Characterization of a New E-Beam Resist

Brian Fetzer
5th Year Microelectronic Engineering Student
Rochester Institute of Technology

ABSTRACT

Waycoat HEBR-214 Positive E-beam resist was characterized for coating properties, thickness vs. dose, and thickness vs. development time. For a thickness of .5 um, resist sensitivity was 65 uC/cm2 for a 2 minute develop, and 20 uC/cm2 for a 4 minute develop. Contrast was 6.28, which promises good resolution. Dry etch selectivity of the resist over oxide and over poly-silicon was attempted, but poor results were obtained.

INTRODUCTION

As lithography tolerances, linewidth and registration, continue to decrease, electron beam (E-beam) exposure systems will become increasingly popular in direct write applications while maintaining it's dominance in maskmaking. E-beam systems exhibit better registration, due to the maskless nature of exposure, and they have better resolution than UV systems since E-beams aren't diffraction limited. There are, however, problems that exist in current E-beam technology which limit their practicality in a manufacturing environment. Included among these are the high cost of the system itself, lower throughput than UV systems, and image transfer limitations. The image transfer limitations occur because smaller critical dimensions require an anisotropic (RIE) etch, and traditional E-beam resists have demonstrated little dry etch resistance. The low throughput in E-beam systems is a result of the slow, direct write mechanism employed for exposure, but can be improved by using a more sensitive resist. A MEBES system has recently been donated to RIT, so the need exists to characterize the resist(s) that will be used in the system.

Currently, some negative e-beam resists exhibit dry etch resistance, but negative resists suffer from other problems, mainly that of image swelling and the need for organic solvents. In most negative resists, exposure yields an insoluble cross-linked polymer. The swelling occurs in the process of dissolving the unexposed polymer, as the solvent penetrates the exposed area and is unable to escape, resulting in swelling. The main problem with organic solvents are that they are a safety hazard and require special disposal procedures. An aqueous base developer would solve many of these problems.

Olin-Hunt has manufactured Waycoat HEBR-214. Information about the chemical structure of the photoactive component in this resist has not yet been released because it remains proprietary information. It is known that it is a novolak based resist that is developable in an aqueous base. This is very similar to the NQD-novolak resist formulation that is common in industry. Because of these similarities, the chemistry involved in the exposure of NQD will be discussed with the assumption that it is similar to this E-beam resist. The NQD-novolak mixture begins as a dissolution inhibitor in aqueous base. Upon exposure to a wavelength of light the resist is sensitive to, nitrogen gas(N_2) is evolved from the photoactive component(NQD). For NQD-novolak systems, Wolff rearrangement occurs, which gives a ketene. The ketene reacts with water to give an indene carboxylic acid, which is a dissolution accelerator in an aqueous base.

Characterizing a resist includes finding the relationships between resist thickness vs. exposure as well as resist thickness vs. development time for a given coating thickness. The best way to find these relationships is to develop thickness versus develop time curves for each exposure dose. Once these curves are done, a dose versus development curve may be created, as well as characteristic curves. From a characteristic curves, resist sensitivity as well as contrast may be found.

A final important parameter that needs to be found is that of dry etch selectivity to both oxide and poly-silicon. This is important because resolution of the etched image is not only a function of resolution of the resist, but also of the image transfer capabilities. Therefore, to obtain vertical sidewalls and maximum image transfer, dry etching must be used. Therefore, the resist must not only have good resolution capabilities, it must also offer good dry etch resistance so that the developed image doesn't wash out while undergoing dry etch.

EXPERIMENT

Before characterization can be done, the wafers must be prepared, which, for this experiment included scrubbing and cleaning the wafers in APM and HPM. About 5000 A of oxide was then grown, which completes the preparation.

To obtain coating characteristics, HMDS was spun on all wafers at 5000 RPM for 30 seconds, followed by the desired spin speed for 30 seconds. The spin speeds tested were 3000,4000,4300,4600,4900,5000,6000 RPM. The spinner was calibrated at each point using the strobe light. After each spin, a softbake was done at 100 C for 30 minutes, then resist thickness was measured on the Nanospec using program 11 (positive resist on SiO_2).

A wafer was coated with HMDS and then resist at 4500 RPM, then softbaked for 20 minutes. The wafer was then cleaved into squares, which were mounted onto SEM sample holders, and baked

another 10 minutes at 100 C. Beam current was measured using a Faraday cup , and the area scanned was measured using the stage micrometer, and from these scan time was calculated for each dose. Samples were placed in the Cambridge SEM and scanned for the appropriate time, with 3 identical doses per sample being exposed. Exposure was done on the SEM at a potential of 25 KeV, a magnification of 200, and the third largest spot size. Doses exposed were 10,20,30,40,50,60,80 uC/cm2. The samples were each developed in Waycoat LSI developer until an image appeared, at which time the sample was rinsed, dried and measured. Then another development step was done for 30 seconds (followed by a rinse,dry, measurement), and these steps were continued until the resist cleared.

The samples were then hard-baked for 20 minutes at 110 C, then mounted to a wafer with silver paint, then baked for 10 more minutes at 110 C. Resist , oxide, and polysilicon thicknesses were measured on the Nanospec using existing programs. The samples were then etched in the Tegal 700 for 1 minute in CHF3, followed by thickness measurements, and another etch. This continued until 10 minutes of etch time had been completed.

RESULTS/DISCUSSION

Figure 1 shows the thickness vs. spin speed data, and from the graph, it appears that a spin speed of about 4500 RPM will yield a .5um thick resist, which was the desired thickness.

Beam current in the Cambridge SEM was measured to be I=1.8nA/cm2 for a potential of 25 KeV,the third largest spot size, and a magnification of 200. The area scanned was measured to be .00452 cm2. From these numbers, and the desired dose, scan time was calculated, as shown below:

Exposure Dose(uC/cm2)	Scan Time(seconds)	Time to Clear(sec)
10	25.1	---
20	50.2	228
30	75.3	204
40	100.0	188
50	125.5	165
60	150.6	135
80	200.8	113

Time to clear ranged from 228 seconds for a dose of 10 uC/cm2 down to 113 seconds for a dose of 80 uC/cm2. No time to clear was found for the 10 uC/cm2 dose as, after 9 minutes of develop, no image had yet formed, so it is possible that this dose is not high enough to generate the photochemical reaction which acidifies the resist. Figure 2 is a plot of resist thickness vs. development time for each dose. This plot shows a few stray points, but the general trends do emerge. A plot of times to clear as a function of exposure dose can be seen in Figure 3, which shows an almost linear plot, as expected. By finding the thickness of each dose at a specific development

Figure 1: Spin Speed Curve

E-Beam Resist Waycoat HEBR-214

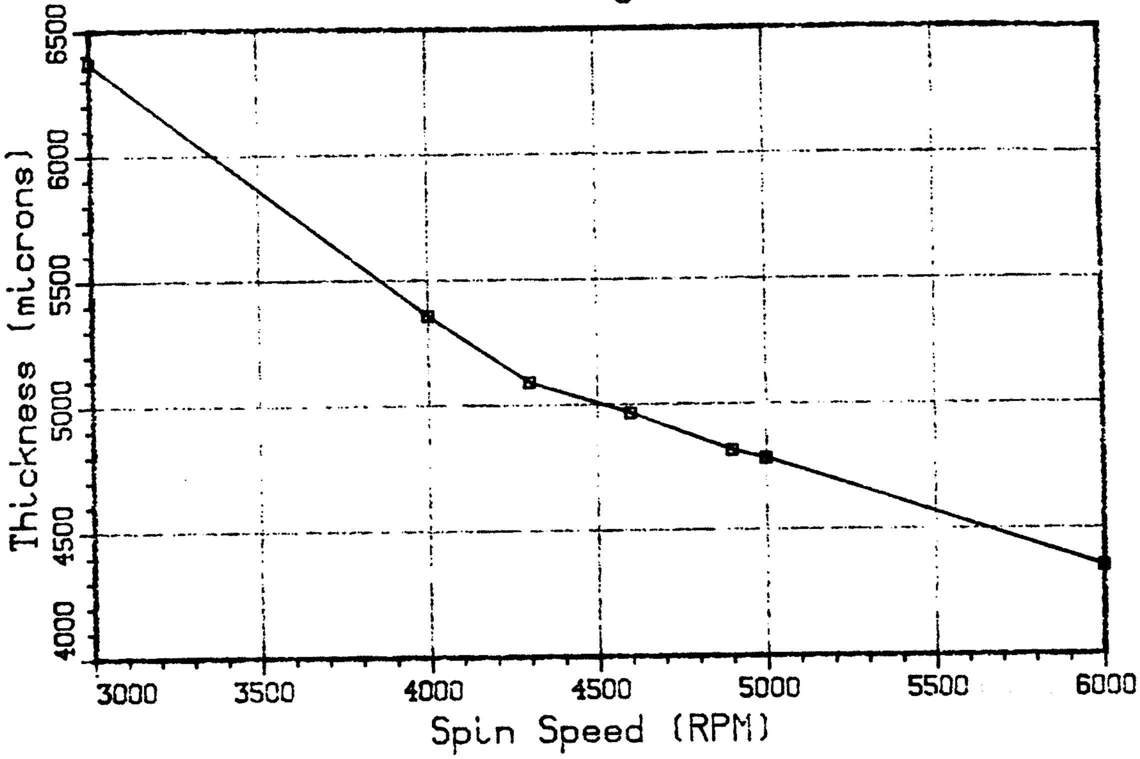
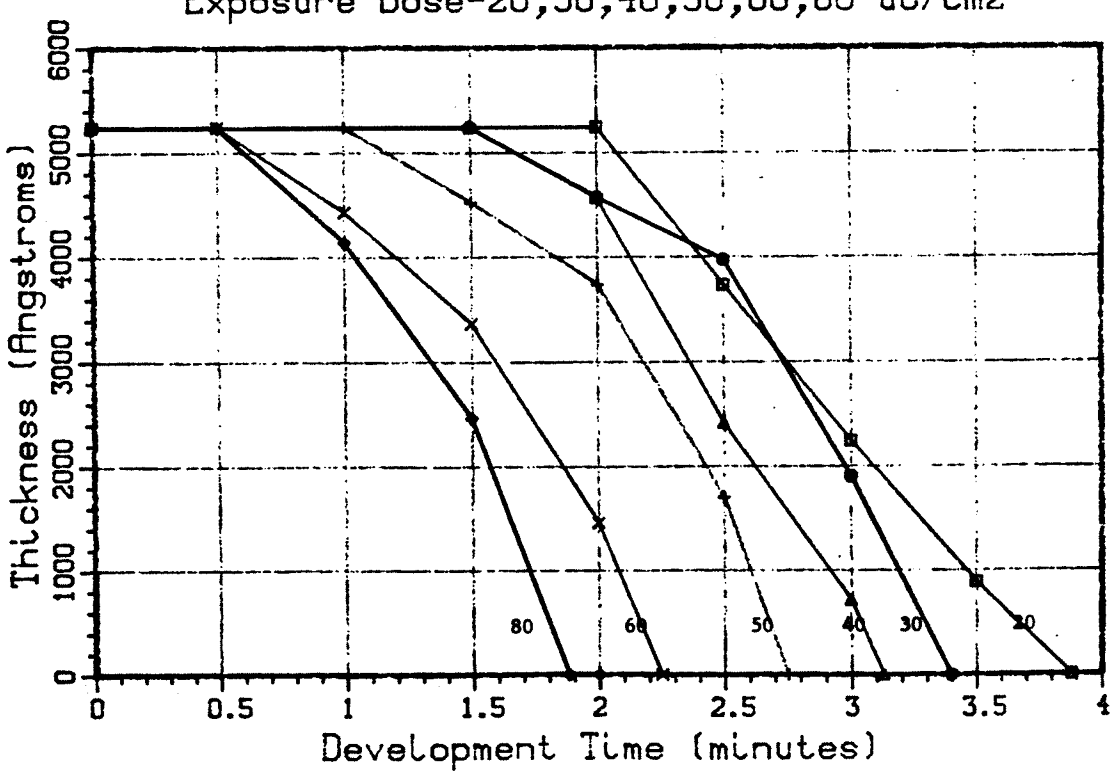


Figure 2: Thickness vs. Development Time

Exposure Dose-20,30,40,50,60,80 uC/cm2



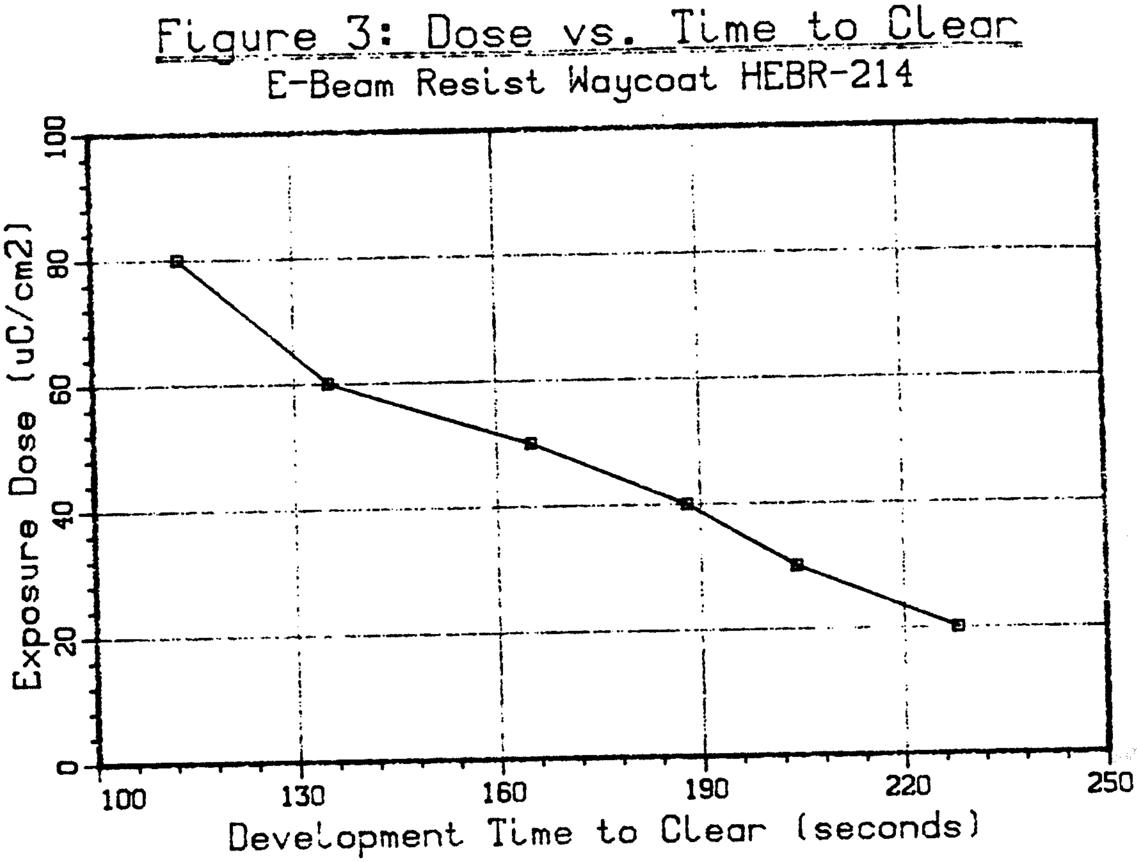


Figure 3: Dose vs. Time to Clear
E-Beam Resist Waycoat HEBR-214
Exposure Dose (uC/cm2)
0
20
40
60
80
100
100
130
160
190
220
250
Development Time to Clear (seconds)

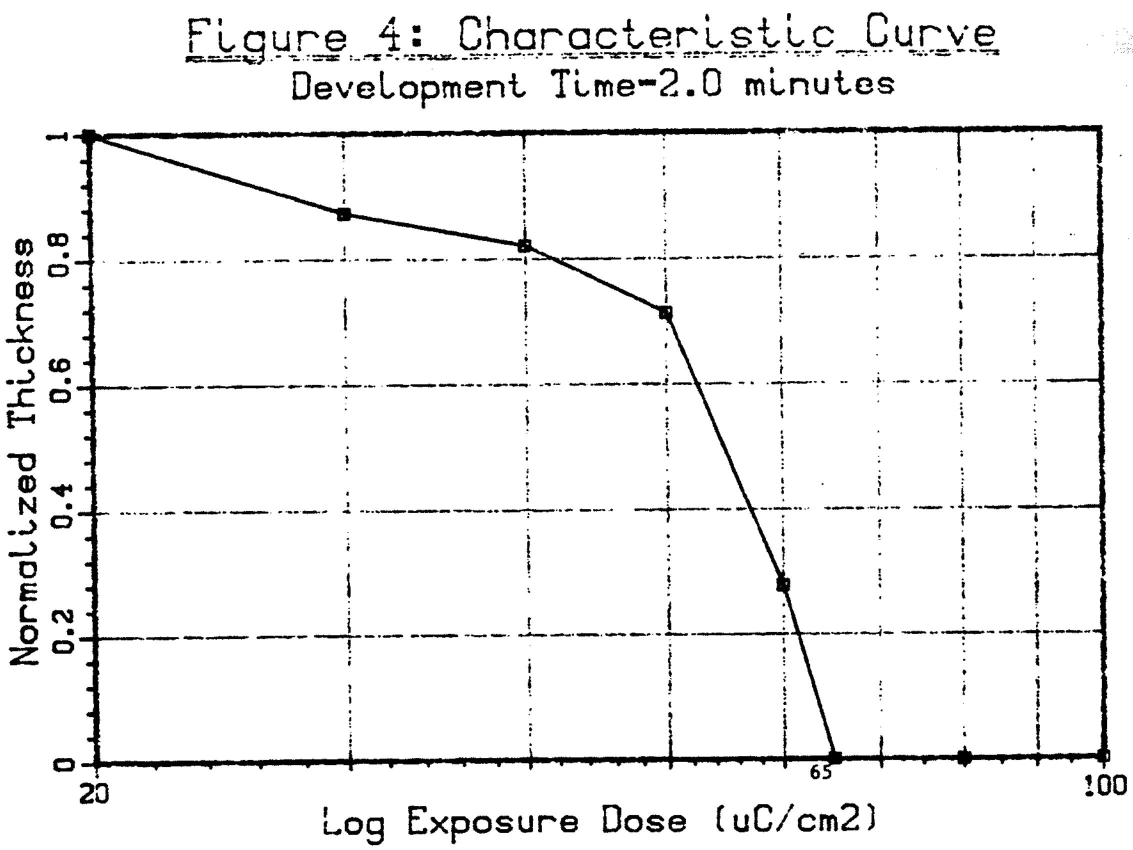


Figure 4: Characteristic Curve
Development Time-2.0 minutes
Normalized Thickness
0
0.2
0.4
0.6
0.8
1
20
65
100
Log Exposure Dose (uC/cm2)

time, a characteristic curve (Figure 4) can be made, which shows a sensitivity of 65 uC/cm2 for a 2 minutes develop, and contrast calculated from this curve was 6.28.

The dry etch selectivity portion was unsuccessful, as the resist etched away within 2 minutes in CHF3, and neither the oxide or polysilicon had begun to etch after 10 minutes of etch time, so there was definitely a problem with the Tegal or my operation of the etcher. A possible cause to these problems would be if oxygen was in the etch chamber, or it could be polymer build up causing the oxide and poly to resist the etch.

CONCLUSIONS

From this project, many favorable resist parameters were found. First, the resist showed excellent coating characteristics, as no problems with adhesion or nonuniformity were found. The resist showed a sensitivity of 65 uC/cm2 for a 2 minute develop, and a sensitivity of 20 uC/cm2 for a 4 minute develop. A contrast of 6.28 was found for a minute develop, which should lead to high resolution capabilities. The resist showed poor selectivity to both oxide and polysilicon, but this must have been a problem with the etch process, and not the resist itself.

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