Measuring the development of stress in Silicon during Ar⁺ ion bombardment.

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**Background**

Using a 250eV Ar⁺ ion beam, we bombarded silicon samples and formed nanoscale ripples and patterns on the surface. Our research was conducted in an ultra high vacuum chamber, operating at pressures as low as 2e-4 torr, and the chamber was designed such that we could change the angle of incidence inside the chamber. Our group used a Plasma Bridge Neutralizer (PBN), in an attempt to take care of a possible charging problem. As the Si we are using has been doped, charge should flow through it. However, during an initial split second it might bend due to charge accumulating on it, disrupting our measurements.

**Methods**

**MOSS**

The MOSS setup in our lab, the laser enters the Ultra High Vacuum chamber and is reflected off of the Si sample during bombardment. The etalon splits the laser into several beams.

**Results**

![AFM of Si bombarded at 60° with PBN (2.2nm RMS roughness), by Peco Myint](image)

At roughly 2000 seconds into bombardment, the sample undergoes tensile stress.

- **60° with PBN**
- **60°**

**12° without PBN**

The sample undergoes compressive stress before reaching its steady state.

**0° without PBN**

Early on into the bombardment, the sample undergoes compressive stress, then reaches its steady state.

**Discussion**

We bombarded the samples for between 40 minutes and two hours; taking data every second or so gave us between 2,400 to 7,500 data points. Our data is in register with previous experiments; tensile stress was observed at the high angle, 60° and compressive stress was observed at angles nearer to normal incidence.

The 60° graph shows a period of relative stability for approximately 15 minutes before the stress slowly trends downwards, reaching its lowest point at over an hour into bombardment, before reaching its steady state at a lower level of tensile stress.

The 12° bombardment showed an almost immediate trend towards compressive stress and began plateauing soon after, at roughly 15 minutes into bombardment.

The 0° bombardment showed results similar to that of Dr. Perkinson, shown below. It peaks at roughly 0.9 GPa after only a few minutes of bombardment, however our data is somewhat different in that Perkinson’s drops much lower after the peak, whereas our graph plateaus at only 0.2 GPa below its peak.

As the ions reaching the Si are plasma, they can heat the sample rapidly so we used water cooling to keep the sample at 20° C and alleviate thermal expansion which can disrupt our curvature measurements. Also, we created an ultra high vacuum where Ar⁺ ions reach the sample without colliding air molecules, by using a roughing pump followed by a turbo. Lastly there were problems with the charging of the sample, occurring in an initial split second when charge would accumulate and cause the sample to bend, and we tried to solve this problem using the PBN, as well as placing the Si on a conductor.

**Equations**

\[ \sigma_{avg} = \frac{1}{(1 - \frac{1}{R_0})} \frac{E_h h_f^2}{6(1 - v_h)h_f} \]

*Equation 1: Stoney’s Equation*

\[ \frac{1}{R} = \frac{\delta d}{E \delta (\cos \alpha)} \]

*Equation 2: Curvature Equation*

**References**

[1] Chason, Eric. Conversion of beam deflection measurements to curvature: angle of incidence correction for different array geometries, Brown University, Providence, RI.


**Acknowledgements**

We would like to thank Dr. Joy Perkinson for designing and giving us her ‘Frankenstein’s Monster’ Ultra High Vacuum chamber, and Elise Erickson for her help with collecting data. Lastly, we thank the Boston University Research in Science and Engineering Program for providing us with this opportunity.