Multi-Functional Platform for Characterization of Nanostructured Polymer Brushes

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Abstract:

Polymer brushes have been of interest because of their unique ability to act as a functional coating. The unique structure of polymer brushes allows them to be used for several applications including antifouling, cell adhesion, resistance to nonspecific binding, and biosensing. With the realized applications of polymer brushes, it has become more important to understand their fundamental structure and the resultant stimuli-responsive behavior. This project aims to create a way to observe the polymer brushes at the molecular level by putting polymer brushes onto the sidewalls of diffraction gratings. Once successful, completed observation can be done on the macro scale by observing the diffraction of light through the gratings, and on the molecular scale by observing the scattering of neutron beams across the sides of the diffraction gratings. These measurements are exemplified in Figure 1. By successfully utilizing photolithography and subsequent multiple etching steps pattern transfer on a sandwich structure to create our multi-functional platform, the base platform has been created and the process to reaching this goal has been furthered.

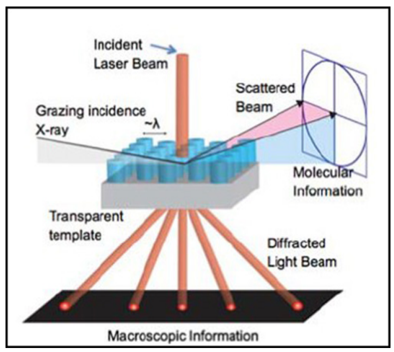

Figure 1: *Diagram showing how laser diffraction and neutron beam scattering can be used to gain macroscopic and microscopic information on the polymer brushes grown on the multi-functional platform.*

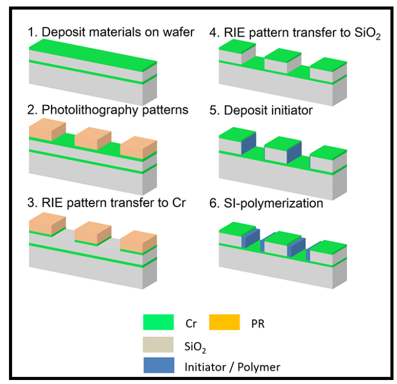

Figure 2: *Wafer development process to create the multi-functional platform.*

Summary of Research:

The focus of this summer's research was on developing a multi-functional platform which could be used to characterize nanostructured polymer brushes. As shown in Figure 2, this was done by developing a sandwich structure on top of a fused silica wafer that could be manipulated through photolithography and etching to create a structure, which only had silicon dioxide exposed on the sidewalls of the structure. Since the small molecule initiator, which is for the polymerization of polymer brushes, can only bind to hydroxyl groups, it will only bind to the sidewalls that have exposed silanol groups. This in turn creates a structure which only has polymer brushes on its sidewalls after polymerization. The structure was characterized with atomic force microscopy (AFM), scanning electron microscopy (SEM), and laser diffraction. These characterization techniques were also used throughout the fabrication process to correct problems along the way and to determine whether the process was being completed successfully.

Results and Conclusions:

In the end, this process was completed successfully as determined using AFM, SEM, and laser diffraction. The multi-functional structure was made so that a diffraction grating was created. As shown in Figure 3a and 3b, this structure was proven after a beam of green laser light with 532 nm was diffracted when shown through the

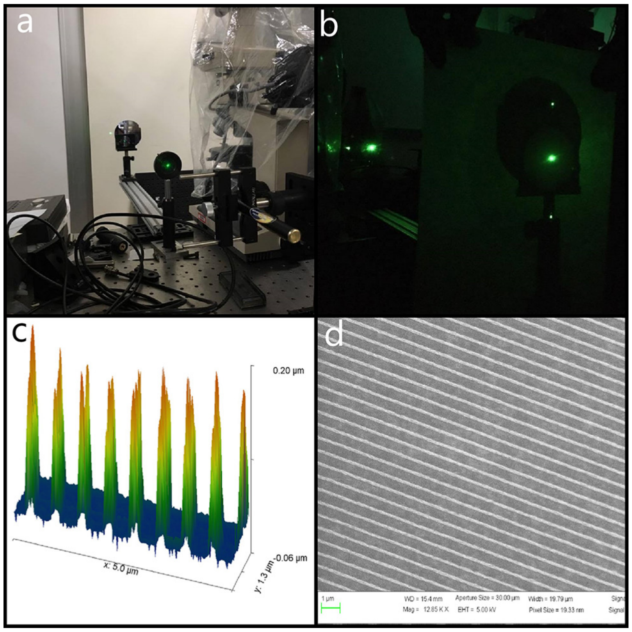

Figure 3: a) the laser diffraction setup b) a laser being diffracted by the final structure of the multi-functional platform c) An AFM image of the pattern on the final structure form d) An SEM image of the pattern on the final structure form.

pattern. Figure 3c and 3d further support this conclusion by showing the diffraction grating through their imaging process. During the creation of the platform it was found that layer uniformity, layer cleanliness, wafer flatness, and ARC/Resist type and coating were all very important to the success of the structure. After completing the process, it was determined that layer uniformity and wafer flatness both worked together to counteract the advances made in photolithography. With a high numerical aperture, it was necessary for the overall shape of the wafer to be very homogeneous and uniform. To fix this, the numerical aperture was lowered and the chromium was coated with a plasma bias which made deposition denser and more uniform. The problem of layer cleanliness was fixed by cleaning and seasoning the chamber of the Oxford plasma enhanced vapor deposition (PECVD) before depositing the silicon dioxide onto the wafer, and by cleaning the wafer before each layer deposition with a hot piranha clean. After trying both negative and positive resists and several types of anti-reflective coatings (ARC), the resist UV210-0.6 was used with the ARC DUV-42P.

The successful completion of this project now allows for a more comprehensive observation and understanding of polymer brushes to be reached which would have never been reached had such a platform never been created. Figure 4 shows what the completed structure looks like.

Future Work:

Using this multi-functional platform, experiments can now be done which isolate the polymer brushes to the sidewalls of the structure which will ultimately enhance our knowledge of polymer brushes and how they work. Initiator will be deposited onto the structure and if it only attaches to the sidewalls like it is supposed to, polymer brushes will be grown here and laser diffraction as well as neutron beam scattering experiments will be able to be done on them. If it is found that the initiator does not only bind to the sidewalls but other areas as well, then the structure will be re-evaluated and recreated in a way that allows us to achieve this structure with silicon dioxide only exposed on the sidewalls. Using laser diffraction and neutron beam scattering information, the study of several different types of polymer brushes can be completed. From the greater understanding of polymer brushes given by these studies, research can be done on applying polymer brushes to their realized applications and to developing new ways that they could be used.

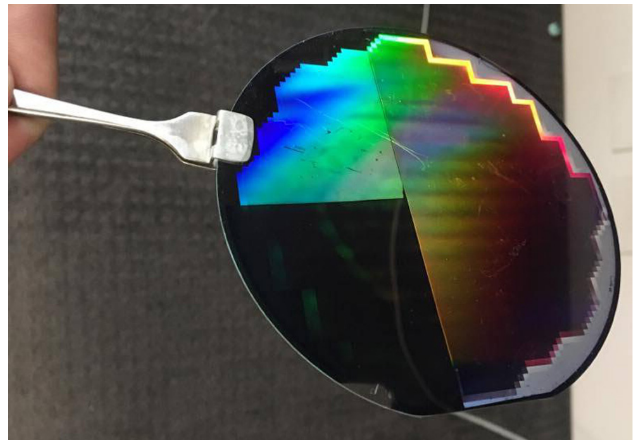

Figure 4: The multi-functional platform after its process completion. Differences in chrome etch time were measured on this wafer but the top half portion is where the pattern was successfully developed and processed.

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