

Homework Assignment #6

Due by online submission by **Friday 10/29/2021** (late Saturday 9 am)

1. In Go & Pohlman (reference [Go10]), they plot measured breakdown voltage vs. electrode gap for many different MEMS structures. The data are taken from many different research papers. As they write, “Fig. 3 highlights the complexity of breakdown at the microscale, where general trends are common but quantitative data are heavily dependent on the electrode geometry, material, and surface roughness.”
 - a. In Figure 3, given all of the different data sets, what is the largest safe voltage (no breakdown in any data set) with a 5um gap? With a 1um gap?
 - b. In Figure 4c, the data sets from references 19 and 24 are for silicon-silicon gaps, which generally have higher breakdown voltages than metal-metal or silicon-metal gaps. For those two data sets, what is the largest safe voltage with a 5um gap? With a 1um gap?
 - c. From Figure 4c, make a table for the data from reference 19, with a column for the gap, the breakdown voltage, and an estimate the electric field at which the devices broke down.
2. In reference [Chu97],
 - a. What is the approximate average vertical etch rate in microns/minute of bulk silicon in XeF₂ (see Figure 5) in the first 15 seconds? In the first 360 seconds? You can use any size aperture you like.
 - b. In figure 8, which structures etched fastest in the first two pulses, the 50um, 200um, or 800um square openings? What about after 12 pulses? What might account for the difference, and the shape of the etch front of the 800um aperture after 12 pulses?
3. In reference [Hamzah12],
 - a. From Figure 1, estimate the etch rate of a mixture of equal parts of 49% HF, 69% nitric, and acetic acids.
 - b. In Figure 13, estimate the radius of curvature at the tip
4. In reference [Brockmeier12],
 - a. In figure 5, cross-sections AA and BB are on the wafer with the standard CMOS orientation and flat. Other than ~54 degrees, what other sidewall angles are possible, what combination of mask layout and processing is necessary to get them, and what crystal planes define them?
5. Coventor problem

[Go10] Go, Pohlman, "[A mathematical model of the modified Paschen's curve for breakdown in microscale gaps](#)", J. Applied Physics, 2010.

[Chu97] Chu et al., “Controlled Pulse Etching with Xenon Difluoride”, Transducers 97, <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=613739>

[Hamzah12] Hamzah et al. “Optimization of HNA Etching Parameters to Produce High Aspect Ratio Solid Silicon Microneedles” J. Micromechanics and Microengineering, 2012
http://iopscience.iop.org/0960-1317/22/9/095017/pdf/0960-1317_22_9_095017.pdf

[Brockmeier12] Brockmeier et al. “Surface tension and its role for vertical wet etching of silicon”, J. Micromechanics and Microengineering, 2012
http://iopscience.iop.org/0960-1317/22/12/125012/pdf/0960-1317_22_12_125012.pdf