Wafer-Scale Electroactive Nanoporous Silicon - Large and Fully Reversible Electrochemo-Mechanical Actuation in Aqueous Electrolytes

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The datasets presented here belong to an investigation of electrochemical actuation of porous silicon immersed in different electrolytes. A thin film of porous silicon, with a thickness below 1 µm, is fabricated on the top of a bulk silicon wafer with a thickness of approximately 100µm and an electrically insulted backside. The sample is shaped in a cantilever geometry. It is electrically contacted, immersed into an electrolyte solution inside an electrochemical cell and installed into a "Multi-Optical Stress Sensor" setup. Here, a laser array is reflected off the smooth backside of the sample into a CCD detector. Through the measurement of the spacing of the laser array a bending of the sample can be detected.

When a potential is applied to the porous silicon sample by a potentiostat, anions from the electrolyte solution accumulate on the internal surface of the porous silicon pore walls. Vice versa, when the potential is reversed, the opposite can be measured – the anions are dispersed off the porous silicon pore walls. Through the anions, a surface stress is enacted onto the porous silicon pore walls and a film stress develops in the porous silicon thin film as a whole. The film stress leads then to a bending of the whole sample, as the expanding or contracting thin porous silicon film is clamped by the underlying bulk silicon. The bending can be measured by the above described setup and quantitatively analyzed by the Stoney equation.

The capacitive behavior of the sample is analyzed by cyclic voltammetry (CV) measurements in perchloric acid ($HClO_4$) electrolyte in the potential range of 0 to 0.9V with different scan rates from 10 to 200 mV/s. The respective measurements are in the file "porous silicon\HClO4\CV HClO4 10-200mV-s.txt". A measurement of the film stress and the incorporated charge, normalized to the outer volume of the porous silicon film, which accompanies the CV measurement conducted with 10mV/s can be found in the file "porous silicon\HClO4\Actuoric HClO4 film-stress-charge-potential.txt". Instead of a linearly changing potential, as is the case in the CV measurements, a rectangular, instantly changing potential is applied in the measurement filed in "porous silicon\HClO4\Step Coulombmetry HClO4.txt".

Furthermore, the effect of a different electrolyte is studied with an isotone saline solution (154 mmol/L sodium chloride (NaCl) in water). An equal capacity analysis with CV measurements can be conducted with the measurements in file "porous silicon\NaCl\CV NaCl 10-100mV-s.txt" and an actuation measurement can be found in file "porous silicon\NaCl\ Actuoric NaCl film-stress-charge-potential.txt".

Lastly, the effect of anion accumulation and dispersion on the surface stress is also studied on a flat bulk silicon sample. Here, the caused surface stress of the accumulated anions directly translates to a

bending of the sample. The respective measurements can be found in “bulk silicon\CV bulk silicon HClO4 10-50mV-s.txt” and “bulk silicon\Actuoric bulk silicon HClO4 surface-stress-charge-potential.txt”.