Modeling of Dielectric Charging in RF MEMS

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Basic simulation method involves self-consistent solving of

\[ \nabla^2 \phi = \frac{4Q}{\varepsilon} \]

Transport equation: \( \frac{dQ}{dt} = f(Q, \phi) \)

**Reliability concerns** – Dielectric charging and degradation, leakage currents, stiction, surface roughness, dielectric heating.

**Motivation** - Integrating different physical models to address reliability concerns with increased confidence.

**Limitations of existing work**
1. Use of Empirical models based on experiments
2. Overdependence on unphysical fitting parameters
3. Nature and distribution of dielectric traps
4. Dielectric degradation and breakdown
5. No space charge variation taken into account

**Proposed approach**

Electro-mechanical response of membrane

Surface properties and degradation

Charging dynamics

**Charging dynamics – Model approach**

A SONOS flash memory cell is a very similar system

SiO₂

SiO₂

Si₃N₄

Substrate

**Planim for experiments**

**Phase 1 – Fixed membrane devices**
1. Determine \( Q(z) \)
2. Determine band properties like workfunctions
3. Calibrate spatial and energy distribution of traps
4. Measure dielectric degradation with applied voltage and temperature stress

**Phase 2 – Moving membrane devices**
1. Determine \( Q(x,y,z) \)
2. Calibrate effect of surface roughness
3. Verification of computational model

**Surface roughness**

Modeling of surfaces using fractals to predict spatial variation of charge density


**Charging current – Transport issue**

- S. Melle, David De Conto (LAAS-CNRS)


Dominant conduction mechanism is Frenkel-Poole

**Distributed dielectric charging** – Poisson issue


Resultant downward force on the membrane is not zero, even for zero charge in the dielectric.

Effect of negative dielectric charge

Note: SRAV = Shift Rate of Actuation Voltages

**Dielectric charging – Transport issue**

- Xiaobin Yuan, Zhen Peng, J.C.M.Hwang (Lehigh)


\[ Q = \sum Q_j \left[ 1 - \exp \left( -f_{0,5\sigma} / \tau_{0,5} \right) \right] \exp \left( -f_{0,5\sigma} / \tau_{0,5} \right) \]

**Membrane response – Simple model**

\[ F_{sp} = m \frac{d^2 y}{dt^2} = F_{el} - F_{sp} - b \frac{dy}{dt} \]

**Plans for experiments**

**A SONOS flash memory cell is a very similar system**

Surface roughness

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