

APPLICATION NOTE

Charging of dielectric materials in MEMS

Detecting local charges and charge diffusion with scanning probe microscopy

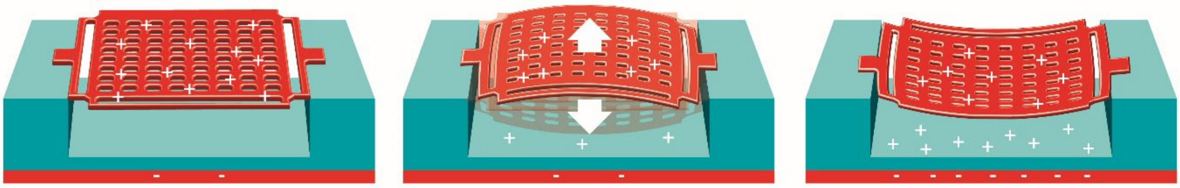

Fig. 1: Schematic of the switching principle of a MEMS device.

In many electronic devices one of the reliability issues is charge transfer between different materials in the device. An example of such a device is a MEMS (Micro-Electro-Mechanical Systems) switch, which is largely used in wireless communication products like cell phones or headphones. In such a MEMS switch, the high electric field between the metal electrodes can result in charge injection in the dielectric layer that separates the electrodes (see figure 1). This can lead to irreversible sticking of the electrodes. The charges and their stability can be detected with Scanning Probe Microscopy, a technique that allows for local measurement of electrical properties with high spatial resolution.

Scanning Probe Microscopy

Various techniques exist for electrical characterization of electronic devices, which yield information on the overall performance of a device. However, in modern micro- and nanotechnology it is often desired to measure electrical properties of individual, very small objects from which the devices are built. Scanning Probe Microscopy (SPM) allows for such measurements, with a spatial resolution down to the nanometer scale. SPM techniques are based on detecting the interaction between an atomically sharp tip and a surface while scanning the tip over the surface. A well-known SPM technique is Atomic Force Microscopy (AFM) for visualizing surface topography with nanometer resolution. However, topography is not the only property that can be obtained. Over the last three decades a wide range of SPM techniques have emerged, which allow the measurement of physical and chemical properties on the nanometer scale. Electrical properties like potential, current, resistance and capacitance can routinely be probed with SPM nowadays.

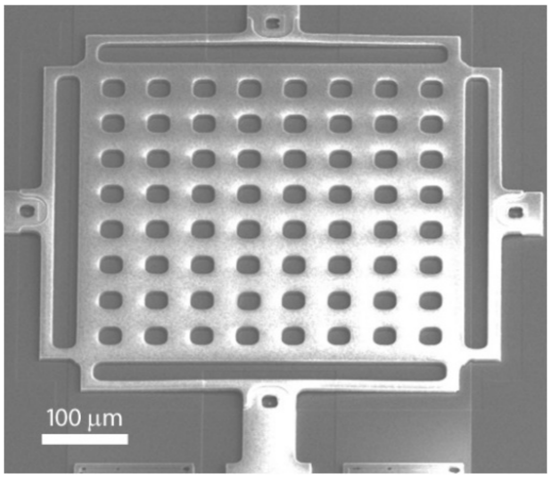

Fig. 2: SEM image of a MEMS capacitive switch showing the device with the top electrode still present.

Detection of charges in a MEMS switch

To investigate the charge distribution in the Si_3N_4 dielectric layer of a MEMS capacitive switch (see figure 2), a high voltage was applied to such a switch until the onset of stiction of the electrodes. Then, the top electrode was removed and the surface potential of the Si_3N_4 layer on the bottom electrode was measured with Scanning Kelvin Probe Microscopy (SKPM), one of the SPM techniques for electrical characterization. The magnitude of the measured surface potential is

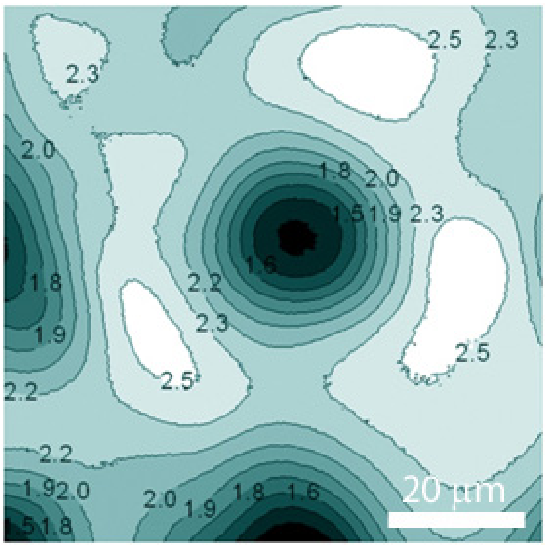

Fig. 3: Surface potential of the Si_3N_4 dielectric layer on the bottom electrode of a MEMS capacitive switch after operation.

directly related to the amount of charge present. The result is presented in figure 3.

One can recognize the locations where the holes in the top electrode have been, by the lower surface potential at these locations (dark areas). No charge was injected there. Furthermore, it can be seen that the charge distribution is laterally inhomogeneous, with several 'hot-spots' (white areas) with larger amounts of trapped charge.
Additionally, it was investigated how permanently the charge is trapped in the dielectric material. Therefore, the surface potential was recorded along a single line, as a function of time. The result is presented in figure 4, which, besides a gradual decrease of the potential at the maxima, also shows an initial increase of the potential at the minima.

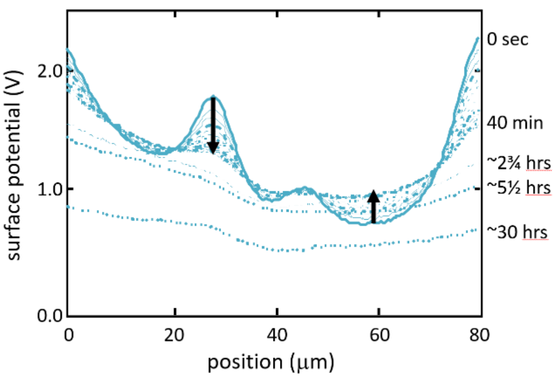

Fig. 4: Surface potential along a line on the Si_3N_4 dielectric layer as a function of time.

Thus, changes in the surface potential are dominated by lateral diffusion of the charge. After several hours, the surface potential also decreases at the minima, showing that on a longer timescale charge leakage back into the metal bottom electrode occurs.
Knowledge of this charge distribution and diffusion behavior can help in improvement of the device.