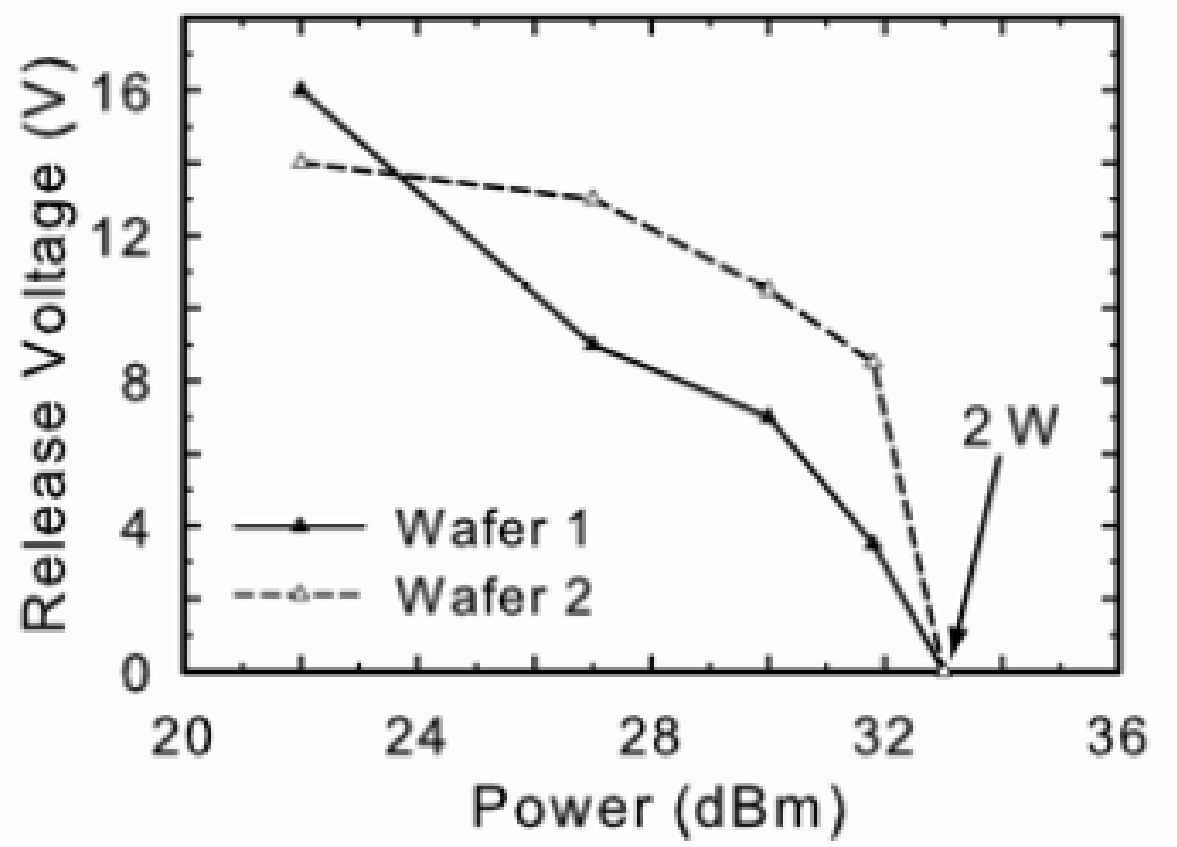


Figure 12: Measured release voltage as a function of continuous RF power at 14 GHz.

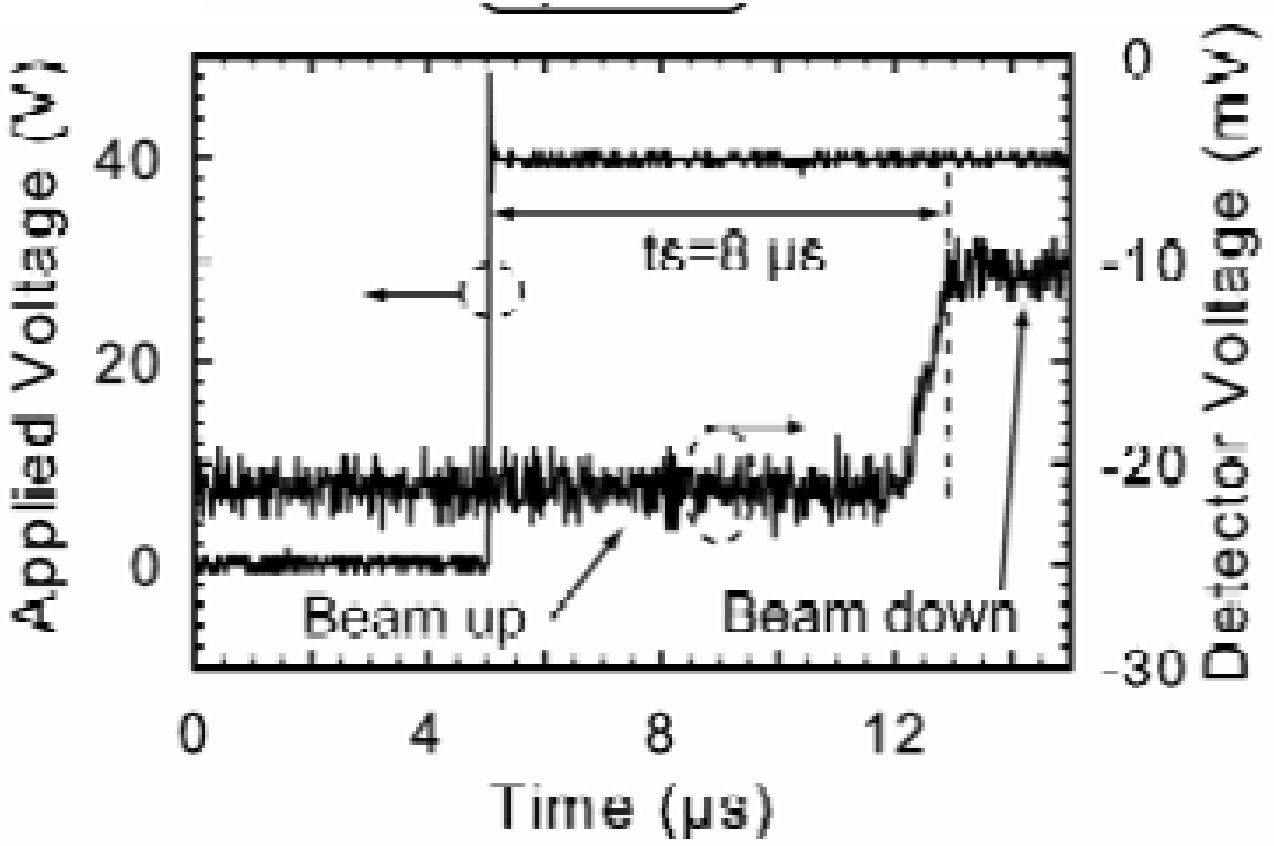


Figure 13: Switching speed and resonance frequency measurement setup (top), and measured switching speed from up-to-down state (bottom).

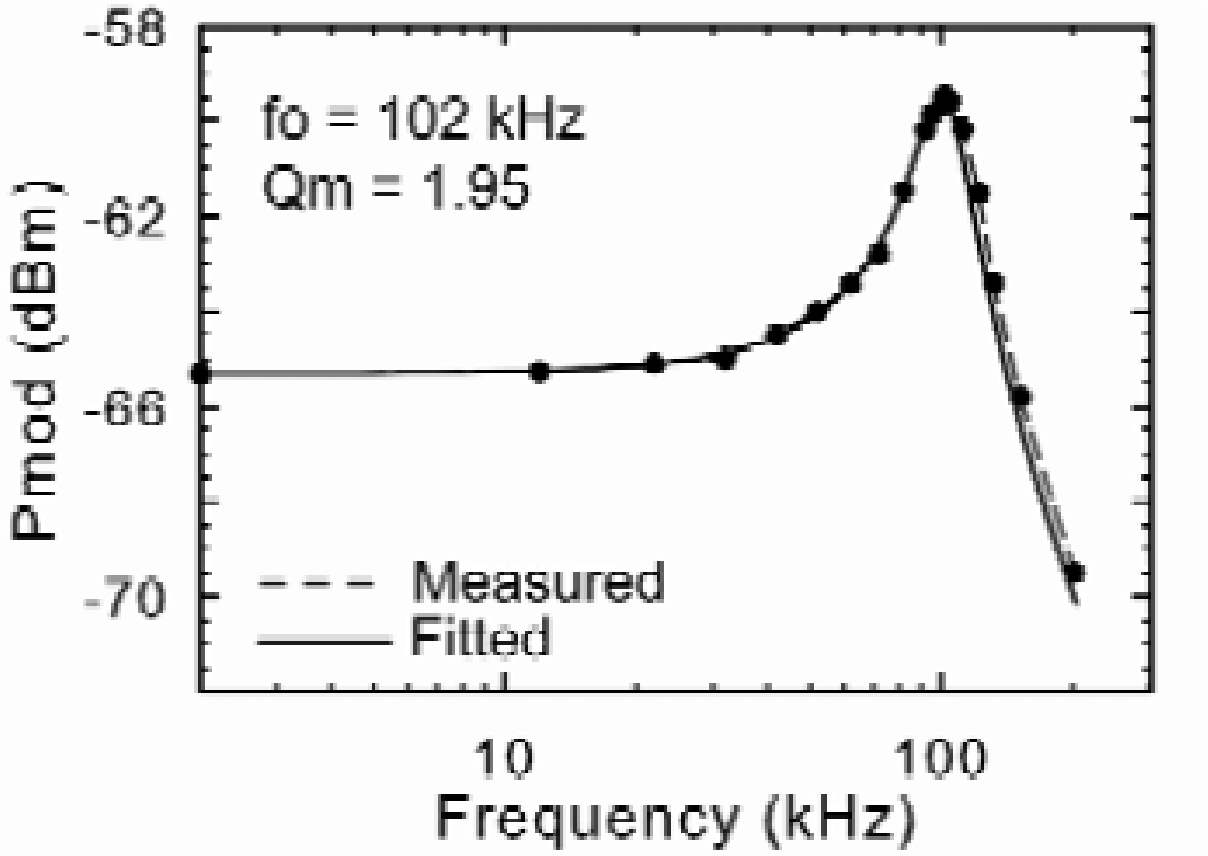


Figure 14: Measured mechanical resonance frequency of the circular switched capacitor.