Material and processing effects on the dissolution properties of thin resist films for high resolution lithography.

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According to the ITRS the long-term lithographic requirements for year 2010 will be 45nm and for the year 2016 just 22nm. In order to keep the aspect ratio in a reasonable range (3:1), resist thickness should be significantly reduced: ~150nm for the 45nm technology node and ~70nm for the 22nm node. Recent studies revealed that the obtained profiles at thin resist films are different from the thicker films mainly due to the film quality after coating, the thermal processing conditions and in particular the development. In order to study in-situ the dissolution of thin resist films, a set-up based on white light interferometry was developed. Visible light is guided through a fiber optic on the film and after reflection it is directed to a spectrometer and recorded in real time. Using this set-up and an appropriate fitting algorithm, based on the interference function, the resist thickness vs. time is calculated.

In the present work, the dissolution of poly(methyl methacrylate) (PMMA) in a 20-300nm thickness range is studied. First results showed that in the case of ultra thin films of high molecular weights, dissolution proceeds smoothly after an initial surface inhibition period while thicker films present a more complex dissolution curve. In the case of low molecular weight (15K) the surface inhibition period is negligible and dissolution proceeds smoothly for the whole thickness range examined.

Methodology

The dissolution study was performed on a home made dissolution rate apparatus consisting of a transparent cell and two optical fibers at proper geometry. The sample is properly mounted on a holder inside a cell filled with the solvent of interest and the data acquisition was properly initiated at sample insertion. During all the experiments, the solvent was stirred with a magnetic stirrer. The white light, guided through one of the optical fibers, the cell window and the solvent, falls on the sample at near-normal incidence. The incident light covers the 470-780nm spectrum where the absorbance of cell, resist and solvent is negligible. The reflected signal from the substrate is directed through the other optical fiber to a PC drive spectrometer with a spectrum acquisition rate of 1 spectrum/sec rate and is finally recorded in the PC.

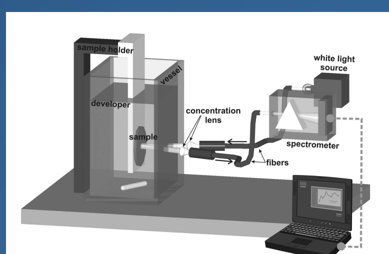
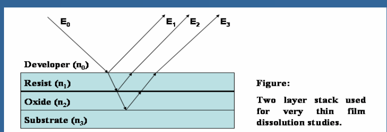


Figure 1: Experimental Dissolution Rate Monitor Apparatus.



Signal Intensity

$$E = X + Y\cos(2kn_1d_1) + Z\cos(2kn_1d_1 + 2kn_2d_2) + W\cos(2kn_2d_2)]$$

$$X = [r_{01}^2 + r_{12}^2(1-r_{01}^2)^2 + r_{23}^2(1-r_{01}^2)^2(1-r_{12}^2)^2]A^2$$

$$Y = 2r_{01}r_{12}(1-r_{01}^2)A^2$$

$$Z = 2r_{01}r_{23}(1-r_{01}^2)(1-r_{12}^2)A^2$$

$$W = 2r_{12}r_{23}(1-r_{01}^2)^2(1-r_{12}^2)A^2$$

n_i=refraction index

r_{ij}=relative refraction index

$$r_{ij} = \frac{n_i - n_j}{n_i + n_j}$$

Figure 2: Principle of Operation.

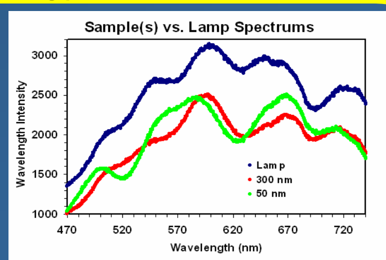


Figure 3: Spectrums from a) the white light source b) samples (SiO_2/Si) covered with 50nm and 300nm PMMA films.

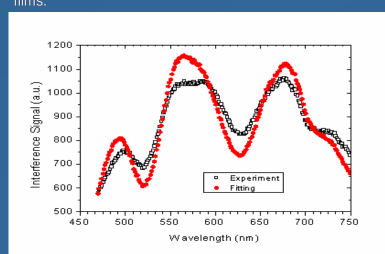


Figure 4: Experimental and simulation spectra for an instance of a dissolution experiment.

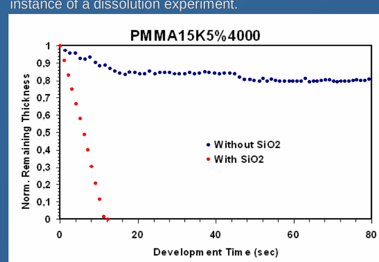


Figure 5: Dissolution curve of PMMA resist film with and without a transparent silicon dioxide film between the resist and the silicon substrate.

Applications

Unexposed PMMA films

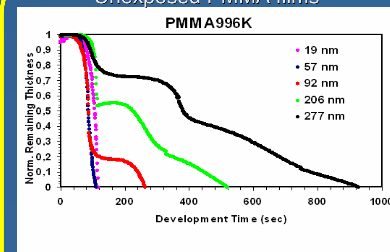


Figure 6: Dissolution curves of PMMA996K resist films in MIBK-IPA 1-1 developer.

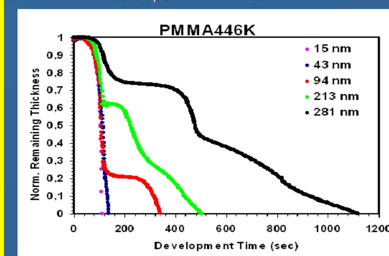


Figure 7: Dissolution curves of PMMA446K resist films in MIBK-IPA 1-1 developer.

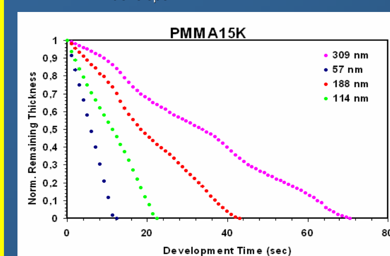


Figure 8: Dissolution curves of PMMA15K resist films in MIBK-IPA 1-1 developer.

Exposed PMMA films

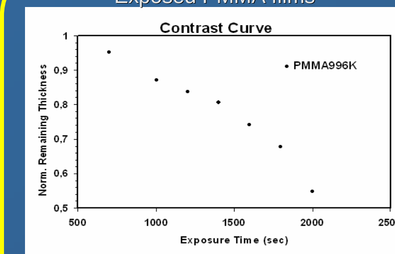


Figure 9: Contrast curve for PMMA 996K exposed with a broadband DUV source (Oriel). Development in IPA-H_2O 7-3 for 60sec.

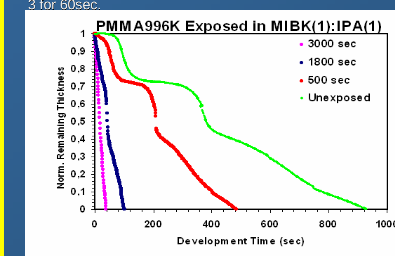


Figure 10: Dissolution curves of PMMA996K resist films in MIBK-IPA 1-1 developer for various exposure doses.

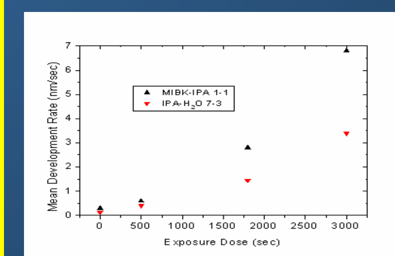


Figure 11: Mean development rate for PMMA (M_w = 996K) for a wide exposure dose range.

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References

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