

Characterization and Modeling of Dielectric Charging in CMOS MEMS



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Electrostatically actuated CMOS MEMS devices (*e.g.*, resonators, inertial sensors) are potential solutions for a variety of commercial and defense applications. One barrier to adoption of these MEMS devices in high-precision applications such as navigation is signal drift due to environmental factors and device non-idealities. Charging in dielectrics of the device is one non-ideality with potentially severe impacts on performance, leading to signal drift, electrostatic pull-in, and decreased device lifetime. Methods of eliminating parasitic charge or mitigating its effects have been proposed, which include biasing techniques and fabrication processes. Predictive models that describe the charging are a critical component of the MEMS design process; studying and modeling charging behavior will enable assessment of new topologies, fabrication processes, and biasing techniques to reduce or compensate for the effects of parasitic charging on resonator performance.

Recent work is focused on the characterization and modeling of charging behavior in the metal-dielectric stack of CMOS MEMS devices, *e.g.* a micro-cantilever (Fig. 1). It is hypothesized that as the electric field applied across the electrostatic comb fingers is modified, dielectric charge on the fingers moves, changing the effective bias across the comb. This mobile charge, in combination with a bias sensitivity in the comb fingers, causes frequency drift of greater than 1000 ppm over several hours (Fig. 2). Analytic evaluation of physical dielectric conduction mechanisms (*e.g.* Frenkel-Poole conduction, ionic conduction) in combination with analytical and finite element analysis models are employed to understand the charging behavior and to inform the design of stable, drift resistant resonators, accelerometers, and gyroscopes.

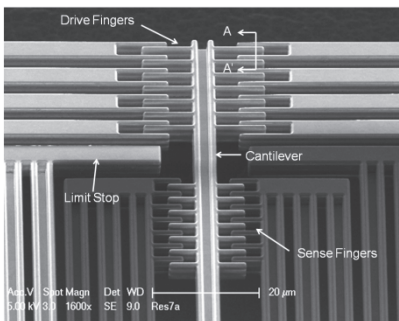


Figure 1: An SEM image of the cantilever resonator with length of 120 μm , width of 4 μm , thickness of 4.7 μm , and finger gap of 0.8 μm . The cantilever is actuated in plane.

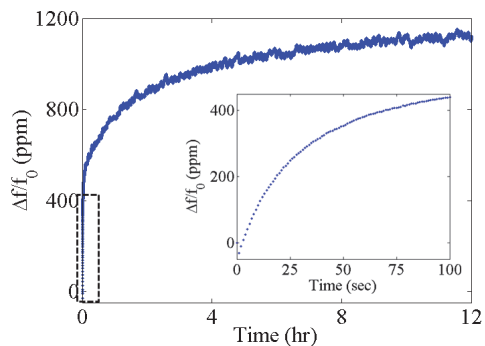


Figure 2: A plot of frequency drift over 12 hours. The bias on the resonator is stepped from ground to 15 VDC and held while resonant frequency is measured once per second.