Photoresist Thin Film Effects on Alignment Process Capability

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ABSTRACT

A crucial aspect of alignment system performance in integrated circuit manufacturing is the impact of photoresist thin film effects over alignment targets. Differences in photoresist coating such as conformal versus planarizing step coverage and symmetric versus asymmetric step coverage can potentially impact the resulting alignment capability and obtainable process window. These differences in coating properties are closely coupled to photoresist material properties including solvent type(s), polymer molecular weights, sensitizer level, dye level and viscosity. Photoresist application has also been noted to have significant impact on step coverage, and includes such factors as dispense technique, spin speed, acceleration, spin time, softbake temperature and softbake time.

Two photoresists were selected for alignment characterization based on their dissimilar coating properties and observed differences on alignment capability. The materials are Dynachem OFPR-800 and Shipley System 8. Both photoresists were examined on two challenging alignment levels in a submicron CMOS process, a nitride level and a planarized second level metal. An Ultratech Stepper model 1500 which features a darkfield alignment system with a broadband green light for alignment signal detection was used for this project.

Initially, statistically designed linear screening experiments were performed to examine six process factors for each photoresist: viscosity, spin acceleration, spin speed, spin time, softbake time and softbake temperature. The resulting alignment process latitude expressed as a function of the alignment target width and alignment key width was used as a response for these experiments. The two photoresists exhibited distinctly different behavior in the screening experiments. Photoresist viscosity was observed as a significant factor for both photoresists. However, OFPR-800 showed a significant effect of both spin speed and spin time while System 8 shows a significant effect of only spin time. These findings from the screening experiments highlight the importance of including an assessment of the impact of photoresist on alignment capability when selecting a photoresist, and not to base selection only on lithographic performance.

Using the results derived from the screening experiments, a more thorough examination of the statistically significant process factors was performed. A full quadratic experimental design was conducted to examine viscosity, spin speed and spin time coating properties on alignment. This included a characterization of both intra and inter wafer alignment control and alignment process capability. Insight to the different alignment behavior is analyzed in terms of photoresist material properties and the physical nature of the alignment detection system.

1.0 INTRODUCTION

The lithography alignment requirements for advanced semiconductor processing place enormous demands on both equipment specifications and process control capabilities. The impact of submicron design rules is apparent in the device registration requirements for sophisticated technologies. A frequently used rule of thumb is that the overlay error should not exceed one fifth of the minimum device geometry[1]. This implies that for a half micron process, the maximum registration should not exceed 0.10 microns. This number approaches lithography equipment specifications and leaves little margin for the process variation effects encountered in a production environment. As a result, it is necessary to consider both alignment and resolution requirements when developing processes which will be maintained under statistical process control. Recent studies have shown that even the metrology tools used to verify process overlay can be subject to significant errors using production wafers with topography near the registration marks[2].

The choice of the alignment system for the lithography tool can have a major impact on process sensitivity. Older systems that used only bright field alignment were extremely sensitive to photoresist process variations. Dark field alignment systems which utilize scattered light were implemented because they are less sensitive to offsets caused by resist coating asymmetries[3]. This is because the alignment mark scatters more light than the relatively planar photoresist layer. However, the photoresist does scatter enough light that it can adversely impact the signal to noise ratio[4]. As alignment requirements have tightened, the impact of the photoresist component in light scattering is becoming more of a significant process issue.

The photoresist influences the alignment capability because of the asymmetric coating which occurs over topography[4]. Extensive modeling work has been done on the coating of polymer materials over simple topography on a spinning disk. Burnside has hypothesized that local planarization is determined by lateral concentration gradients which develop as the photoresist is drying. This suggests that local planarization increases as the rate of drying decreases[5]. Sukanek made a similar observation that if the viscosity rises very rapidly due to solvent evaporation, the film topography becomes frozen-in and can not be planarized by surface forces[6]. In addition, LaVergne has shown that global planarization is enhanced by photoresists with higher solids content[7]. These all suggest that the photoresist properties of viscosity and solvent vapor pressure can indirectly impact the potential light scattering for dark field alignment.

The orientation and density of topography structures on the wafer also affect planarization. The degree of planarization has been shown to be greater for densely packed topography than for isolated structures[5]. Work by Peurring[8] and Manske[9] attribute this planarization variation to surface tension forces near the edge of a feature that accelerate flow in narrow channels and retard the flow for wide channels. The orientation of the structure relative to the center of the wafer also impacts local planarization. Increased step heights are observed in the perpendicular direction as the polymer tends to build up on the sidewall of the step[10]. The difference between the parallel and perpendicular orientation becomes less prominent as the feature size decreases[10,11]. The same photoresist buildup also occurs near the periphery of the wafer. Changes in step height of over 0.10 microns have been experimentally observed near the wafer edge[12].

Photoresist processing parameters can also impact planarization properties. It was experimentally observed by Castel that shortening photoresist spin coating cycles improved alignment accuracy on an Ultratech 900 system[13]. A shorter coating cycle allows more of the photoresist drying to occur in a relaxed state. Similarly, it has been suggested by White that lower spin speeds should be used to obtain more uniform coatings over topography[10]. Another process parameter that can be varied is photoresist bake temperatures. Clearly higher temperatures will cause increased thermal flow near the glass transition temperature[11]. However, high bake temperatures can adversely impact photoresist sensitivity and resolution.

Each photoresist material has unique properties based upon its polymer chemistry, molecular weight and choice of casting solvents. Therefore, certain photoresists will have characteristics which enhance planarization. One material that has been utilized for its planarization properties in a number of studies is OFPR-800. It has been experimentally observed that OFPR-800 shows smaller orientation alignment effects than HPR204, HPR206 and OCG PMMA[10].

The incorporation of dyes in a photoresist material also impact alignment capabilities. Dye materials can be selected for sensitivity at either the exposing or alignment wavelength. The anti-reflective dyes that absorb at the exposure wavelength frequently have a negative impact on alignment because of the type and concentration of dye[14]. However, dyes that absorb at the alignment wavelength optimize the detection signal and the characteristic alignment peak is more easily recognized[14].

Surface tension effects in photoresists have also been noted to result in film thickness variations and striations[15]. Surface film variations of 0.28 microns can occur for typical one micron films depending on the solvent evaporation rate and surface tension. Such an effect can deteriorate the resulting signal-to-noise ratios of an alignment target from the variable scattering component of the top photoresist surface. Fortunately, many photoresist materials have suppressed this through addition of proper surface leveling agents.

A better understanding of the impact of the above properties of photoresist coating and ultimately alignment target acquisition are critical for successful implementation of a lithography process. Hence, successful development of a lithography process requires concurrent consideration and optimization of alignment target design, photoresist material, and photoresist coating conditions and resulting alignment target capability. In this project an examination of the effects of photoresist processing parameters with regard to alignment target process latitude and alignment capability will be performed.

2.0 EXPERIMENTAL METHODS

2.1 CMOS Process Description

The alignment study used short loop experimental four inch wafers based on an advanced submicron complementary metal oxide semiconductor (CMOS) process which incorporates multiple polysilicon and metal interconnect layers. Two sections of the process were selected for evaluation. The first is a front end field silicon oxide step which routinely shows excellent process latitude. Here a 1000 Å silicon nitride film was deposited over a thin pad oxide on silicon and patterned with a variety of Ultratech targets using a standard key and target reticle. The pattern was transferred into the nitride film using an Applied Materials etcher model 8110. Subsequently, a 5000 Å field oxide was grown by thermal oxidation and the remaining nitride stripped in a wet etch. The wafers were then coated and prebaked as specified in section 3.0. This process level will be denoted as N-well for subsequent discussion.

The second section of the process evaluated is a backend metal interconnect. The metal step coverage requirements for this process necessitate planarized films for all the interlevel dielectric layers. This approach planarizes the lithography alignment targets as well as the device topography with the effect of reducing process margin for these targets. Therefore, an alignment test between metal layers was selected an a sensitive indicator of process latitude.

The initial layer patterned for the short loop wafers is the first level metal with 8000 Å of silicon dioxide on silicon. The wafers used the standard metal one process of 5500 Å of aluminum with copper (Al/Cu). Lithographic patterning of the metalized wafers was accomplished using the same standard key and target reticle to produce a variety of Ultratech targets. The pattern transfer of the Al/Cu layer is achieved using an Applied Materials etcher model 8130.

The intermetal dielectric deposited on the top of the metal one pattern is a plasma enhanced chemical vapor deposition (CVD) film of tetraethyl orthosilicate (TEOS) oxide. This film is planarized using a combination of photoresist etchback and TEOS oxide redeposition to achieve a final dielectric thickness of 10000 Å. The top level metal for the experimental wafers consists of 12000 Å Al/Cu which is coated and prebaked as specified in the section 3.0.

2.2 Process Equipment

An Ultratech Stepper model 1500 was used for all lithographic imaging and alignment experiments. The projection optics are based on the Wynne-Dyson-Hershel 1x lens design, with broadband illumination of the g and h mercury lines as well as the continuum from 390 to 450 nm. This system features a site-by-site darkfield alignment system utilizing green light (450 - 600 nm) for alignment signal detection. Alignment signal detection is facilitated by scanning the wafer and collecting the resulting darkfield light scatter from the wafer target. The Ultratech utilizes the same projection optics for imaging and the alignment process, and hence performs direct through the lens alignment. The final alignment processing is the conversion of the scattered light to an electronic signal utilizing a PhotoMultiplier Tube (PMT) for ultimate determination of alignment target center in both the *x* and *y* locations prior to exposure.

Alignment targets for the stepper can consist of either lightfield (mesa) or darkfield (valley) crosses. These are 200 x 200 microns along each cross extent. For this study, darkfield polarity was examined for target widths of 1 to 5 microns in the initial screening activities. Alignment reticle key sizes were also evaluated over a range of 2 to 6 microns.

The photoresist coat and softbake processes were performed on an SVG model 8826 track system. Static dispense techniques were used for all photoresist coating applications, with the spin time, acceleration, spin speed varied intentionally in the experimental designs. Softbake and post-exposure bake processes were performed using hard contact hot plates. Finally, all photoresist development processing was performed using batch immersion method.

2.3 Photoresist Materials

Two commercially available positive photoresists, Dynachem OFPR 800 and Shipley System 8, were selected for characterization due to their dissimilar coating properties as well as their previously observed differences on alignment capability. Both materials are positive photoresist formulations based on diazonaphthoquinone sensitizers and novolak resins; however, OFPR-800 utilizes a casting solvent of primarily Ethyl Cellosolve Acetate (2-ethoxyethyl acetate), while System 8 utilizes an Ethyl Lactate casting solvent. These two casting solvents have been reported to have significant differences in two key properties with a solvent viscosity of 1.84 centipoises versus 195 centipoises and solvent vapor of 5.3 mm Hg. versus 0.6 mm Hg. for Ethyl Cellosolve Acetate and Ethyl Lactate respectively[16].

Ethyl Cellosolve Acetate (ECA) represents a common solvent used for many years in the photoresist industry due its excellent compatibility with novolak resins. Ethyl Lactate (EL) has recently become a more standard solvent in photoresists since it is considered a relatively safer and hence less toxic solvent compared to ECA. EL has a reportedly slow rate of evaporation which has made it a desirable choice for brushing lacquers applications.

2.4 Measurement Techniques

Two measures of alignment performance were established as response criteria. The alignment target signal quality as detected on the stepper was implemented in the initial screening experiments. A software package, Auto KT, was run on the stepper for automated acquisition of alignment target signal quality[17]. This software has been shown to be an effective tool in selecting optimum alignment target designs since it objectively determines alignment target signal quality using the alignment system of the stepper[18].

The subsequent response surface analysis was based on the performance of the alignment process by analysis of the wafer alignment errors. The level-to-level alignment errors were measured using a KLA 5015 coherence probe which utilizes box-in-box structures.

3.0 SCREENING DESIGN - RESULTS AND ANALYSIS

3.1 Screening Design Experiments

Three separate linear screening experiments were performed first to examine six factors based on photoresist and coating properties: viscosity, spin acceleration, spin speed, spin time, softbake time and softbake temperature. As discussed in section 1.0 all have been observed to impact planarization properties. The three separate screening experiments were conducted as indicated in Table 1.0:

Experiment	Photoresist	Level
1	OFPR - 800	N-well
2	OFPR - 800	Metal 2
3	System 8	Metal 2

Table 1.0 Three Screening Experiments

The resulting alignment process latitude expressed as a function of the alignment target width and alignment key widths was used as a quantitative response for these experiments.

Each screening design consisted of 18 wafer trials, including 5 replicate wafers for examining experimental error and center conditions. The screening designs were orthogonal which allowed determination of the linear effects of the six factors without confounding. All experimental trials were randomized to remove the influence of any systematic process effects. Table 2.0 summarizes the low and high values of the various coating factors used in all three screening experiments, with the exception that different viscosities were used for each photoresist based on availability. These process ranges represented outer limits of typical or baseline coating conditions used in the processing of each photoresist material. Resulting photoresist film thicknesses for the conditions of this design ranged from 5000 Å to 25,000 Å based on a planar substrate as a reference. Of course, the actual topography of the experimental wafers will give different ranges of photoresist film thicknesses.

Factor	Low	High
Viscosity OFPR-800/System 8 (cp)	20/14	50/28
Spin Acceleration (Krpm/sec)	5	20
Spin Speed (Krpm)	2	7
Spin Time (secs)	15	75
Softbake Time (secs)	30	120
Softbake Temperature (C)	85	115

Table 2.0 Screening Design Low and High Factor Values

For each wafer trial a full matrix of the standard target sizes of 1 to 5 microns and alignment key sizes of 2 to 6 microns, both in 1 micron increments, were characterized at multiple sites on the wafer. Using the AutoKT software package, a corresponding assessment of target quality was quantified based on measured variations in target width, target center and target variation. Hence, values of target quality above 10 indicate a unacceptable alignment target, while values below 5 indicate a good target. The relationship of Target Quality to the three components of alignment target variation[17] is expressed as follows:

$$\text{Target Quality} = 6\,\sigma_{\text{center}} + 6\,\sigma_{\text{alignment}} + 2\,\sigma_{\text{width}} \qquad (1)$$

Next for each wafer and thus a specific experimental process condition, an alignment target process latitude was defined as the average target value over the target/key matrix range. Equation (2) below expresses the response alignment target latitude. This alignment target latitude is a useful metric for quantifying the relative target/key latitude over the matrix of sizes for each specific process condition. The denominator is used for averaging purposes of the total quantity of distinct target and key combinations on the test reticle.

$$\text{Alignment Target Latitude} = \frac{\sum_{i=2}^{6} \sum_{j=1}^{5} \text{Target Quality at } i, j}{(i_{max} - 1) * j_{max}} \qquad (2)$$

where i refers to the reticle key size and j refers to the target size

3.2 Alignment Target Latitude

It is instructive to examine the alignment target latitude for the process conditions in terms of target quality for each specific combination of key and target size, of which there are 25 ((6-1)x5) distinct cases. Figures 1.0 and 2.0 display the maximum and minimum case alignment target latitudes for the case of metal 2-to-metal 1 using OFPR-800 photoresist. In both cases the usable process window is more than adequate for use in production manufacturing, with a latitude of at least three target sizes. The major difference in the two conditions are reflected by the two critical factors of viscosity and spin speed identified in the screening experiment. Figure 1 represents conditions of low viscosity at 20 centipoises and low spin speed of 2000 rpm versus a high viscosity at 50 centipoises and high spin speed at 7000 rpm in figure 2.0. The larger process latitude for the conditions in Figure 1.0 are a result of degradation in target quality at sizes of 4 and 5 microns.

3.3 OFPR -800 Results

Figure 3.0 displays the results of the screening designs for OFPR-800 for both the metal 2 and N-well process levels in terms of effect magnitudes for each factor on the response alignment target latitude. The Analysis of Variance (ANOVA) for these two experiments revealed viscosity, spin time and spin speed are statistically significant effects. All effect values are normalized with respect to their maximum value to allow relative comparisons. Both magnitude and effect polarity are displayed for each factor. For example, spin speed exhibits the largest effect magnitude of all factors with a positive effect. The positive effect indicates that as the value of spin speed is increased in the experiment from 2000 to 7000 rpm, there is an increase in the alignment target latitude. This behavior is consistent for both process levels examined and thus suggests higher spin speeds apparently improve variations in target quality over the matrix of target sizes due to more planarized photoresist coatings. Spin time also exhibits a large effect, particularly for the metal 2 experiment, where an increase in spin time results in a reduction in the alignment target latitude. This dependence on spin time is in accordance with the reported behavior that shorter spin times reduce the asymmetric photoresist coating due to solvent drying occurring in a more relaxed state.

An interesting note is the relative lower sensitivity of the N-well level to photoresist coating conditions as compared to metal 2. Clearly spin speed is the main dominant effect for N-well, while metal 2 displays additional dependence on viscosity, spin time, softbake temperature and time. This behavior can be attributed to the nature of the topography of the two levels, since the N-well level typically has a less severe step due to the oxidation process near a nitride edge. Additionally, it is plausible that the highly reflective and grainy nature of the metal level makes it more susceptible to photoresist coating variations over a larger distance than the less reflective nitrides films on the N-well level.

3.4 Metal 2 Results

The third screening experiment performed examined the use of Shipley System 8 photoresist on the same metal wafers using the identical screening design. This approach allows a comparison to be made of the impact of differences in photoresist properties on alignment target latitude. Figure 4.0 displays the corresponding comparison of System 8 and OFPR-800 for these two experiments. The dominant effects appear to be similar for both photoresists in terms of viscosity, spin speed and spin time. However, relative magnitudes and polarities of these effects are not necessarily the same. Increasing viscosity for System 8 is the major effect with a detrimental impact on alignment target latitude, while the effect is smaller with an improvement for OFPR-800. One explanation is that the higher solvent vapor pressure for the ECA solvent in OFPR may be providing better coating properties over a range of target sizes.

Photoresist coating acceleration rates also plays a larger role for System 8 than OFPR-800, where lower acceleration rates improve alignment target latitude. While it was previously observed that spin speed for OFPR is significant, the effect of spin speed is negligible for System 8.

Perhaps the most interesting effect is spin time, which is large for both photoresist but with completely opposite effects. Although reduced spin times are beneficial for OFPR-800, possibly due to less asymmetric coating effects, System 8 which has a low solvent vapor pressure for EL and higher viscosity appears to require longer spin times to effectively planarize.

4.0 QUADRATIC RESPONSE SURFACE - RESULTS AND ANALYSIS

4.1 Quadratic Design Experiment

The screening experiments demonstrated the importance of three crucial photoresist coating parameters: viscosity, spin speed and spin time in terms of alignment target latitude. To characterize these effects more fully for process parameters, alignment error was selected as a response indicator. A full quadratic experiment was designed in order to more accurately understand the impact of the three factors on alignment target latitude using the metal 2 wafers. A twenty three wafer quadratic experiment was implemented with low, mid and high factor values as shown in Table 3.0.

Factor	Low	Mid	High
Viscosity (Centipoises)	8	20	50
Spin Speed (Krpm)	3.0	4.5	6.0
Spin Time (seconds)	20	40	60

Table 3.0 Quadratic Design Low, Mid and High Factor Values

All wafers were aligned using a site by site technique with a 2.0 micron darkfield target and a 2.0 micron reticle key. This target/key combination was selected since it was observed to be robust over the process window in the previous screening design experiments as shown in figures 1.0 and 2.0. Alignment measurement for metal 2-to-metal 1 was quantified with a KLA 5015 coherence probe microscope. A total of twelve sites per field, 8 fields per wafer for each wafer trial were measured. Both x and y alignment components were collected. This provided in excess of 2000 measurements of alignment error for analysis purposes. In order to have a single response gauge, error magnitude was defined in terms of the alignment error contributions of the x and y components:

$$\text{Error Magnitude} = \sqrt{x^2_{error} + y^2_{error}} \qquad (3)$$

where x_{error} and y_{error} represent the *x* and *y* alignment error components respectively.

A quadratic regression analysis was performed to fit the experimental data for the three factors: viscosity, spin time, and spin speed. The model included both first order, second order, and interaction effects of the three factors, which demonstrated statistical significance at $P<0.05$ from the ANOVA. Additionally, wafer radial position was included in the model to account for radially dependent alignment effects as discussed in section 1.0. Although the fit of the model was marginal, it was useful in examining the relative impact of the various factors on alignment error magnitude and acted as a qualitative tool for understanding the impact of the various factors. The lack of fit of the model is hypothesized to be due to the processing variations of the metallization deposition, interlevel dielectric planarization and metal 1 etching. Additional considerations include other alignment variation contributors that the model is not designed to accommodate. However, it still provides insight into desirable and undesirable process conditions.

4.2 Low Viscosity Conditions

Response surfaces displayed in figures 5a, 5b and 5c depict alignment error magnitude at three different wafer radial positions: center of the wafer, 19 mm from the center of the wafer, and 38 mm from the center of the wafer for the conditions of low viscosity (8 centipoise). Each response surface includes spin time and spin speed on the x and y axes. The first major feature is the lack of sensitivity of towards radial position on alignment error magnitude. Although there is an alignment error, the response surface appears to remain consistent for the three radial positions. Of the two factors, the predominant effect is spin speed. Since there appears to be a competing effect as spin speed is increased, there is not a preferred spin speed. Finally, a short spin time is recommended to avoid the steep region of the response surface.

4.3 High Viscosity Conditions

The analogous set of responses surfaces for the high viscosity conditions of 50 centipoise are shown in figures 6a, 6b, and 6c. Unlike the previous low viscosity, radial alignment effects are significant as evidenced by the dramatically different response surfaces at the three radial sites. In terms alignment variations with respect radial changes on a wafer, the most stable regimes are at the low spin speeds of 3000 rpm with stable latitude for spin speed over the range of 20 to 60 seconds. Higher spin speeds, especially toward 6000 rpm are severely detrimental resulting in significant radial variation. There are also indications of competing effects of spin time with regard to radial position. At the center radial position, longer spin times are preferred, while at the radial position of 38 mm, short spin times are preferred. Possibly the higher angular speeds associated with larger radial positions in conjunction with high spin speeds are inducing severe asymmetric resist coatings. These results suggest that high spin speeds and high viscosity conditions should be avoided for enhanced alignment control.

4.4 Effect of Viscosity

The previous response surfaces indicate a substantial effect of resist viscosity, and spin speed on alignment error. The effect of increasing viscosity on alignment error is illustrated for radial position R=38 mm, in figures 7a, 7b and 7c. At viscosity’s 8 and 29 centipoise, the response surfaces are comparable except for the highest spin speeds of 60 seconds. However, at the extreme case of 50 centipoise there is a severe departure of the surface with a significant detrimental effect of the longer spin times at high spin speeds. This suggests that the combination of high spin speeds, long spin times in conjunction with the angular component of radial velocity are causing a substantial alignment error. Clearly, these conditions should be avoided for photoresist processing.

5.0 DISCUSSION

The results of the experimental designs clearly attest to the significance of photoresist properties and photoresist coating techniques as crucial determinants for alignment capability. Of the six factors evaluated, photoresist viscosity, spin speed and spin time are all statistically significance for both OFPR-800 and System 8. Unfortunately, extrapolating the exact results of these two photoresists to other commercially available products is not viable. However, it is reasonable to expect these same photoresist properties and photoresist coating techniques to be critical for other photoresists. For example, the observed detrimental effects of extended spin times and spin speeds are probably ubiquitous for other photoresists but with potentially different magnitudes and polarities. In fact this was confirmed by comparisons of OFPR-800 and System 8.

A major finding of this study is the dominance of radial coating variations on alignment error. Since four inch wafers were used for all experiments, it is probable that the observed effects will be greater on six and eight inch wafers. Although a site-by-site alignment technique was used in this study, the same concerns of photoresist coating effects would severely effect the performance of Enhanced Global Alignment (EGA) techniques. In an EGA configuration, the selection of alignment sites is particularly crucial, since a small number of scattered alignment sites impacts the overall wafer alignment.

The results of this study clearly suggests the importance of including an assessment of the impact of photoresist on alignment capability when selecting a photoresist or optimizing a photoresist process. Lithographic performance alone is inadequate for process optimization. Clearly, photoresist coating properties are directly coupled to alignment capability and must be considered as an integral part of an alignment process.

6.0 SUMMARY

Photoresist thin film effects due to differences in material properties and application techniques have been illustrated to impact two critical alignment process metrics: alignment target latitude and alignment error. The observed behavior of OFPR-800 and System 8 photoresist coating techniques such as spin speed and spin time are consistent with the results of other investigators. The major highlights of this study can be summarized as follows:

1. Both OFPR-800 and System 8 photoresist each exhibit unique behavior towards alignment target latitude on a difficult alignment level (metal 2 process).

2. Spin speed, spin time and photoresist viscosity all significantly impact metal 2 alignment error for OFPR-800 photoresist.

3. Of the three photoresist viscosities evaluated for OFPR-800, the lowest viscosity of 8 centipoise exhibits the least impact on alignment error while the highest viscosity of 50 centipoise exhibited the largest impact.

4. Intrawafer radial alignment variability is substantial for high viscosity (50 centipoise) and high spin speeds (>5 Krpm) conditions of OFPR-800. This suggests to avoid operating under these conditions by operating with a lower viscosity and spin speed to achieve the desired photoresist thickness.

7.0 ACKNOWLEDGMENT

The authors acknowledge Mark Merrill of KLA Instruments Corporation for his gracious support of registration measurements.

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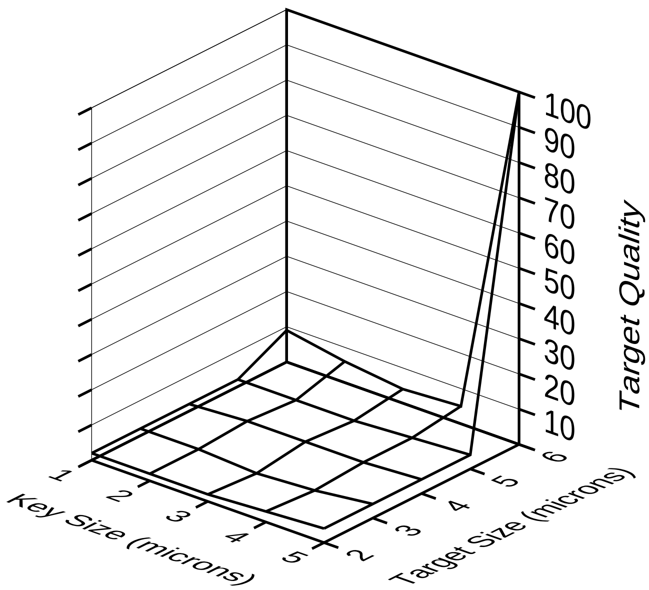

Figure 1.0 Case of maximum alignment target latitude for Metal 2 to Metal 1.

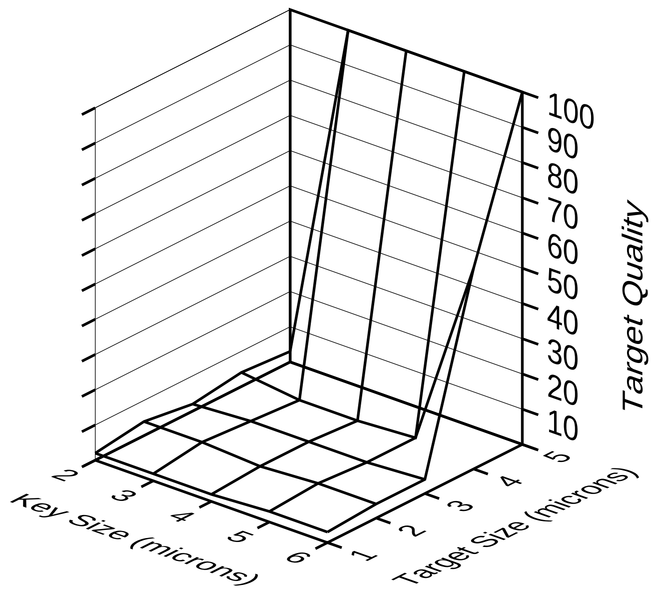

Figure 2.0 Case of minimum alignment target latitude for Metal 2 to Metal 1.

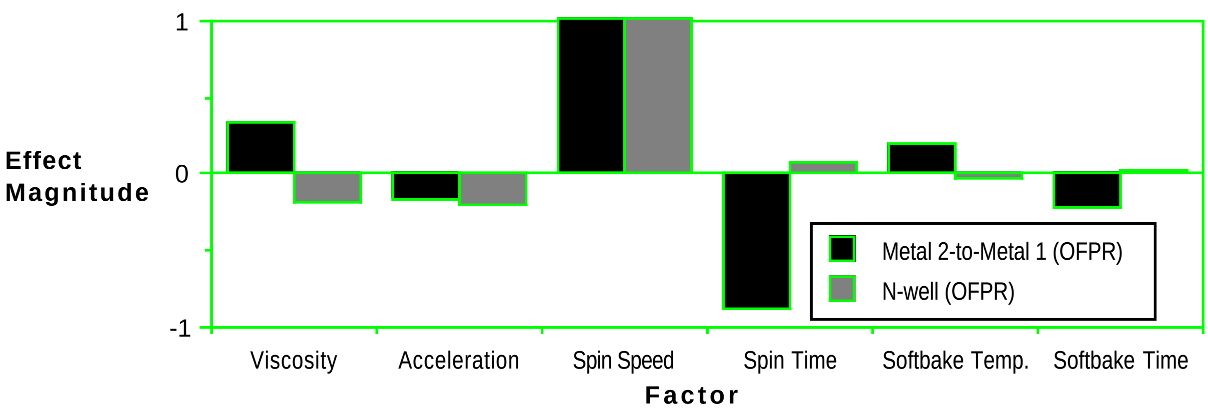

Figure 3.0 Screening design effects for OFPR-800 photoresist. Comparison of Metal 2 and N-well Levels. Response: Alignment Target Latitude.

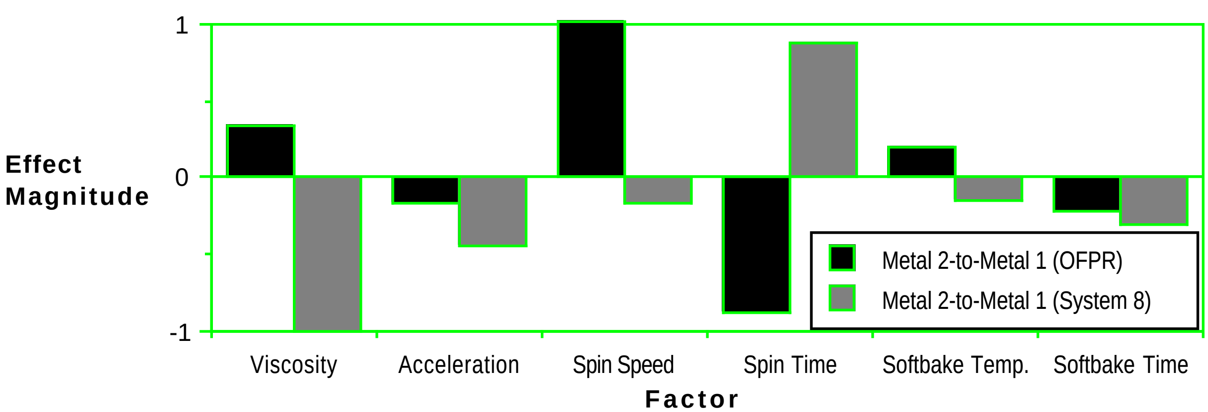

Figure 4.0 Screening design effects for Metal 2. Comparison of System 8 and OFPR-800 photoresists.Response: Alignment Target Latitude.

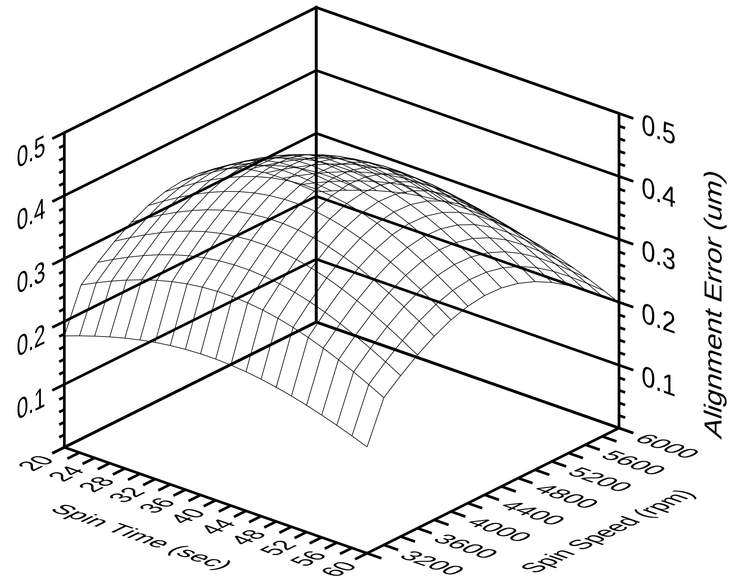

Figure 5a: Alignment Error versus spin time and spin speed for OFPR-800 photoresist at a viscosity of 8 centipoise. Position: Center of the wafer (R=0).

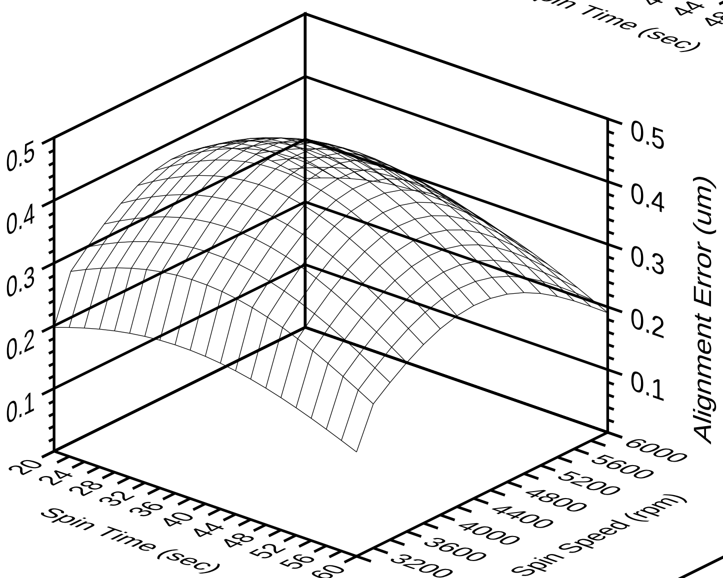

Figure 5b: Alignment Error versus spin time and spin speed for OFPR-800 photoresist at a viscosity of 8 centipoise. Position: 19 mm from the center of the wafer (R=19).

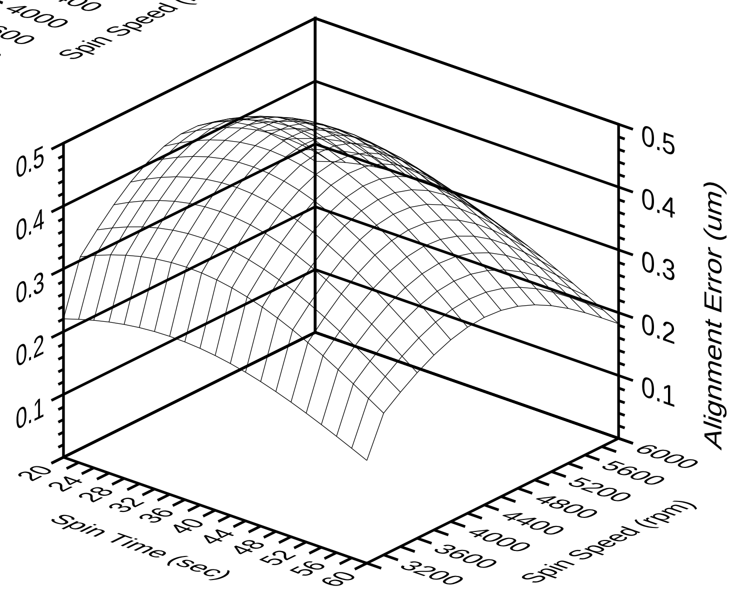

Figure 5c: Alignment Error versus spin time and spin speed for OFPR-800 photoresist at a viscosity of 8 centipoise. Position: 38 mm from the center of the wafer (R=38).

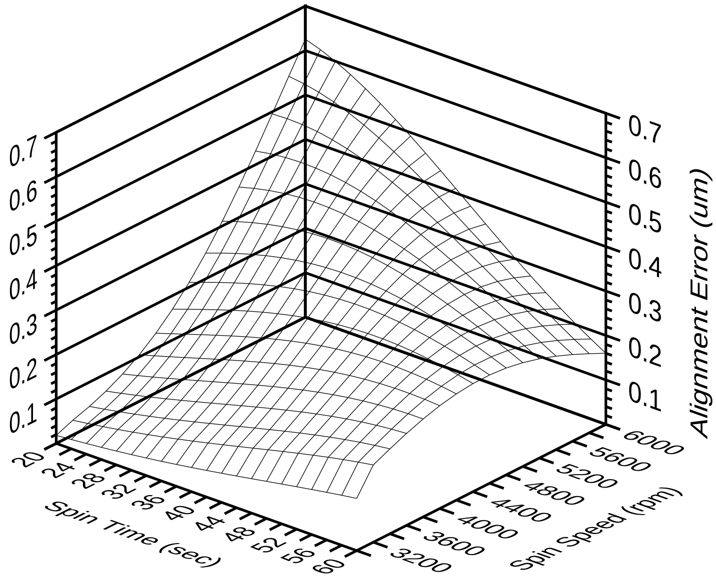

Figure 6a: Alignment Error versus spin time and spin speed for OFPR-800 photoresist at a viscosity of 50 centipoise. Position: Center of the wafer (R=0).

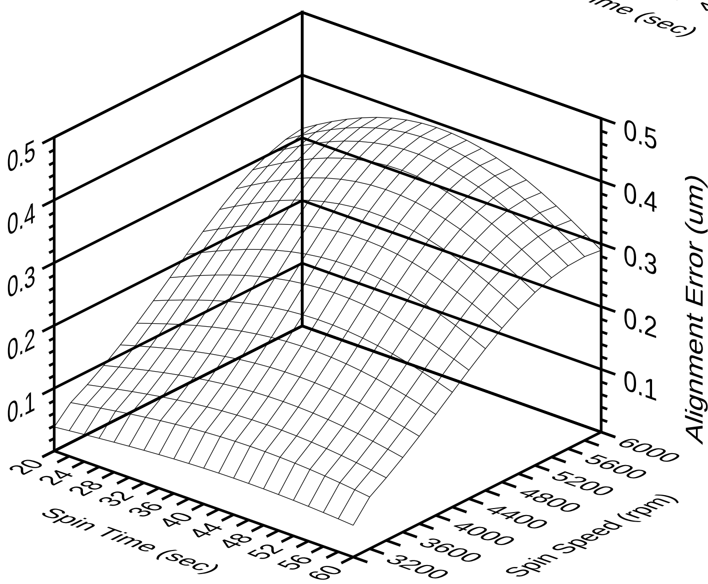

Figure 6b: Alignment Error versus spin time and spin speed for OFPR-800 photoresist at a viscosity of 50 centipoise. Position: 19 mm from the center of the wafer (R=19).

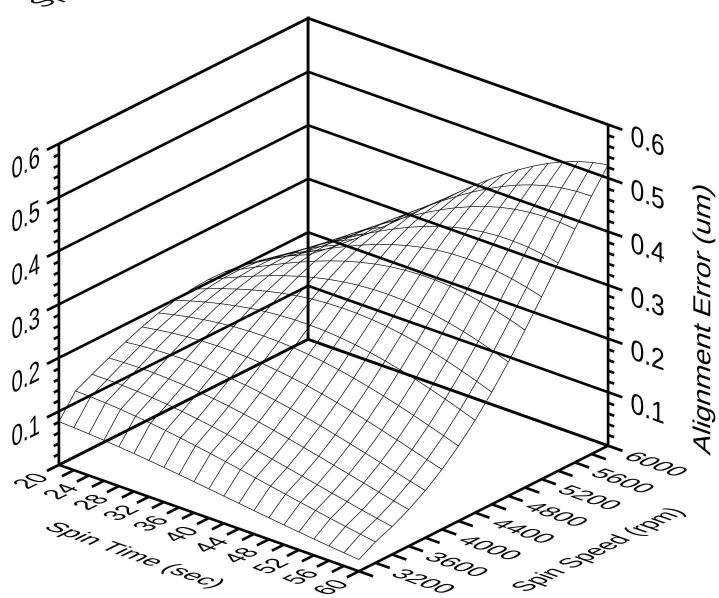

Figure 6c: Alignment Error versus spin time and spin speed for OFPR-800 photoresist at a viscosity of 50 centipoise. Position: 38 mm from the center of the wafer (R=38).

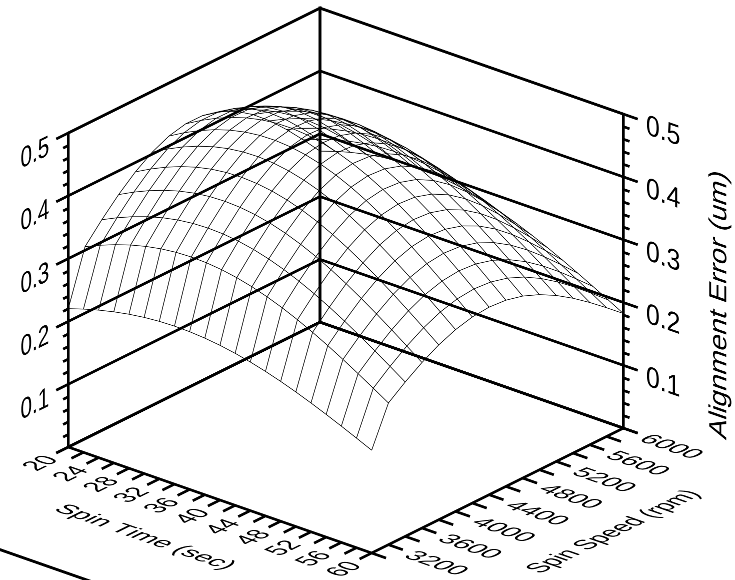

Figure 7a: Alignment Error versus spin time and spin speed for OFPR-800 photoresist for viscosity of 8 centipoise. Position: 38 mm from the center of the wafer (R=38).

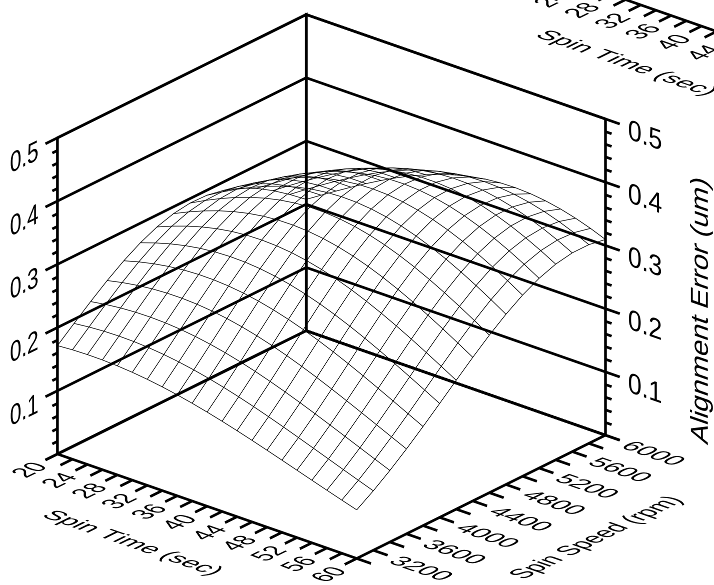

Figure 7b: Alignment Error versus spin time and spin speed for OFPR-800 photoresist for viscosity of 29 centipoise. Position: 38 mm from the center of the wafer (R=38).

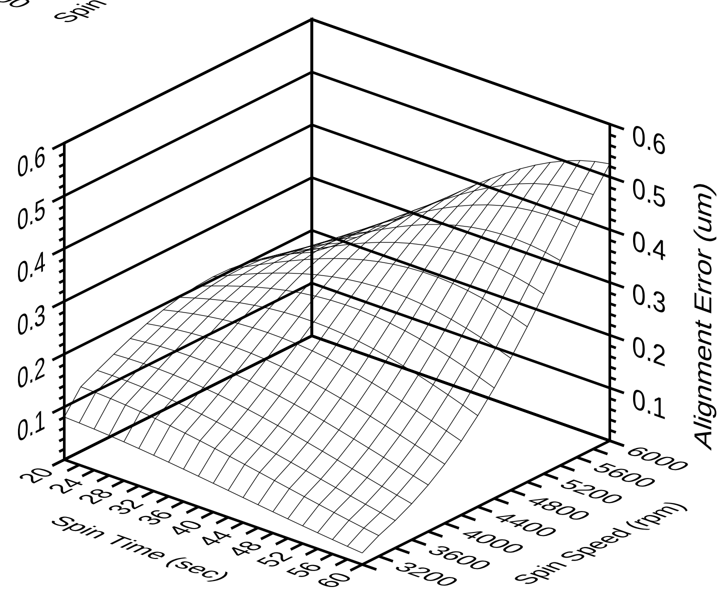

Figure 7c: Alignment Error versus spin time and spin speed for OFPR-800 photoresist for viscosity of 50 centipoise. Position: 38 mm from the center of the wafer (R=38).