Characterization and Optimization of ZEP520A Electron Beam Lithography Resist

Nathan Olds, Physics and Electrical Engineering, University of Washington

NNIN REU Site: Microelectronics Research Center, Georgia Institute of Technology
Principal Investigator: Kevin Martin, Microelectronics Research Center, Georgia Institute of Technology
Mentor: Devin Brown, Microelectronics Research Center, Georgia Institute of Technology
Contact: nolds@u.washington.edu, kevin.martin@mirc.gatech.edu, devin.brown@mirc.gatech.edu

Abstract:

The goal of this project was to determine the ultimate nanometer pattern resolution in ZEP-520A electron beam resist. E-beam lithography was done using a JEOL JBX 9300FS system. Thickness measurements of ZEP-520A were taken using a Woollam Ellipsometer, Tencor KLA Profilometer, and a Veeco Atomic Force Microscope (AFM). Line edge and surface roughness were compared across a range of E-beam doses using the AFM. E-beam dose was compared to the depth and clarity of trenches of varying dimensions drawn in AutoCAD and written in ZEP-520A. Exposed resist was developed using ZED-N50. Trenches of 18 nm were demonstrated previously. Resolving 10 nm trenches was the specific goal in achieving the maximum resolution of ZEP-520A.

Introduction:

Electron Beam Lithography (EBL) is a method to create nanoscale patterns in resist-coated wafers. A positive resist undergoes chain-scission and becomes soluble. A negative resist reacts to electrons by crosslinking or becoming insoluble. A solvent is used to dissolve away exposed soluble areas of a positive resist or leave behind the exposed insoluble areas on a negative resist. ZEP-520A is a positive electron beam resist suspended in Anisole, hence the A.

Characterization of ZEP-520A involved determining what thicknesses of ZEP-520A were coated onto 3" silicon wafers given a certain dilution and RPM. The optimization of ZEP-520A involved choosing a spin speed, thickness, e-beam parameters, and dilution corresponding to the clearest and most properly resolved features.

Procedure:

This project involved gathering thickness and trench-width data of a 4 to 1 dilution and a 3 to 1 dilution of ZEP-520A after writing features in the resist. Several different tools were used for resist measurements and comparisons made. Thicknesses were measured via KLA Profilometer, Woollam Ellipsometer, and Veeco AFM. Widths of features were also measured using an AFM and Scanning Electron Microscope (SEM).

The first part of this project involved collecting data on thickness variation as two dilutions of ZEP-520A were spun at 2000 to 6000 RPM. Two vials of 3 and 4 parts Anisole to 1 part bottled ZEP-520A were diluted using an electronic scale. These dilutions were dropped onto 3" silicon wafers using a 0.2 µm filter. Wafers were individually coated and then spun at different speeds. Immediately after being spun, wafer were placed on a hot plate, set to 180°C, for 90 seconds. They were then removed and cooled by the ambient cleanroom temperature. Resist thickness was first measured on the Woollam Ellipsometer. Each wafer was then scratched to reveal the silicon substrate for a KLA Profilometer second measurement. Once measured, the data was compiled into a Microsoft Excel spreadsheet with the resultant graphs shown in Figures 1 and 2.

AFM measurements were taken after writing and developing trenches with the e-beam and ZEP-520A developer respectively. Only the 3:1 dilution of resist spun at 3000 RPM was used in the AFM thickness measurement.

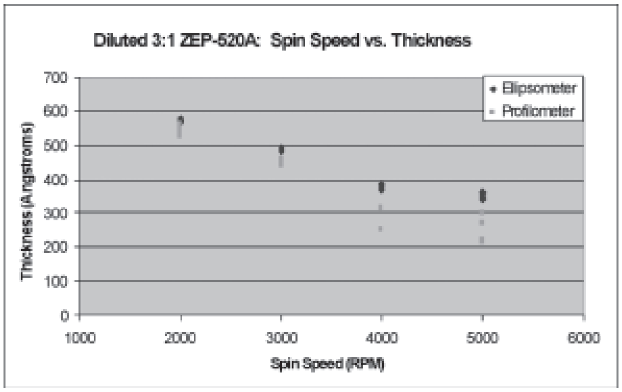
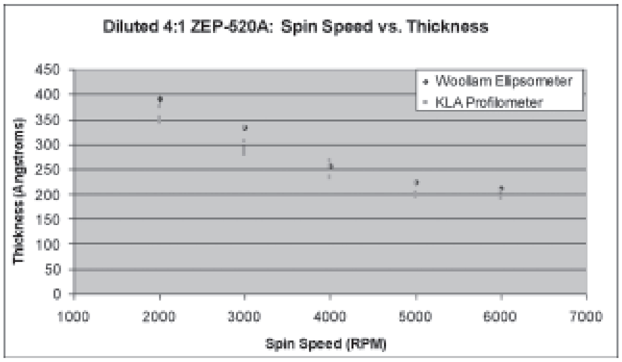


Figure 1, above: Speed vs. thickness for 3:1 dilution of ZEP-520A.

Figure 2, below: Spin speed vs. thickness for 4:1 dilution of ZEP-520A.



An AutoCAD drawing, consisting of several lines per dose and line width, was converted to GDSII format by a program called LinkCAD. Dose vs. depth for ZEP-520A is shown in Figure 3.

SEM imaging was also done on a line patterned in AutoCAD to be 10 nm. This was written by programming the JEOL JBX 9300FS with a 10 nanoamp beam current for a relatively fast exposure. This fast exposure resulted in the data shown Figure 4.

Results and Conclusions:

For EBL it is important to understand how spin speed affects the thickness of ZEP-520A resist layers. Spin speeds were compared, for a 3:1 dilution and a 4:1 dilution, to their resulting thicknesses as shown in Figures 1 and 2. These data were used to determine which spin speed corresponds to which thickness of resist in order to optimize the development process.

Measuring resulting trench depth across several doses compared the clarity of developed lines or trenches. AFM measurements of how resist depth compared to electron beam dose are compared in Figure 3. Assuming the 10-20 nm AFM tip was significantly narrower than the trench width, this data would show the dose at which features start to resolve. The 30 nm data or dark blue data in Figure 3 shows this resolution of trench depth to occur around 700 $\mu C/cm^2$.

The project goal was to resolve features smaller than 20 nm. An attempt to make a 10 nm line using very fast settings and a 10 nanoamp beam current resulted in a line about 52 nm wide as shown in Figure 4.

Future Work:

Future work could involve optimizing exposure of the e-beam or using dose correction software. Setting up the e-beam to run more precisely involves narrowing the beam to a minimum spot size of 4 nm or possibly using dose correction software. Several parameters are bundled up into the term "dose". Varying many of these can result in the same dose and possibly a different line width. Further optimization could involve working more directly with 9300FS software to modify these parameters. Different dilutions of resists could also be used, maybe 5:1, although 4:1 dilution at 6000 RPM left areas of uncoated wafer.

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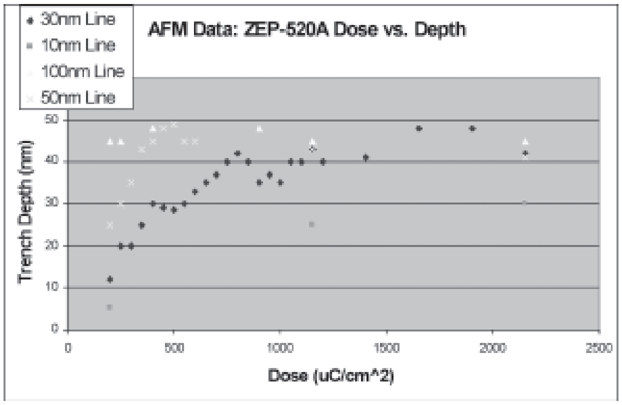

Figure 3, above: Veeco AFM trench depth variability with several incremented doses by 50uC/cm2.

Figure 4, below: 3:1 dilution of ZEP-520A trench width measurement using SEM of 10 nm line attempt as 52.42 nm measured.