Non-obtrusive lifetime characterization technique for RF-MEMS

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**RF-MEMS cantilever switch**

![RF-MEMS cantilever switch diagram]

**Why do we need non-obtrusive characterization technique?**

- Simulation of a typical characterization procedure for RF-MEMS lifetime using consecutive stress-measure cycles, comparing expected $\Delta V_{PO}$ with (Measured) and without (Actual) measure step. The device is said to have failed when $\Delta V_{PO}$ exceeds a preset value of 10V.
- Characterization using stress-measure cycles yields pessimistic estimates of device lifetime.

Other non-obtrusive characterization techniques for dielectric charging:

1) Kelvin Probe Force Microscopy (KPFM) (U. Zaghloul et al., JVSTA, 2011)
   - Requires exposed dielectric surfaces.

2) Optical resonance detection (J. W. Lee et al., JMEMS, 2010)
   - Requires optical access to the membrane.

3) Center-shift method (R. W. Herfst et al., ICMTS, 2006)
   - Sensitivity and accuracy in determining $\Delta V_{PO}$ is unknown.

**Measurement setup and simulation**

- Capacitance of the cantilever RF-MEMS device is measured with varying AC measurement frequency. Resonance frequency (FRES) is determined as the frequency of peak in measured capacitance.
- From simulations, FRES is found to decrease with increasing VG (spring-softening effect) and increasing dielectric charge (increasing $\Delta V_Q$).
- The complete electronic nature of this characterization technique opens possibilities for measurements on packaged devices, as well as for in-situ implementation of degradation detection circuits.

**Resonance frequency measurements**

Measurement of capacitance-frequency characteristics of a packaged RF-MEMS switch for different gate voltages ($V_G$) and voltage shifts due to dielectric charging ($\Delta V_Q$) were performed to obtain resonance frequencies for each operating conditions. The obtained measurement data is found to have trends similar to those obtained from simulations.

Dielectric charging (represented by $\Delta V_Q$) is characterized by a downward shift in $F_{RES}$ for a given $V_G$.

**Lifetime determination**

- Determine RF-MEMS lifetime from measured transient of $\Delta F_{RES}$.
- Determine $\Delta V_{PO}$ for a given measured $\Delta F_{RES}$.