Center for Optical Technologies

LEHIGH UNIVERSITY
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Northampton Community College
Ben Franklin Technology PArtners Northeastern Pennsylvania
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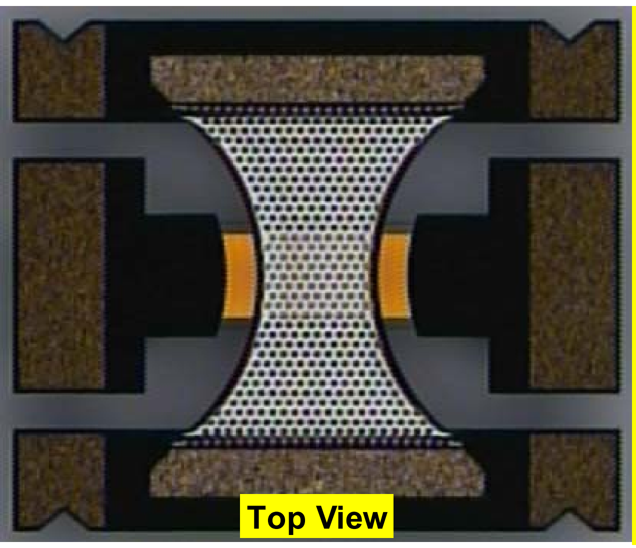
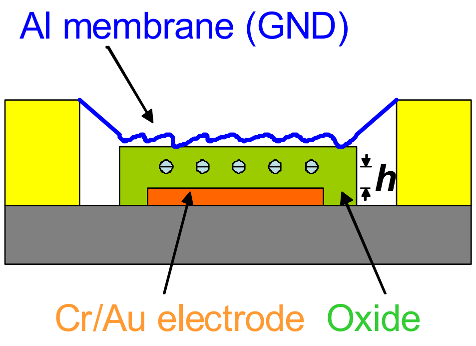
Dielectric-Charging Model for RF MEMS Capacitive Switches

Xiaobin Yuan and James Hwang, Lehigh University, Bethlehem, PA 18015 USA
David Forehand and Charles L. Goldsmith, MEMtronics Corporation, Plano, TX 75075 USA



Commercialization of MEMS devices is hindered by the need for continuing improvement in reliability and packaging. In particular, the lifetime of electrostatically actuated RF MEMS capacitive switches is limited by dielectric-charging effects For the first time, charging and discharging of traps in the dielectric of state-of-the-art RF MEMS capacitive switches were characterized in detail. A charge model was constructed to predict the amount of charge injected into the dielectric and the corresponding shift in actuation voltage. The model was verified against the actuation-voltage shift under different control waveforms and found to be in good agreement with the experimental data. Therefore, for RF MEMS capacitive switches that fail mainly due to dielectric charging, the present model can be used to design control waveforms that can either prolong lifetime or accelerate failure.



Cross Section View

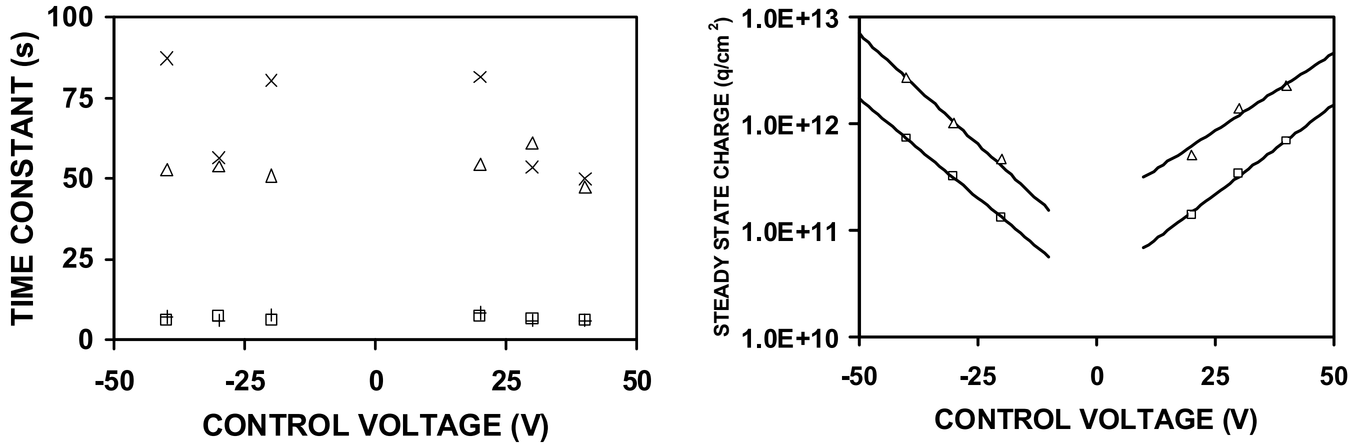
The injected charge density in the dielectric is modeled as

$$\Delta Q = \sum_{J=1,2} \Delta Q_0^J \exp(V / V_0^J)[1 - \exp(-t_{ON} / \tau_C^J)]\exp(-t_{OFF} / \tau_D^J)$$

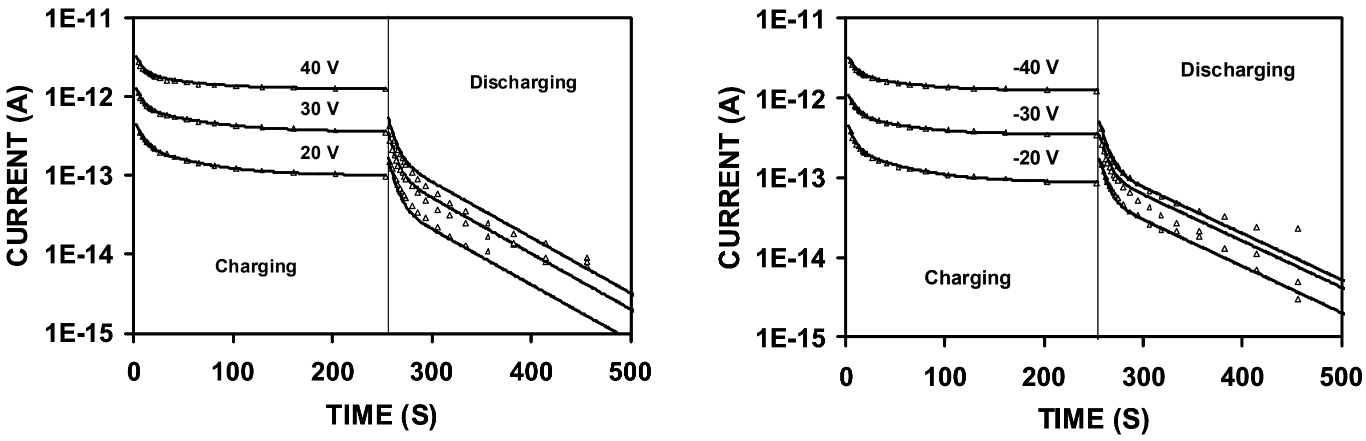
where ΔQ^J is the steady-state charge density of the *Jth* species of trap, τ_C and τ_D are charging and discharging time constants, t_{ON} and t_{OFF} are the on and off times of the switch corresponding to the charging and discharging times.

Model Parameters

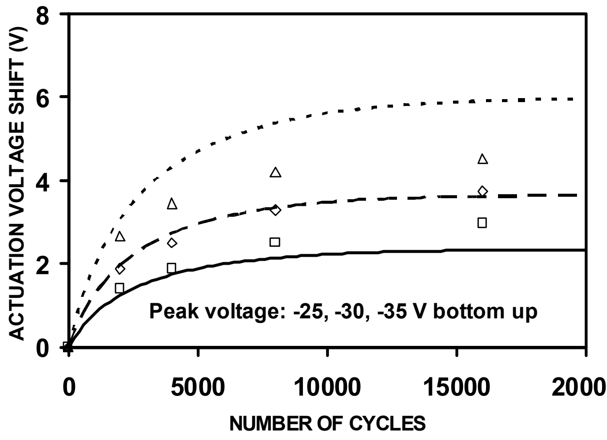
POSITIVE				
J	τ_C(s)	τ_D(s)	ΔQ_0 (cm^{-2})	V_0 (V)
1	6.6	6.8	3.1× 10^{10}	12.9
2	54.3	61.6	1.6× 10^{11}	14.9
NEGATIVE				
J	τ_C(s)	τ_D(s)	ΔQ_0 (cm^{-2})	V_0 (V)
1	6.5	7.0	2.4× 10^{10}	11.7
2	52.5	74.7	6.0× 10^{10}	10.5



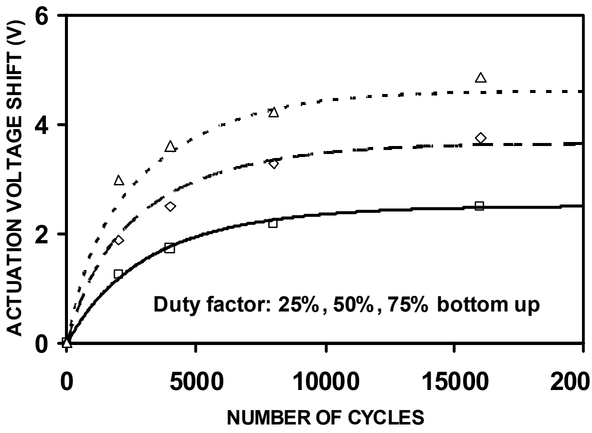
(left) Trap 1 (□) charging and (+) discharging and trap 2 (Δ) charging and (x) discharging time constants and (right) (symbols) extracted and (lines) fitted steady-state charge densities for (□) trap 1 and (Δ) trap 2 under -40, -30, -20, 20, 30, and 40 V. The time constants show no significant bias dependence whereas the steady-state charge densities are exponentially dependent on the control voltage.



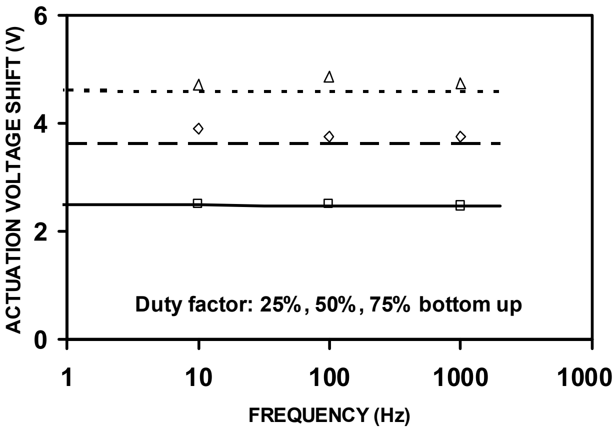
(symbols) Modeled and (lines) measured transient currents are in good agreement under both (left) positive and negative control voltages.



Voltage Acceleration



Duty Factor Acceleration



Frequency Independence

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