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ENGR 241

Addressing Grassing and Overetch in SiO2 Hard Mask

Introduction:

The motivation of our ENGR 241 project was to discover a method for a clean dry etch of Indium Antimonide. InSb has long relied on a wet etching process, which effects the size and quality of the etched features. In order to create smaller and higher quality features, we wanted to find a process that created a smooth anisotropic etch of InSb. Going into the project, we knew we would encounter problems with, as there has been little success in literature to dry etch InSb due to difficulty of creating volatile byproducts in the etching process and its low melting point.

When designing our experimental process, we decided that it would be best to use an SiO2 hard mask because of its favorable selectivity over Shipley 3612 photoresist and SiN hard mask. Hard mask etching was done by the Oxford-RIE instrument and InSb etching by the Oxford-35. While running through our DOE, we immediately noticed considerable line edge roughness (LER) and top surface roughness in our InSb substrate after Ox-35 Etching, preventing our project goal of a smooth etch of InSb to being realized.

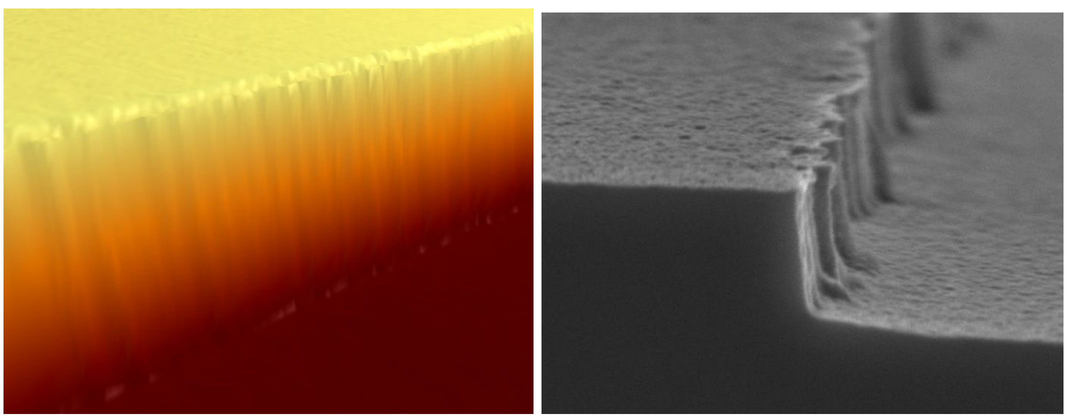

Figure 1 and 2: Line Edge Roughness seen in AFM and SEM Imaging

Going into the fabrication process, it would have been beneficial to understand where this problem comes from before carrying out so much of our DOE and how it could be addressed going forward. In the following paper, we will provide advice and tips for using the OX-35 and OX-RIE etchers to avoid such roughnesses.

Solution:

The Oxford-35 etcher is an inductively coupled (ICP) reactive ion etcher used on III-V semiconductors. This dry etching process relies on the formation of a plasma with reactive species that strikes the substrate to form a reactive byproduct, etching away areas of the substrate that are not covered by hard mask or photoresist. In our experiment, we relied on the OX-35 etcher to etch away areas of our InSb substrate not covered by a SiO2 hard mask. However, we experienced issues with the LER and surface roughness, creating roughness on the sidewalls and trenches of our substrate. As we went on through the quarter, we learned how to address these problems and create smooth and clear features using OX-35.

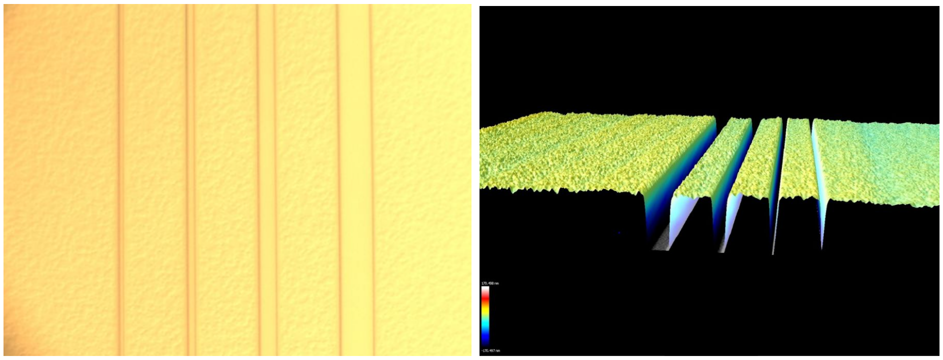

Figure 3:Optical Microscope image and S-neox Profilometry of top surface roughness

Issues we encountered with surface roughness was the byproduct of many issues that are associated with learning how to use the etcher. In the case of top surface roughness, we used an SiO2 hard mask that was much too thin and was being etched through by the OX-35 etcher. This caused the piece itself to be bombarded by the ions from the OX-35 plasma, which damaged the substrate on the surface of the piece. A solution to this was to look closer into the etch rates of the processes in both the CCP and OX-35, where the rate depends heavily on the surface chemistry, which changes with each recipe. Our solution was to more closely measure etech rates from each step and process and to also create a thicker hard mask which would not be etched through by the OX-35 process. This solved the issue with the top surface roughness.

Another more challenging issue we encountered was that of the LER. After discussing our results with our mentors Jim McVittie and Usha Raghuram, we noticed that many samples with this LER and grassing issue were seen in recipies which had a low and non-integer number flow rate of the inert gas species (i.e. 3.5), argon in our case. Our mentors were concerned that the species was not flowing accurately and this was preventing sputtering from occuring with the argon. This inaccurate flow rate was due to the rate being non-integer and less than 10% of the maximum flow rate of the etcher, 50 sscm in the OX-35 for argon. After increasing the flow rate of our inert gas species to a minimum of 10% of the flow rate maximum and increasing RF bias dramatically, we noticed smoother falls and trenches, as figure four highlights.

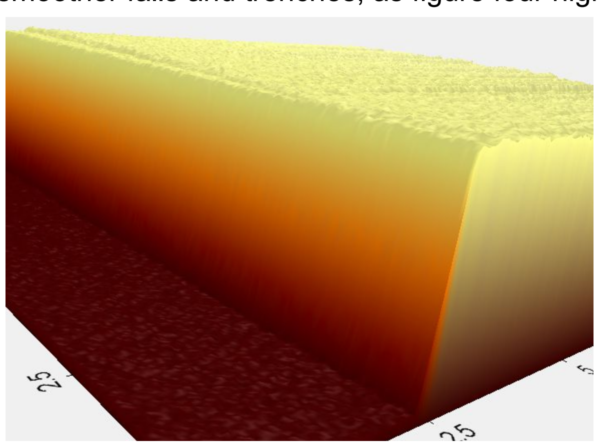

Figure 4: Smooth sidewalls and trench after increased Ar flow rate and RF bias