Development Rate Monitor: Process Integration and Resist Parameter Extraction

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Abstract — Development rate measurement (DRM) analysis yields very accurate resist modeling parameters. A procedure for extracting these parameters was instituted for the Perkin-Elmer DRM tool at RIT. New software packages for the DRM tool and ProDRM simulations were used to extract development rate parameters for current i-line resists. The process established will be repeated for future resists.

I. Introduction

As optical lithography is being pushed to its limits from every direction, resist modeling and simulation are becoming more and more important. DRM analysis easily yields accurate and reliable modeling parameters for any new resist. These parameters are used in the simulation software to give very good descriptions of the resist behavior.

The DRM tool analyzes the reflected interference patterns of the resist in real time during development. Through a known refractive index the thickness versus time curve can be plotted for each of 15 different exposure doses. Development rate versus depth into the resist is extracted for use in ProDRM software. This software package, provided by FINLE Technologies, analyses the development rate versus PAC concentration and extracts the following resist development parameters:

R_{max} = development rate of fully exposed resist
R_{min} = development rate of unexposed resist
M_{th} = threshold relative PAC concentration
n = developer selectivity

II. Preliminary Process

There had not been a procedure developed for using the DRM tool at RIT since new PC based software made the tool more practical to use. Prior to gathering any data a few items had to be addressed. Since primarily i-line resists exposed with the Canon 2000-i1 stepper will be used for this process it was necessary to retrofit the DRM machine to handle six-inch wafers. This was done by a simple modification to the wafer holder. It was also necessary to write a job for the Canon 2000-i1 i-line stepper designed for this experiment. Another initial item was to reconfigure the DRM tool optics. The reflected light had to be correctly aimed into the detector. Finally a few test runs were necessary to eliminate any questions concerning the operating procedures for the DRM tool and software. Once the preliminary considerations were complete the DRM tool was then operational for use.

III. Data Collection and Analysis

The wafer coating process generally followed the process specified by Shipley, the resist manufacturer, for the individual resist under test. First the wafers were given a dehydration bake at 250° C for 90 seconds. HMDS was dispensed, spun off then baked at 100° C for one minute on a hot plate. The resist was then spun on at a rate that yielded a uniform and consistent thickness. The prebake and PEB time and temperature were both based on the recipe provided by Shipley for each of the two resists under test. The exposure was done using the Canon i-line stepper. The exposure consisted of 15 zones across the wafer, each zone with increasing dose. The development was done in the DRM tool.

The DRM tool recorded reflected intensity across the wafer throughout the development process. Data was recorded as the wafer was developed for twenty minutes. This length of development time was needed to establish the development rate of the unexposed resist. Figure 1 is an example of the raw data output from the DRM tool. The constructive and destructive interference nodes continue until the resist has been removed completely.

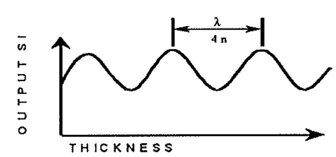

FIGURE 1 - Output Interference Patterns

The new PC based DRM analysis software was then needed to decipher the raw data. Each exposure zone was defined by the user. After completing the rest of the step by step procedure for the software a variety of plots can then be created. From the resist thickness versus develop time plot, shown in Figure-2, the development rate versus thickness can be calculated.

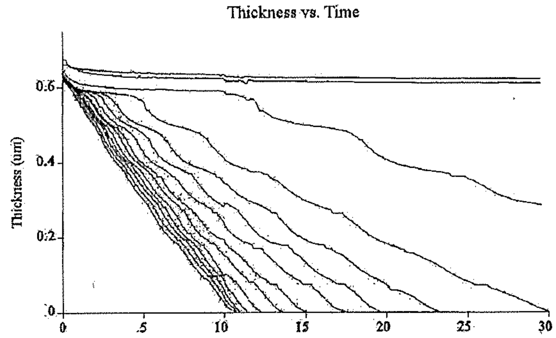

FIGURE 2 - DRM Output

The development rate versus thickness remaining data was then extracted and used in FINLE Technology's ProDRM software. Some manipulation of the DREAMS data had to be done so that it was in the proper format for the ProDRM analysis. A manual for this alteration is currently under development.

The ProDRM software uses ABC parameters that must be extracted prior to DRM analysis. These parameters describe the absorption characteristics and optical sensitivity. They describe the destruction rate of the dissolution inhibitor over time in the following Equation-1. [Dill]

$$\delta M / \delta t = - I(z,t)\, M(z,t)\, C \qquad \text{EQUATION 1}$$

From these parameters and the rate versus depth data from the DRM the ProDRM simulations can be done. The output of the ProDRM is a plot of the development rate versus PAC concentration (M). Figure -3 below shows this output plot. ProDRM also will match a curve to the data. From the best-fir curve the four parameters shown are extracted. These parameters are the ones that are used in resist process simulations based on the Mack resist parameter model. The formulas used to fit the curve are shown below in the Equation -2. [Mack]

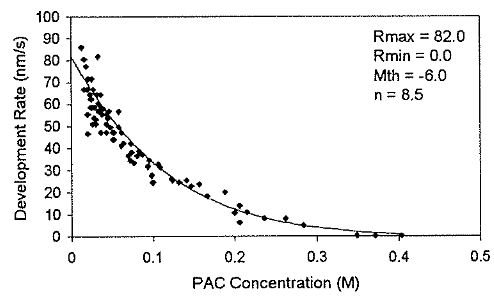

FIGURE 3 - ProDRM Output

$$\alpha = \frac{n+1}{n-1}(1-M_{TH})^n$$

$$r = r_{\max}\frac{(\alpha+1)(1-M)^n}{\alpha+(1-M)^n} + r_{\min}$$

EQUATION 2 - The Mack Model

The extracted parameters are defined as follows:

R_{max} = development rate of fully exposed resist
R_{min} = development rate of unexposed resist
M_{th} = threshold relative PAC concentration
n = developer selectivity

The two resists studied in this experiment yielded the following resist parameters. Included are the ABC parameters used in ProDRM to extract the final parameters.

	SPR-500	ULTRA-i 120
A	0.696	0.742
B	0.0666	0.1134
C	0.0298	0.0251
n (index)	1.703	1.703
Rmax	80	82
Rmin	0.35	0
Mth	-10	-6
n (selectivity)	6.0	8.5

IV. CONCLUSIONS

DRM will now be an ongoing project at RIT. New resists will continue to be characterized by this procedure. This procedure can easily be modified for negative as well as 248 nm resists. The data gathered will soon be made available on the internet. Semiconductor companies interested will be encouraged to download the parameters or even the raw data to use in their resist process simulations.

V. Key References:

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VI. Acknowledgements

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