CHARACTERIZATION OF THE PERKIN-ELMER MODEL 140 PROJECTION ALIGNER EXPOSURE SOURCE AND MODELING OF RESIST PROFILES

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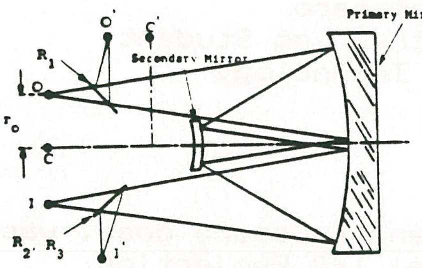
ABSTRACT

A correlation between scan speed and exposure dose, was obtained for the Perkin-Elmer Model 140 Projection Aligner to facilitate accurate resist profile modeling. A photovoltaic cell collector with filtering was mounted on a modified wafer chuck to acquire exposure data. The relationship between scan speed and exposure was found to be linear when plotted on log-log scale and predictable to within 5%. Lines of 1.4 um in Shipley 1400-27 resist and 1.6 um in KTI 820 resist were successfully imaged. Modeling of the scanner's output aerial image via PROSIM (Perkin- Elmer resist profile model) was performed with fair results.

INTRODUCTION

The Perkin-Elmer 140 Projection Aligner uses a scanning slit exposure system and 1:1 projection optics to create a uniform exposure capable of high resolution over the entire wafer surface. Figure 1-A shows the unfolded projection optics, and one should note that the image and object planes are conjugate planes located at a radius r . The optical system shown in Figure 1-B consists of a spherical concave primary mirror, a concentric spherical convex secondary mirror, and an array of three flat folding mirrors. The radii of the primary and secondary mirrors are adjusted to create an annular region of nearly perfect optical imagery for the object/image plane. The array of three flat folding mirrors is included so that the mask and the wafer may be locked together in a single assembly for a single direction scan.[1]

The projection optics used have several inherent advantages. The geometry promotes telecentricity evidenced by the parallelism of the principal rays to the system axis at each focal plane. This allows the mask plane to depart from the nominal object plane and system focus can be preserved as long as the wafer plane is displaced by the same distance from the nominal image plane. This is exactly the case as the mask and the wafer are locked on a single assembly. The all-reflective optics mean there are no color aberations and the entire spectrum of the illumination source may be utilized. Narrow band filters are not needed thereby avoiding the substantial light loss and interference effects caused by the filters.



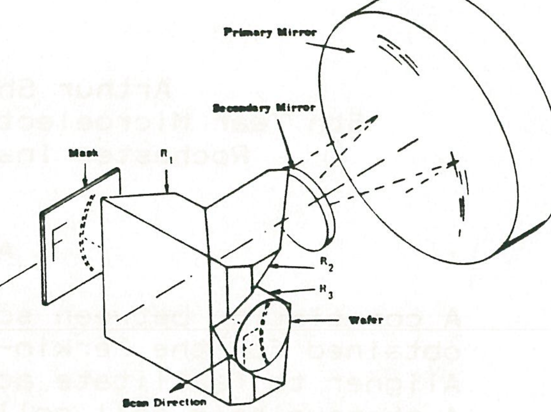


Figure 1-A: Projection Optics

Figure 1-B: Projection System with Folding Mirror Array

The High Performance Condenser system HPC pictured in Figure 2 supplies uniform, intense ultraviolet and visible illumination to the projection optics. A high pressure mercury lamp is imaged on a slit that controls the width of the field of the projection optics. The lamp energy passes through an aspheric corrector, which is a lens with a reflective coating on half of the back surface and is reimaged by the reflective portion of the aspheric lens onto the primary mirror. The aspheric lens acts as a secondary mirror and superimposes a 7.5x magnified image of the mercury lamp onto a 1.o mm slit.

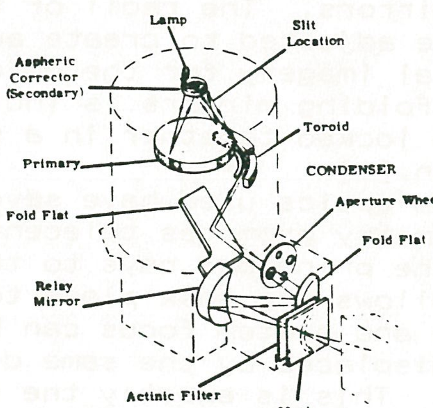


Figure 2: High Performance Condenser Assembly

The energy then passes through the slit to a torroid mirror that acts as a very strong field lens and via one flat fold mirror images the energy onto an aperture. The aperture permits simultaneous variation of energy throughput and cone angle of illumination. There exists the inherent trade-off between better resolution (cone angle) and exposure dose (energy throughput). After the stop, the energy is imaged onto the mask plane via a fold and a relay mirror. The HPC assembly also contains an actinic filter used to block the UV radiation when viewing the wafer for alignment, and a light-sensitive diode for monitoring the mercury lamp intensity and internally adjusting the carriage speed to maintain a given exposure.

Although the carriage speed controls the exposure dose, it is desireable to know the actual exposure dose in units of mJ/cm2, a fairly standard unit in any literature research or data collection. Since the exposure is a scanning slit mechanism,the irradiance had to be collected and integrated along the slit and the wafer surface. The detector is a photovoltaic cell that converts input photons to electric pulses. These pulses are then sent to the integrating radiometer which has a built-in sensitivity of 2.36E-3 amp*cm/watt. The radiometer sums the pulses, and thus the input photons over a small time constant, and the result is a measure of amp*secs. The amp*secs are then divided by the sensitivity factor to arrive at the irradiance in watts/cm2. The total exposure is equal to the integration of the output current and can be found by dividing the radiometer output current amp*secs by the senstivity factor amp*cm2/watt.

The collected data will be used as input for PROSIM, a Perkin-Elmer resist profile simulation. The calculation by PROSIM requires three steps: Image, Rate, and Develop. Image requires exposure device characteristics in order to generate an aerial image output. Rate requires the input of remaining resist thickness vs. time in the developer (Perkin- Elmer DREAMS software) to produce the dissolution rate vs. depth for each incident exposure. The thickness vs. time data is generated via DREAMS which uses interferometry measurements during development to record signal strength during development time. Develop needs the Image and Rate outputs to arrive at the final simulated resist profiles.

The goal of this research work was to develop an in-line method of measuring the total exposure dose in milli-joules per square centimeter, and then to use this data to successfully model profiles in the resist exposed with the Perkin-Elmer Model 140 scanners.

EXPERIMENT

A wafer vaccuum chuck for the Perkin-Elmer 140 Projection Aligner was modified to hold a radiometer detector head, as depicted in Figure 3. An International Light model XR140A collector with an additional neutral density of 2.0 was used in conjunction with an IL700A integrating radiometer to measure the exposure dose for scan speeds ranging from 10 to 999. The addition of the neutral density filter was neccessary to avoid

saturation of the integrating radiometer and to prevent photo-multiplication in the collector. A relationship between the scan speed and the exposure dose was established. This data was used in the subsequent processing and modeling of Shipley 1400-27 and KTI 820 resist films on four inch silicon wafers.

Ten four inch wafers were cleaned using the RCA process. The wafers were then primed with HMDS spun on at 4000 rpm for 20 secs and coated with either Shipley 1400-27 or KTI 820 resists dynamically dispensed at 500 rpm for 5 secs and then ramped up to a final spin speed of 5000 rpm for 20 secs. The resultant 1 um resist films were then prebaked in a convection oven at 95 C for 20 mins. These wafers were processed through the Perkin-Elmer Model 140 Projection Aligner and then developed in a beaker. The Shipley resist was developed in diluted Microposit 351 and the KTI resist was developed in diluted KTI 934, both of varying concentrations. The process was then optimized for each resist using image critical dimension measurements of line/space pairs and SEM analysis. The Perkin-Elmer scanner was operated in the manual mode and one is referred to the operation manual for the actual procedure.

The PROSIM model was performed to set up the aerial image using the scanner device parameters which were a numerical aperture of 0.17, a partial coherency factor of 0.6, a illumination wavelength of 436 nm, and a defocus distance of 2.0 um.

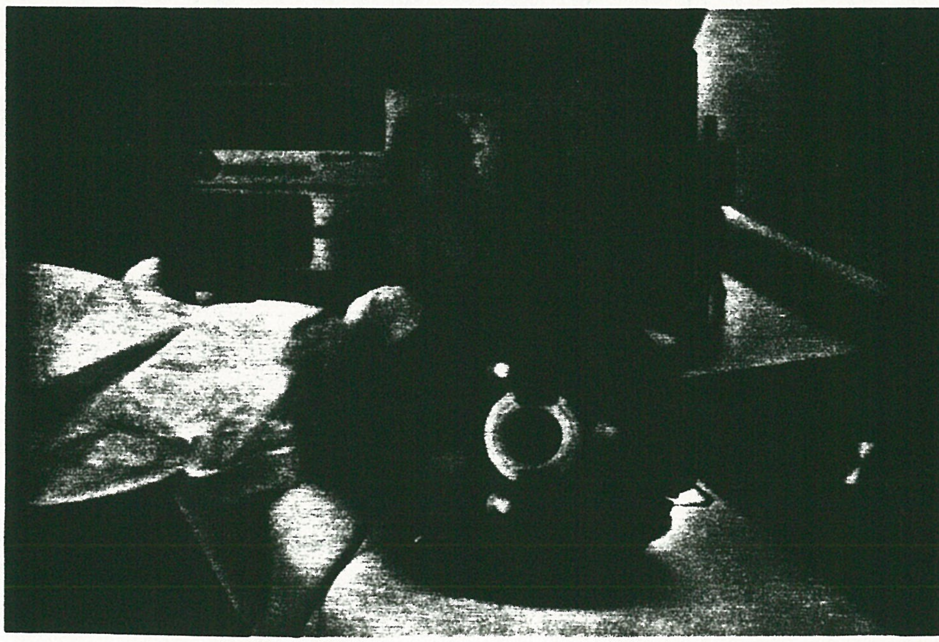


Figure 3: Modified Wafer Chuck and Integrating Radiometer

RESULTS

The relationship between the scan speed and the exposure dose was found to be non-linear with doses ranging from 530mW/cm down to 5.2mW/cm. The data is shown in Figure 4. The correlation is repeatable and exposure doses can be predicted to within 5% of actual using the linear relationship obtained on a

log plot, shown in figure 5. The resolution capabilities using the scanner were found to be 1.4um for the Shipley 1400-27, and 1.6um for the KTI 820. Both resists were capable of resolving finer geometries but without any linewidth control, as evidenced in Figure 6. Optimum Processing for the Shipley resist included exposure at a scan speed of 50 and development in 351 developer diluted 4:1 (DI:dev) for 25 seconds. The KTI 820 was exposed at a scan speed of 65 and developed in KTI 934 developer diluted 4:3 (DI:dev) for 25 seconds. The PROSIM image profile, shown in Figure 7 was set up and can be used for resist profile simulation.

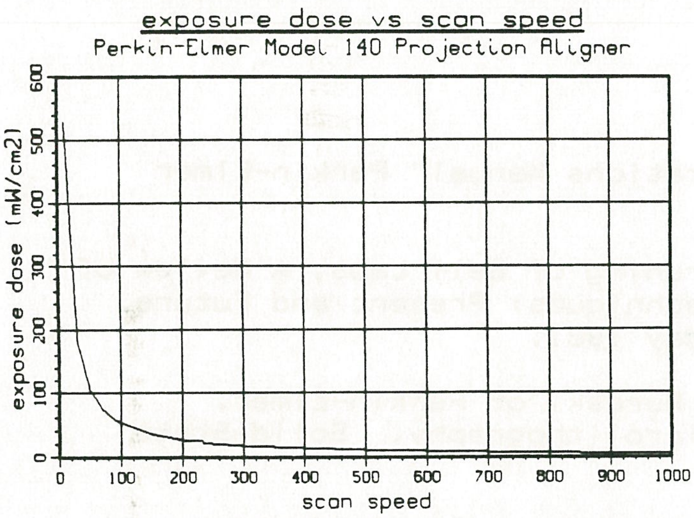


Figure 4

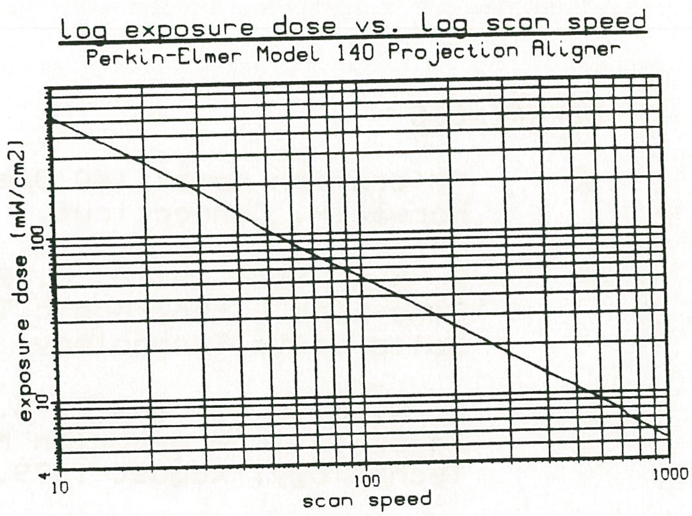


Figure 5

Figure 6: SEM of Resist Profile

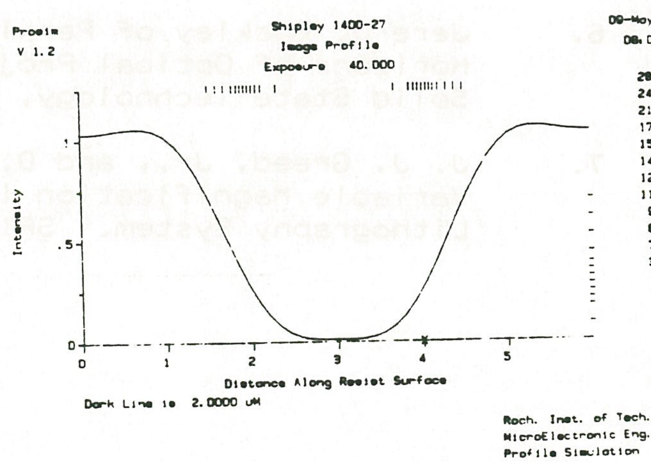


Figure 7: Scanner Aerial Image

CONCLUSIONS

Three goals were achieved with this work. The scan speed was correlated to exposure dose with 5% accuracy for the Perkin-Elmer Model 140 Projection Aligner. The process parameters were set up for both the Shipley 1400-27 and the KTI 820 resists. Thirdly, the scanner aerial image was successfully modeled via PROSIM.

ACKNOWLEDGEMENTS

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