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On the Impact of Relative Humidity and Environment Gases on Dielectric Charging Process in Capacitive RF MEMS Switches Based on Kelvin Probe Force Microscopy

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Dielectric charging is among the major reliability issues that have prevented the commercialization of RF-MEMS Capacitive switches in spite of the extensive study performed on the topic. Moreover, a little work has been performed to study the effect of the relative humidity (RH) and environment gases on the dielectric charging process.

In this work we present the effect of RH and the environment gases on the charging/discharging processes in PECVD silicon nitride films based on Kelvin Probe Force Microscopy (KPFM) methodology. The measurements have been performed in ambient air and under N₂ flow, both under different RH levels (from 6% to 40% RH). In addition, the influence of the dielectric film thickness, SiN deposition conditions and the substrate nature on the charging process have been investigated under different environment conditions. This has been done through depositing SiN films with different thicknesses ranges from 100nm to 400nm over bare silicon substrates and over evaporated Au layers and using both Low Frequency(LF) and High Frequency(HF) PECVD deposition modes.

For both measurements performed in ambient air and under N₂ flow, the surface potential decay with time follows the stretched exponential law. The decay time constant decreases strongly as the RH increases (1.230E+03 sec and 650 sec for 6%RH and 40%RH respectively, for the HF 200nm thick SiN film deposited over evaporated Au). The measured decay time constant is found to be shorter in case of N₂ than in ambient air measurements. The surface potential distribution is represented by the Full Width at Half Maximum (FWHM) for charges which have been injected in a single point with the AFM tip. The FWHM becomes smaller as RH decreases. Charge injection duration is controlled to range from 10 ms to 100 sec. The FWHM is found to be always larger in air comparing to FWHM measured in N₂ flow for different charge injection durations. Moreover, FWHM increases almost linearly with increasing the charge injection time for different RH measurements. Charge lateral diffusion has been observed at larger RH only and is attributed to the more hydrophobic SiN material at smaller RH levels which prevents water condensation at the surface and thereby inhibits lateral charge migration due to the electrical conductivity of a possible water film. The FWHM is found to be smaller in thinner SiN films than in thicker ones and the relaxation time is found to be larger in the thinner SiN films, independently of the substrate nature. Finally, the decay time constant is found to be smaller in case of dielectric films deposited over Au layers comparing to films deposited over bare silicon substrates.