

# i-line Resist Process Monitor

Joseph G. Perez  
Microelectronic Engineering  
Rochester Institute of Technology  
Rochester, NY 14623

**Abstract--** In order to confidently reproduce results obtained from experimentation or standard processing, the stability of the involved equipment's performance must be understood. Therefore, it is important to monitor, on a regular basis, the outputs of an equipment set which are delivering a desired process. In this paper, a qualification test or "qual" will be defined for RIT's 150mm i-line photolithography process which utilizes a Canon FPA 2000-i1 exposure tool.

## 1. INTRODUCTION

Currently RIT utilizes a g-line(436nm) lithography process for fabrication of devices with minimum feature sizes of 1 $\mu$ m. Recently, a Canon FPA 2000 i-1 stepper was donated to RIT. Transitioning to an i-line(365nm) process will enable research and academic instruction in sub-micron devices. This new capability for RIT is predicted by Rayleigh's formula for projection optics as follows:

$$R = k_1 \frac{\lambda}{NA}$$

where  $k_1$  is the process factor, typically  $\approx 0.7$ ,  $\lambda$  is the illumination source wavelength = 365nm for i-line, and NA is the numerical aperture of the system, which is 0.52 for this Canon stepper. With these values, the minimum feature size, R, is approximately 0.5 $\mu$ m.

This sub-micron capability has the consequence of smaller process windows. Therefore it is import to understand and monitor the parameters associated with producing 0.5 $\mu$ m features. This report will define a series of tests to monitor the parameters associated with reproducing sub-micron features consistently. A procedure for performing these tests, not included in this report, will be place in the clean room for reference.

## 2. CHARACTERISTICS

The practice of monitoring the performance of a piece of equipment or process is commonly referred to as a qualification, or "qual." A qual is performed on some interval found to be representative of the typical

performance associated with a tool or process. In this case, the qual was performed on a daily basis. For this qual the following parameters were monitored for RIT's i-line resist process:

### A. Hg-arc lamp intensity & field uniformity

The Hg(mercury)-arc lamp is the illumination source used in the stepper. There are several peaks in the Hg spectrum as shown in figure 1. The Canon FPA 2000 i-1 stepper is tuned to utilized the i-line peak at 365nm. The lamp intensity is monitored to understand the lifetime limitations of the light source. Although the lamp lifetime is specified as 1,500 hours of use, expenses to RIT can be reduced by monitoring the performance of the lamp and replacing it only as necessary based on process monitor data. Measurement of the lamp intensity is a utility performed using Canon's AUX IUC command.

### B. Resist thickness

Prior to lithographic patterning, the wafers are coated with photoresist. The thickness of photoresist is optimized based on the requirements of the pattern imaging, etch selectivity, and implant blocking. Therefore, it is important to monitor the thickness of the resist coating process, and determine if the variation is acceptable based on the requirements above. For the resist thickness monitor, the resist is measured on five locations(fig. 2) on the coated wafer using the Nanometrics Nanospec AFT-200.

### C. Ambient environmental conditions

Lithography is one of the few process in the fab where the wafers are processed out in the open. As such, the resist coating process, and to a lesser extent, the resist-exposure reaction are sensitive to fluctuations in the temperature and the humidity of the fab environment. Although there is no immediate control of these conditions, monitoring the temperature and humidity will allow correlations to be made regarding the impact of environmental conditions on the resist process. To monitor temperature and humidity in the fab, a digital

thermometer/hygrometer was mounted near the wafer track.

#### *D. Stepper focus*

Optimum focus is crucial to lithographic imaging. For a given device level, a focus setting is defined as an offset from the stepper system focus. By monitoring the stepper system focus, the accuracy of offset focus values can be ensured. Focus is determined as a result of exposing the coated wafer using the qual job. The focus evaluation array is located on the right side of the wafer. The focus job creates a "Christmas tree" pattern by exposing a  $0.5\mu\text{m}$  grating through a matrix of focus & exposure values. The location of the peak of the "Christmas tree" indicates a focus correction whereby right of center is a positive correction and left of center is a negative correction. See fig. 3.

#### *E. Dose to Clear ( $E_0$ )*

The dose to clear or  $E_0$  value is the exposure energy at which an open exposure field is completely cleared of resist. This value is sensitive to the interaction of the resist and developer chemistries and will be indicative of instability elsewhere in the process. The  $E_0$  array is located on the left side of the wafer. Fig 3 shows the qual wafer layout and indicates specific  $E_0$  dose values.

#### *F. Critical dimension (CD)*

The  $0.5\mu\text{m}$  CD feature is the primary parameter of interest in the i-line resist process. This might be the only lithographic parameter(excluding overlay) monitored during semiconductor and microsystems device fabrication. By monitoring the CD performance regularly as part of the qual, the history collected will allow for process excursions to be investigated and correlated to other parameters. The CD pattern is imaged on the qual wafer using the Canon 365 reticle. The  $0.5\mu\text{m}$  lines are then measured at five locations on the wafer as shown in fig. 3. The measurements are made using the Hitachi S-6780 CD-SEM.

#### *G. Data logging*

The data tracking system in use at RIT, MESA, allows only for lot data to be entered. At this time, equipment related data can not be tracked in MESA. Also, there are no other statistical packages available in the clean room to allow equipment data tracking. Therefore, paper logs are being used to track the data. A blank log sheet is shown in fig. 4. The raw data measurements are hand written at the bottom of the screen and then a data point is hand plotted on the graph above. Each data point is then connected to

form a trend chart. These logging sheets will be posted at each machine for ease of view ability.

### 3. RESULTS AND DISCUSSION

The qual was run and data collected on a daily basis from April 16 through May 4. Data points were logged once a day, except for April 20, where a continuous run of 7 wafers was performed in order to get an idea of wafer to wafer stability. Because of the small number of data points collected, statistical parameters were not calculated at this time.

Fig. 5 shows the temperature and humidity of the fab environment. Alone, this graph does not indicate anything except how well the building's environmental controls operate. However, when correlated to the resist thickness performance shown in fig. 6, there is evidence that fab environmental controls may need to be improved. This is further evidenced in fig. 7, where the  $E_0$  variation appears to show correlation to resist thickness variability that resulted from the instability in environmental conditions. Fig. 8 shows the  $0.5\mu\text{m}$  CD performance. For this graph, only the stability between measurement is meaningful. The optimum dose to size the  $0.5\mu\text{m}$  lines was not used because the CD-SEM was inoperative during the data collection portion of this project. All wafers were run at a dose of 150mj, and were stored until the SEM was available for measurements. Fig. 9 shows the performance of the focus test. This parameter, while not controllable must be track and corrected at every excursion. The last qual graph is the Hg-arc lamp intensity shown in fig. 10. Again this parameter is not controllable. This graph is used to track to lamp life time. As the lamp ages, the intensity degrades. Although the Canon specification for minimum lamp intensity is  $600\text{mW}/\text{cm}^2$ , for RIT budget reasons the lamp is run until lithographic performance degrades.

### 4. CONCLUSION

In this project, a series of qualification tests have been established. Regular monitoring of these qual results will allow the performance and capability of RIT's i-line lithography process to be understood. As more data is collected, statistical parameters can be calculated such as control limits and capability indices. Additional future projects relating to this work should include stepper overlay and stage precision monitoring, migration of data collection to MESA, similar testing for the g-line and DUV process, and continuous process improvement.

### ACKNOWLEDGMENTS

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## HIGH PRESSURE MERCURY VAPOR LAMP



A circle with five points labeled X1, X2, X3, X4, and X5. X1 is at the center, and X2, X3, X4, and X5 are on the circumference.

Fig.2

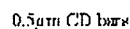
[illegible]

Fig.4 Blank Data sheet

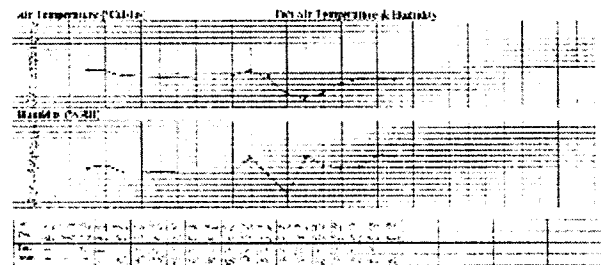


Fig. 5 Fab Temperature & Humidity

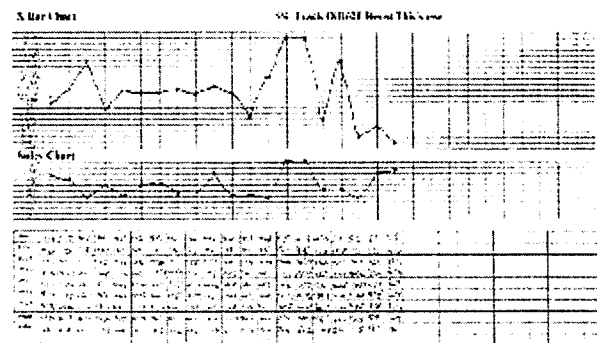


Fig. 6 Resist Thickness & Stdev.

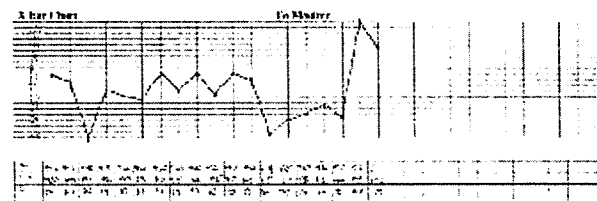


Fig. 7 Eo Monitor

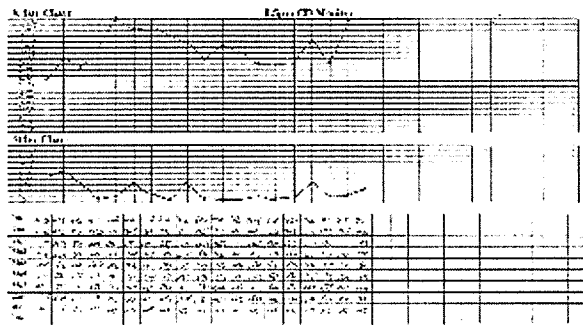


Fig. 8 0.5 $\mu$ m CD Monitor

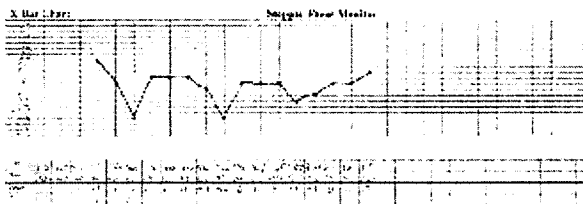


Fig. 9 Stepper Focus Monitor

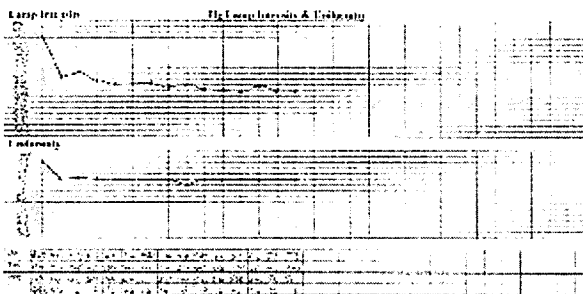


Fig. 10 Hg-arc Lamp Intensity & Uniformity