Characterization and Modeling of Uniformity in Chemical Mechanical Polishing

by

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Abstract

Chemical Mechanical Polishing (CMP) has become the preferred planarization method for multilevel interconnect technology because of the high degree of feature-level planarity it achieves. Methods are needed, however, to understand and model both wafer-level and die-level uniformity in polishing. This thesis first contributes an analysis of wafer-level uniformity models as a function of measurement pattern and number of sample points. In particular, a grid pattern with at least 30 samples is found to result in good wafer level models. Second, this thesis examines the variation of die-level planarity across the wafer. Substantial dependency of planarization length (a characteristic length which determines die-level planarity) on die position is found, with planarization length in an experimental oxide polish process varying from 5.0 mm to 8.6 mm across the wafer. Finally, the wafer-level and die-level uniformity are both found to depend on process conditions such as table speed and down force. Together, these results demonstrate that wafer-level variation must be considered carefully in the modeling and optimization of uniformity in chemical mechanical polishing.

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Table of Contents

List of Figures

List of Tables

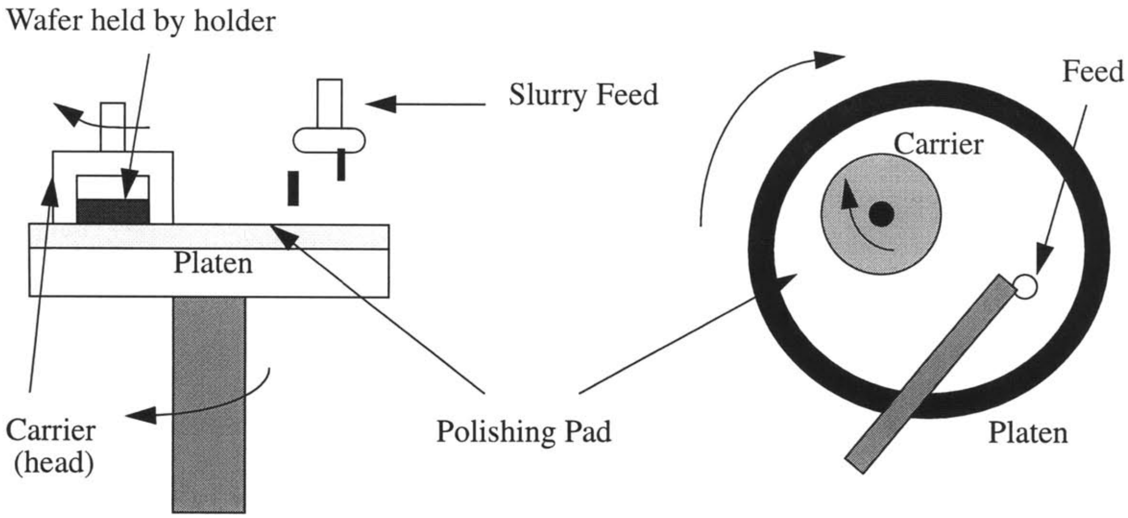
Chapter 1

Introduction

1.1 Background

Chemical Mechanical Polishing (CMP) has become the chosen planarization method for advanced multilevel interconnect technology. Engineers and researchers are aware of how important it is to eliminate particles from the cleanroom but even though CMP involves the introduction of particles through the use of slurry, it is popular because it offers the best planarization performance to date. Although CMP achieves good feature-level planarity, there is still much to be discovered and improved in CMP. Understanding of die-level and wafer-level uniformity issues is needed. In addition, the polish evolution of dies at the edge of the wafer is still to be investigated and the polishing characteristics of metals such as copper and tungsten still need to be modeled [8].

Figure 1.1 illustrates a typical example of a CMP machine set-up. Although this machine has one head, multiple-headed machines are also available. During the polishing process, the wafer is held face down using tdown force on the carrier spindle. The wafer is then polished by the rotating head of the carrier pressed against the rotating platen (table). The rotating platen contains a polyurethane pad with a slurry of colloidal silica within an aqueous solution suspension. Slurries of varying selectivities (that is with different chemical compositions) are used in polishing the metal and other films. The polishing action is brought about by the different rotating axes of the carrier and table, even though they are rotating in the same direction. The polishing action is primarily achieved through the combination of mechanical forces created by the exertion of the pad on the colloidal silica particles and chemical forces exerted by the slurry activity. Over time, the pad surface begins to wear and the polish rate diminishes. However, this problem can be alleviated by conditioning the pad surface with a diamond-tipped conditioner. The most common machines are of rotary type but linear machines are being explored because of their high speed alternative pad approaches [4], which may improve die and wafer-level performance.



(a) Side View (b) Top View

Figure 1.1: CMP Polishing Machine (Rotary Configuration)

1.2 Uniformity Issues in Oxide CMP Processes

This thesis analyzes two types of uniformities, namely wafer-level uniformity and die-level uniformity. The former is characterized by the variation in some parameter (e.g., oxide thickness) on the wafer scale. Die-level uniformity, on the other hand, is restricted to the region of the die on the wafer. Figure 1.2 (a) shows a typical non-uniformity on the die-level while Figure 1.2 (b) shows the wafer-level equivalent.

(a) Die-Level Non-Uniformity (b) Wafer-Level Non-Uniformity

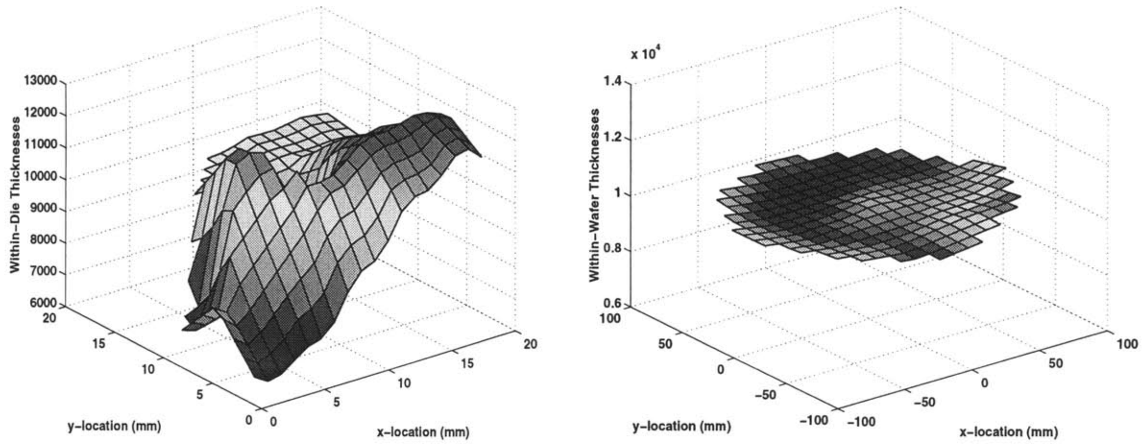


Figure 1.2: Wafer Level and Die Level Non-Uniformities

CMP planarization of oxide results in good short-range planarity (on the scale of a few microns) compared to other planarization techniques such as oxide reflow or resist etchback, but remains hampered by systematic pattern sensitivities. Excellent global uniformity in CMP processes is crucial since the feature size of present microelectronic structures is shrinking and multilevel interconnect technology requires excellent planarity to achieve lithographic depth of focus requirements. The need for good uniformity has motivated the study of how to better model uniformity in oxide CMP processes and how non-uniformity affects the planarization length at different die positions on a wafer. Uniformity concerns have also motivated the study of the effect of different process conditions such as table speed and down force on planarization length. Recent literature shows that the planarization length does increase with relative polishing speed and decrease with down force [4].

1.3 Overview of Statistical Metrology and Contribution of Thesis

Key polishing feature definitions are illustrated in Figure 1.2. As illustrated in Fig-

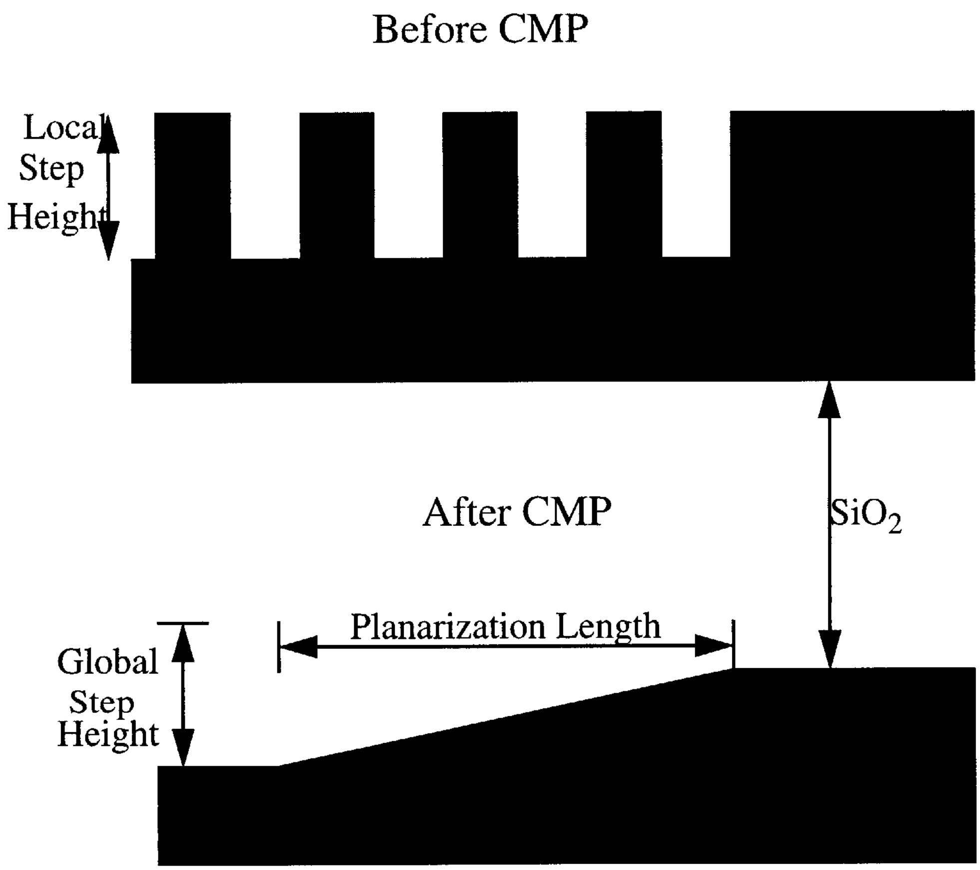


Figure 1.3: Definition of terms in polishing

ure 1.2, the local step height is the difference between the heights of the up and down areas (before planarization) and the global step height is the same difference except after planarization has been achieved. Ideally, the raised areas are polished without any polishing of the down areas but in actuality there is a small amount of polishing that takes place in the down areas and this varies with the width of the down area. However, if the width of down area is much less than the planarization length of the pad, there is negligible down area polishing because the polish pad cannot fold into the down areas. This is the primary reason for the good planarity that is achieved with CMP. Some important parameters can be defined as follows:

planarization length: the length scale over which layout density affects local planarization rate [5] *rate of local planarization:* rate of step height reduction with time

Total Indicated Range (TIR) or global step height reduction: the difference between the highest and lowest points on the die.

Due to the capability of CMP to planarize most of the local features, step height reduction capability is not the main factor to be assessed in CMP. On the contrary, the TIR for a die gives a good measure of the global planarization performance for a particular set of process conditions with a given set of consummables. However, the disadvantage of using TIR as a metric of merit is that its value is unpredictable for different layouts except those for which it is determined. The planarization length is a more comprehensive characterization parameter because given the planarization length for a process, the TIR may be obtained for any layout that is polished under identical process conditions [14]. CMP still has problems associated with it, namely pattern dependent thickness variation which manifest as global (but within-die) thickness variation. Other problems include wafer-scale variations in removal rate across a wafer because of macroscopic wafer-scale process variations which are superimposed on the within-die variation.

Statistical metrology is the body of methods for understanding variation in microfabricated structures, devices, and circuits. It is a bridge between manufacturing and design. The Statistical Metrology Group at MIT has made a significant contribution in the characterization and modeling of CMP processes. In the beginning, there was an emphasis on the characterization of variation, not only temporal (e.g. lot-to-lot or wafer-to-wafer drift), but also spatial variation (e.g. within-wafer, and particularly within-chip or within-die). A second important defining element is a key goal of statistical metrology: to identify the systematic elements of variation that otherwise must be dealt with as a large "random" component through worst-case or other design methodologies. The intent is to isolate the systematic, repeatable, or deterministic contributions to the variation from sets of deeply confounded measurements. Such variation identification is critical to focus technology development of device or circuit design rules which minimize or compensate for the variation [10, 12, 13].

The development of CMP characterization and modeling has evolved through five channels as shown in Figure 1.3 [1]. These phases are variation identification, variation modeling, semi-physical model calibration, circuit impact modeling and design rule generation. These methods come about to tackle the problem created by ILD thickness variation after CMP. Variation identification involved screening experiments and variation decomposition methods to separate and identify the components of oxide thickness variation. Phase II involves developing models of the variation in phase I. These methods include factor experiments and empirical experiments, which result in models with a functional dependency on particular layout practices (e.g. the density, pitch, or area of layout structures). In the oxide CMP case, density was found to be the primary explanatory factor, enabling the development of semi-physical modeling for oxide polishing in phase III. Here, it is important to create tightly coupled characterization and calibration methods for extraction of model parameters such as blanket removal rate and planarization. This is where this thesis makes its contribution.

The central focus of this thesis is to study how well CMP planarizes and how to optimize data collection for more efficient modeling to better understand wafer-level and die-level non-uniformity. In addition, we will study wafer-levelnon-uniformity effects on planarization length. The latter eliminates the unverified assumptions made in the past that planarization length is constant for a given wafer that undergoes a particular process condition. Wafer-level uniformity is affected by process conditions such as table speed, down force and slurry selectivity; errors in uniformity models arise from variations in the number and method of data collection used to obtain these models [4].

1.4 Thesis Organization

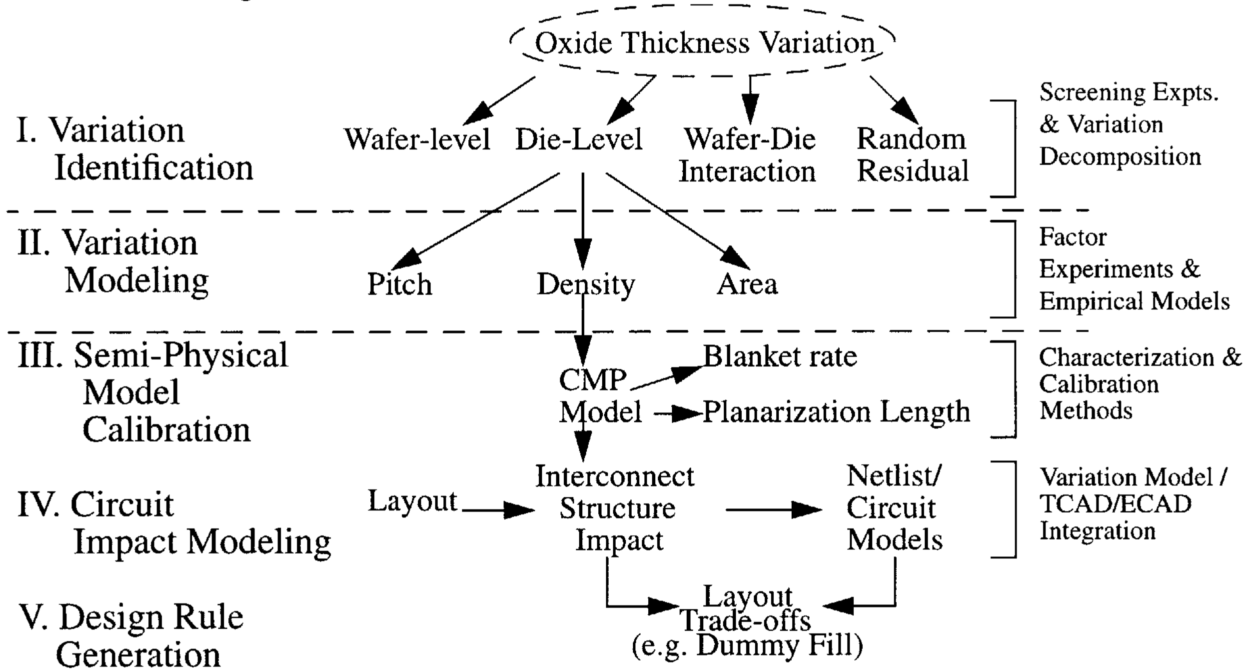


Figure 1.4: Phases of Statistical Metrology Development as Applied to Oxide Thickness and CMP Variation

This thesis is divided into four main sections. In addition to the introduction, which gives a brief overview of statistical metrology, the contribution and organization of this thesis, Chapter 2 presents the methodology part of this work. In Chapter 2 we look at how to minimize the amount of data required for accurate wafer-level uniformity modeling. In Chapter 3, we identify the effect of wafer-level oxide thickness variation (i.e., wafer-level non-uniformity) on planarization lengths and how process conditions affect planarization lengths. Chapter 4 then summarizes the main body of this thesis together with suggestions for improvement and extension of the work. The appendices present detailed data and experiments associated with wafer-level uniformity modeling (Appendix A), as well as data related to planarization length as a function of die position (Appendix B).

Chapter 2

Variation of Uniformity Models with Spatial Distribution and Number of Sample Points

2.1 Introduction

Wafer-level uniformity has become a very important factor in semiconductor processes. Reliable methods of modeling non-uniformity already exist; however, these models are not currently being applied efficiently. The Multiple Response Surface (MRS) method [2] is used to compute the non-uniformities on various wafers for different numbers of measurements and as a function of process conditions. Additional methods are available for modeling of the spatial wafer-level surface in addition to computing a wafer-level uniformity metric [3]. This thesis proposes a solution that will efficiently apply the MRS to non-uniformity metric modeling. Specifically, we show how the measurement distribution (location in space) and number of measurements will affect the non-uniformities calculated [2]. Hence for a given error tolerance, only the minimum number of measurements is required. Measurements are often taken on a wafer without a prior quantitative knowledge of the degree of accuracy achievable using a non-uniformity model, a spatial sampling pattern and a given number of measurements.

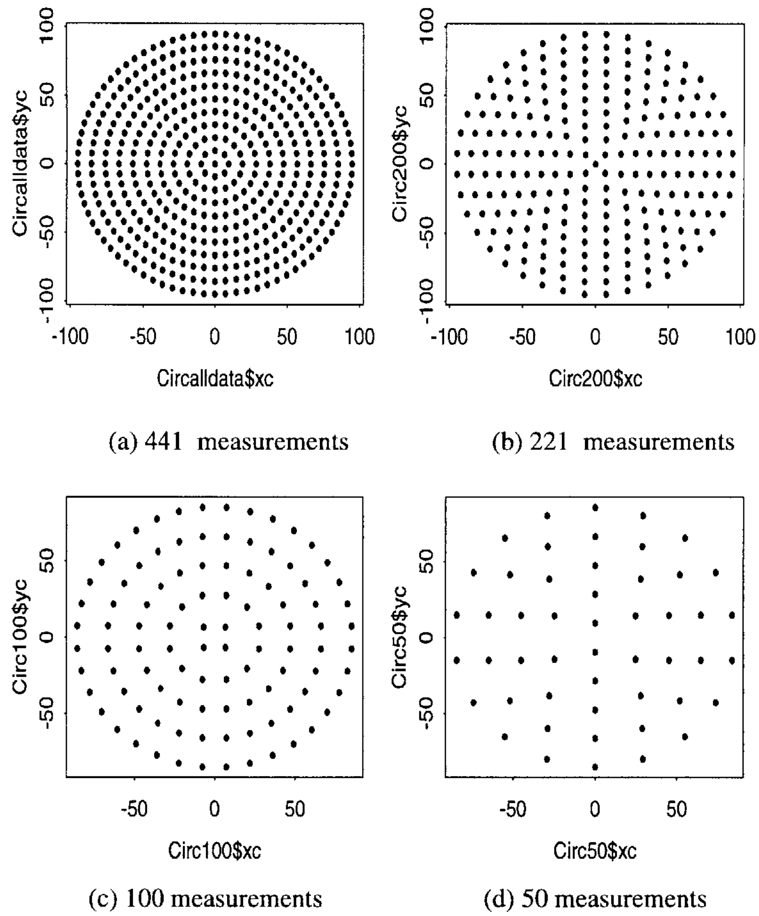
This study investigates how the non-uniformity metric values obtained from MRS models deviate from their true values as the number of sample points on the wafer is varied. Furthermore, the variation with different sampling or measurement patterns will be investigated. A quantitative measure of how accurate the non-uniformity models are for different sampling patterns and number of measurements will increase efficiency. This is because, depending on the work involved, only the minimum number of sample measurements needs to be taken on a wafer to achieve a desired accuracy, with a corresponding time savings.

This chapter has been divided into sections to explain the experiments and analyses performed to arrive at the conclusions. Chapter 2.2 explains the processes which the wafers underwent before and after polishing and the method of analyzing the data; Chapter 2.3 gives the theoretical basis of the non-uniformity metric. The results are presented in Chapter 2.4 and discussions in Chapter 2.5. The final section summarizes our conclusion.

2.2 Experimental Methodology and Raw Data

A process sequence was performed to deposit silicon on the blanket wafers prior to Chemical Mechanical Polishing (CMP) on 200 mm diameter wafers. A blanket deposition of LPCVD TEOS then followed. The wafer lot used in these experiments were polished on a rotary system (IPEC/Planar) at conventional speeds using the IC1400 polishing pad. The down force ranged from 4.8 psi to 8 psi; the table speed range was from 32 rpm to 80 rpm and the carrier speed range was from 28 rpm to 60 rpm. Optical oxide film thickness measurements were taken before and after CMP; together with the polish time, the removal rates were computed. In the next section, a detailed description of how the non-uniformity metric was computed from the raw data is given.

A total of 441 oxide thickness measurements were taken using the circular pattern shown in Fig. 2.1. The actual measurements are shown in Appendix A. These measurements form the detailed "baseline" dataset from which we select subsets of data to study other sampling patterns. For example, the circular pattern with 221 measurements was obtained by taking every other point on the first pattern with 441 points. By reusing the same data but in a subset fashion, we avoid the introduction of additional data measurement noise as we compare one sampling pattern against another. The same method was applied to the 221 point circular pattern to get the 100 point circular pattern and a similar method on the 100 point pattern yielded the 50 point pattern, as illustrated in Figure 2.1.



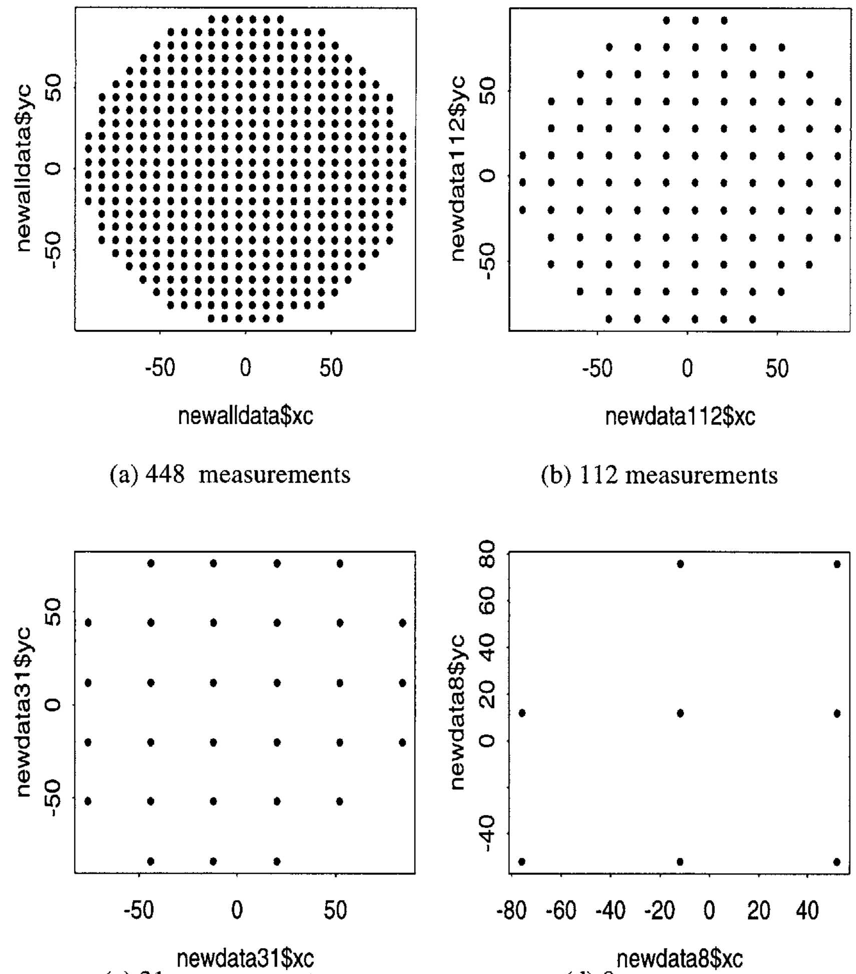
(a) 441 measurements (b) 221 measurements

(c) 100 measurements (d) 50 measurements

Figure 2.1: Different Samples of the Circular Pattern.

The radial pattern was generated by dividing the wafer area into eight parts separated by 45 degrees and taking those points that lie along these lines of separation. The first radial pattern has 81 measurement points. The second radial pattern was obtained from the first by taking every other point on the first pattern. The same method was applied to the 41 measurement points on the second radial pattern to generate the third pattern with 20 measurement points, as illustrated in Figure 2.3.

The grid pattern was generated by interpolating over all the circular measurements. The largest grid pattern has 448 measurement points. The second largest grid pattern was generated by taking every other point on the x-axis and every other point on the y-axis of the largest grid pattern. The same technique is applied to the 112 points of the second grid pattern to get the 30 points on the third pattern. A similar method is used to extract 8 points for the last grid pattern, as illustrated in Figure 2.2.



(a) 448 measurements

(b) 112 measurements

(c) 31 measurements

(d) 8 measurements

Figure 2.2: Different Samples of the Grid Pattern

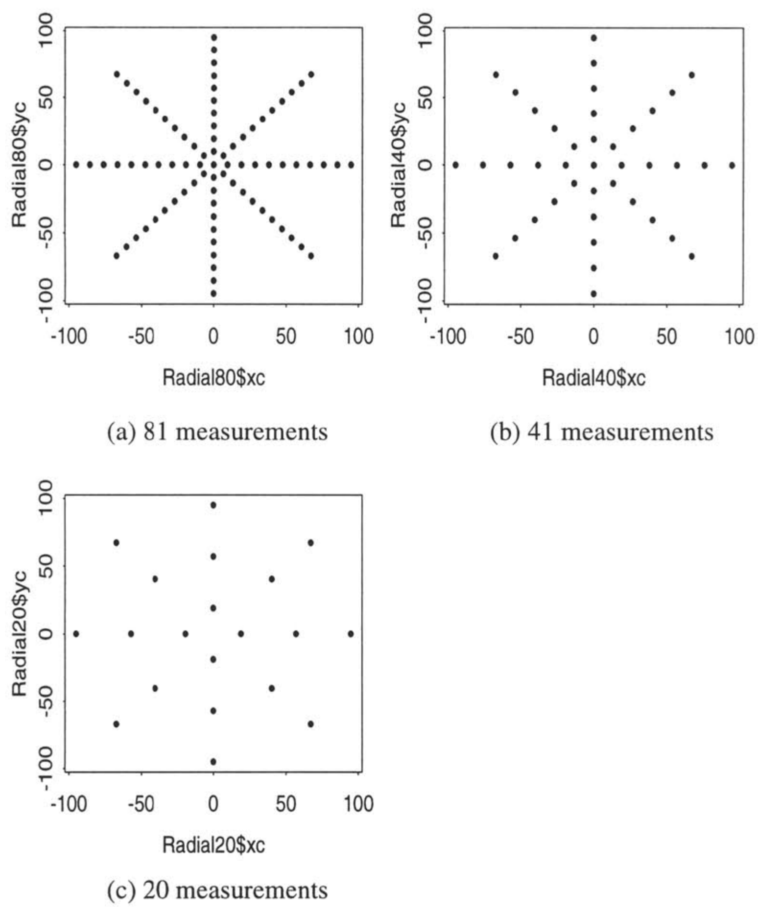


Figure 2.3: Different Samples of the Radial Pattern

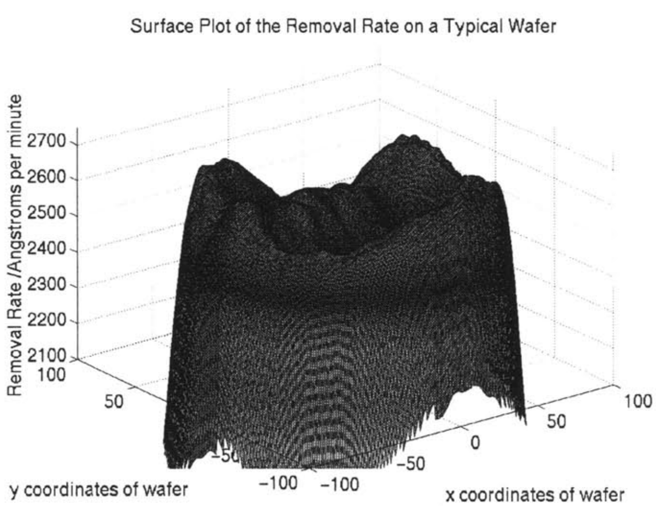


Figure 2.4: Surface Plot of the Removal Rate on a Typical Wafer

As an example of the wafer-level observed, Figure 2.4 shows the surface plot of the 441 removal rates of the circular pattern. It should be expected that different sampling patterns and sample point densities will result in different values for non-uniformity.

2.3 Determination of Non-Uniformity

Based on the measurement patterns described above, we want to compare how the non-uniformity metric varies depending on this plan. In this section we describe the Multiple Response Surface which we will use to compute non-uniformity. In Chapter 2.4 we then apply it to our experimental data.

Table 2.1: Multiple Response Surface Modeling

Process Split	P1	P2	rr_{d1}	rr_{d2}	...	rr_{dN}	$\frac{\sigma}{\mu}$
1	S_{11}	S_{12}	rr_{11}	rr_{12}	...	rr_{1N}	$\left(\frac{\sigma}{\mu}\right)_1$
2	S_{21}	S_{22}	rr_{21}	rr_{22}	...	rr_{2N}	$\left(\frac{\sigma}{\mu}\right)_2$
...	...	...	...	...	...	...	...
n	S_{n1}	S_{n2}	rr_{n1}	rr_{n2}	...	rr_{nN}	$\left(\frac{\sigma}{\mu}\right)_n$

The Multiple Response Surface method can be illustrated using Table 2.1. In this table, *P1* and *P2* are process setting, rr_{dN} is the removal rate at the position of die *N*, *N* is the number of dies on a wafer, *n* is the number of process splits and S_{xy} is the process setting for process factor *Py* and process split *x*. In the Multiple Response Surface method, we regress the removal rates, for each particular die location in each process split, on to process factors. For example, the values in the 4th column in Table 2.1 (rr_{d1}) are regressed over the process settings in the second and third columns (S_{11} and S_{12}) to get the following die site model:

$$drr_x = \alpha + \beta P1 + \gamma P2 + \tau P1.P2 \qquad (1)$$

where drr_x is the removal rate at the position of die x as a function of the process conditions and α, β, γ and τ are constants found by the regression. Consequently, the removal rate for any die position at known process settings (that is, known values of $P1$ and $P2$) can be calculated. The non-uniformity metric is σ/μ and can be computed from the following definitions for the estimated mean and standard deviation:

$$\mu = \frac{1}{N}(drr_1 + drr_2 + \ldots + drr_N) \qquad (2)$$

and

$$\sigma = \sqrt{\frac{1}{(N-1)}\left[(drr_1 - \mu)^2 + \ldots + (drr_N - \mu)^2\right]} \qquad (3)$$

The non-uniformity is often reported as a percentage, or 100 σ/μ.

Non-uniformity can be computed using either the final oxide thicknesses or the removal rates. The removal rates are useful in the case where the wafers are not totally uniform before polishing because the removal rate takes into account the fact that the wafers may not have equal oxide thicknesses everywhere before polishing.

2.4 Results

We first consider the trend in estimated non-uniformity for each of the sampling patterns considered, as a function of the number of samples. Looking at Figure 2.5 (a), the apparent non-uniformity decreases as the number of sample points increases in the case of the grid pattern. In other words, if the grid pattern is used for taking measurements, fewer measurements will infer that the wafer surface is less uniform than it actually is. On the other hand, when the circular pattern and the radial pattern are used for taking measurements on the wafer, the fewer the number of measurements the more uniform the wafer surface appears to be.

The grid-based estimates appear to converge to a constant value as the number of points increases. In addition, the circular pattern converges but to a different value. This is likely because the circular pattern may effectively weight different regions of the wafer more heavily or differently, so depending on the underlying spatial pattern different sampling patterns may result in different uniformity values.

From Figure 2.5 (b), the change in non-uniformity with the number of samples for the grid pattern varies at a lower frequency compared to the change observed with the radial and circular patterns. Again looking at Figure 2.5 (b), the non-uniformity in the case of the grid pattern varied over the smallest range of number of samples compared to the radial and circular patterns. There was no clear difference observed when comparing the non-uniformity range for the radial and grid patterns.

A look at the plots for the mean of the MRS models in Figure 2.5 (c) shows the opposite variation compared to that observed in the non-uniformity which is in accordance with the fact that non-uniformity is inversely proportional to the mean. On the other hand, the standard deviation of our MRS model varied in a similar fashion as the non-uniformity

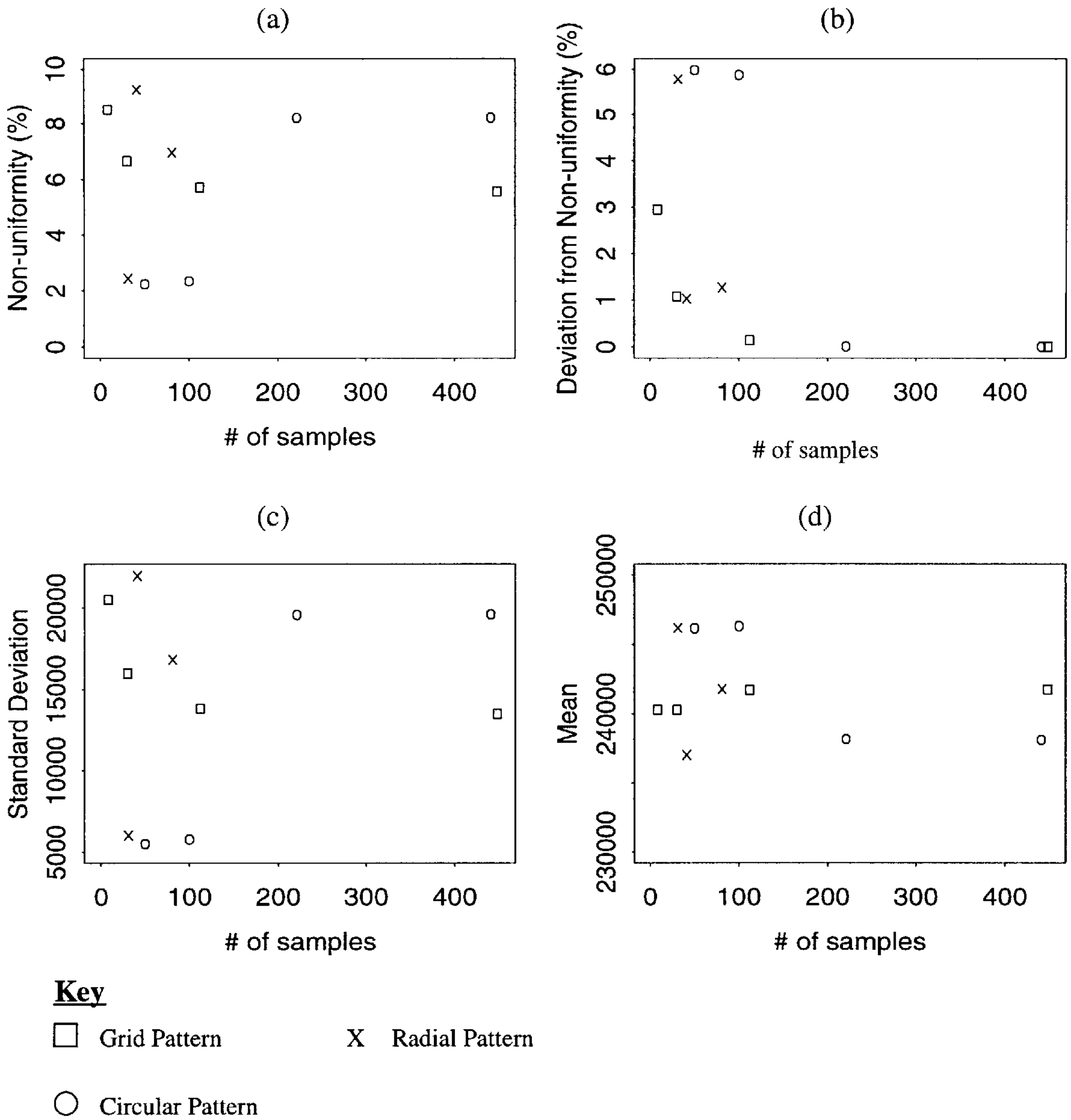


Figure 2.5: Variation of Non-Uniformity Standard Deviation and Mean with the Number of Samples

itself. Since the standard deviation dictates the trend in the non-uniformity with number of samples, it does suffice (as expected) to only look at the standard deviations. This is simply because the standard deviation is a constant multiple of the non-uniformity or can equally be viewed as the spread from the mean value.

From the graph of non-uniformity versus the number of samples in Figure 2.5 (a), the error in the computed non-uniformity for various numbers of samples is summarized in Table 2.2.

Table 2.2: Error in the computed non-uniformity for various numbers of samples

Sample Distribution	# of samples	Error (%)
Circular	441	0.000
	221	0.007
	50	5.985
Grid	448	0.000
	112	0.140
	30	1.078
Radial	81	1.250
	41	5.800
	20	1.050

2.5 Discussions and Suggestions for Improvement

The grid pattern seems to offer the best results for the CMP conditions and wafer data considered. Not only does the grid pattern result in a smoothly varying non-uniformity for different numbers of samples but the deviations from the actual non-uniformity is the least among other patterns. If a 1% deviation from the correct non-uniformity is tolerable, only 35 grid measurements are needed instead of 205 circular measurements. The next best results were obtained for the circular pattern which requires about 205 points to give an error no more than 1%. The radial pattern gave the worst results. The discrepancies apparently come from the way the measurement sites are distributed on the wafer surface. The more reliable results of the grid pattern can be attributed to how well each grid site represents a fraction of the wafer area [3]. Consequently, the poor performance of the radial pattern is significantly attributable to the highly irregular area representation of the radial measurements. However, these problems can be minimized using the methods in the next paragraph.

The reliability of these wafer-level uniformity results can be improved by using a more sophisticated spatial modeling approach beyond using linear regressions to find relations between the removal rate at a particular die position and the process conditions, and then computing mean and standard deviation. Thin-plate splines are very useful functions that may correct the biasing that is manifest in our results. As an alternative approximation, a weighting function can be applied to the experimental data to appropriately standardize the data for the unequal area representation of the measurement sites [3].

In order to explore the effect of area representation, a weighting function method was used on the largest data set (that is, the 441 circular measurement points). Each point was weighted using the area of the sector surrounding it as shown in Figure 2.6.

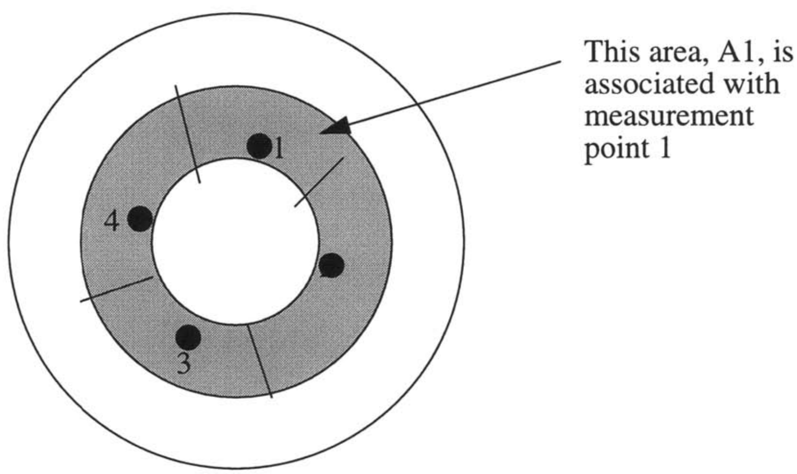


Figure 2.6: Weighting Function Modification to MRS Model

The measured removal rates were then scaled by the ratio of the area of the sector to the total area of the wafer without the 6mm exclusion region. Table 2.3 summarizes and compares the results of using and not using the weighting function. Please note that all previous non-uniformity computations have been done without the weighting function approach. Using the weighting function approach involves scaling the removal rates, for

Table 2.3: Effect of Weighting Function on Non-Uniformity

441 Circular Pattern Measurement Points	Non-Uniformity
With Weighting Function	8.20%
Without Weighting Function	6.75%

example, the removal rate at the location of "point 1" (rr_1) in Figure 2.5 is:

$$rr_1 = (A_1 * drr_1)/A$$

where A_1 is the area associated with "point 1", drr_1 is the original removal rate at the location of "point 1" and A is the area of the wafer without the 6mm exclusion region.

2.6 Conclusions

Our results show that the grid pattern is the most reliable sampling pattern of measurements on a wafer for non-uniformity analysis, for the experiments considered here. The next best distribution is the circular pattern and unless reasonable accuracy is not essential, radial distributions can be used. A summary of these results are presented in Table 2.2. With the incorporation of thin-plate splines and a weighting function to account for the area representation of the wafer, the wafer non-uniformity analysis is expected to be even more representative of the true non-uniformity.

Chapter 3

Variation of Planarization Length with Process Conditions and Wafer Edge Effects

3.1 Introduction

Planarization length is a very important parameter in the characterization of oxide and Shallow Trench Isolation (STI) Chemical Mechanical Polishing (CMP) processes. This chapter utilizes several statistical and modeling techniques to help understand how planarization length varies across process conditions, as well as within a given wafer. The effects of downforce, table speed, and die position on planarization length have been characterized. Even with a 6mm edge exclusion during processing, our analysis reveals that die position plays a crucial role in the value of the planarization length. The die-to-die variation of the planarization length within a wafer can be as much as 3.2 mm, compared to an average planarization length of about 7.5 mm for the process we examined. In particular, the die at the opposite end of the wafer notch consistently exhibited the lowest planarization length. The characterization results also show that the planarization length increases with table speed and decreases with downforce.

CMP of inter-layer dielectrics results in excellent feature-level planarity, but is also affected by systematic pattern sensitivities. In the past, we have always assumed planarization length was approximately uniform across a wafer. This is because planarization length is mainly determined by the polish pad type, the relative speed of the pad and wafer, the down force, and other process parameters. However, in the 8” wafer era, the spatial distance over which the pad has to polish has increased and this assumption no longer holds. Now we are in a better position to predict the planarization length of a CMP process at a specific die position which is useful in ULSI technology circuit design and layout. It is important to use the correct planarization length because planarization length is used to determine the correct effective pattern density. For example, a large planarization length across a wafer corresponds to a low effective pattern density range across all the dies on the wafer; therefore, if the planarization length is not the same on all the dies then the effective pattern density range will vary across the wafer. Consequently the correct planarization length is necessary to predict the correct Total Indicated Range (TIR) [1].

This chapter has been divided into Chapter 3.2 which describes the experimental plan and the analysis method, Chapter 3.3 where we present our data analysis and Chapter 3.4 which discusses the results. Chapter 3.5 summarizes our findings and describes future projects.

3.2 Methodology

This section will give an overview of the experimental setup and the processing conditions the wafers underwent, then the analysis method will follow. The latter will detail the theoretical approach used to analyze the measure data on the processed wafer.

Experimental Setup

A total of 15 8" wafers underwent the following processing sequence. The short loop test monitor used for this evaluation consisted of a combination of PETEOS and HDP SiO_2 deposited over a patterned and etched metal stack. The metal film was deposited over a blanket PETEOS film of 7500 Å on 200 mm substrates. The initial dielectric step height measured ranged from 0.92 μm to 0.94 μm across the two test lots processed. The initial ILD thickness before CMP was between 2.65 μm and 2.7 μm. A target of 1.0 μm dielectric removal from the 100% density structures was used to define the planarization target time when the entire step height should be removed from all structures. Figure 3.1 shows the 12mm density mask from the MIT characterization mask set that was used for the metal patterning [4]. The 12mm mask has a 1mm buffer region and 25 square density blocks, each 2mm in dimension. The densities increase in steps of 4% from a density of 4% in the bottom left corner of the mask to 100% in the top right corner [7].

Table 3.1 summarizes the process conditions that were employed during CMP. The polish pad was the IC1000 Suba IV and the slurry used was SS25.

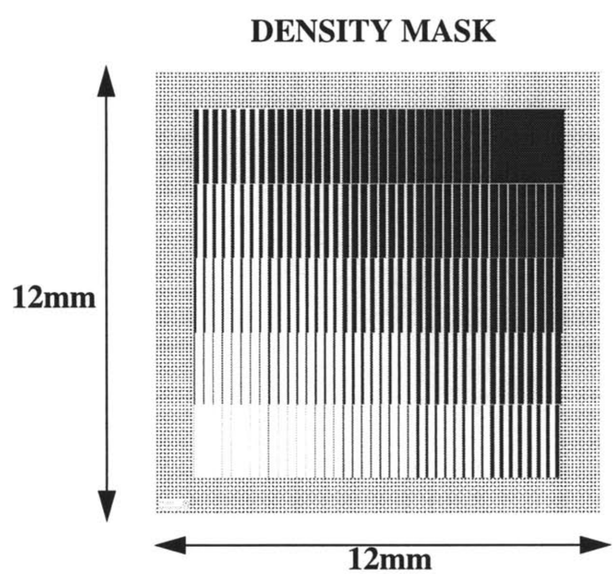


Figure 3.1: Layout mask used in wafer processing; Density Mask

Table 3.1: CMP Process Conditions

Experiment Level (Speed/Down Force)	Number of Wafers	Polish Time (sec)	Table Speed (rpm)	Down Force (psi)
Midpoint	3	136	37	6.71
Low/Low	3	174	20	5.69
High/High	3	98	54	7.74
High/Low	3	130	54	5.69
Low/High	3	142	20	7.74

Thickness measurements were taken over metal (up areas) and in the down areas (between metal lines). A total of 17 dies were measured per wafer and 49 measurements were taken per die: 25 over the metal at each of the blocks in Figure 3.1 and 24 in the down areas. Figure 3.2 shows the positions of the dies measured on each wafer. The sampling pattern shown in Figure 3.2 was chosen to capture as much of the entire wafer surface as possible and the symmetry was chosen to compare the polish characteristics of dies at symmetric positions on the wafer, for example dies 10 and 14 in Figure 3.2.

Analysis Methodology: Determination of Planarization Length

In this section we give an overview of the procedure for determining the planarization length of a polished die for a given process condition. According to Stine et al., [5] the

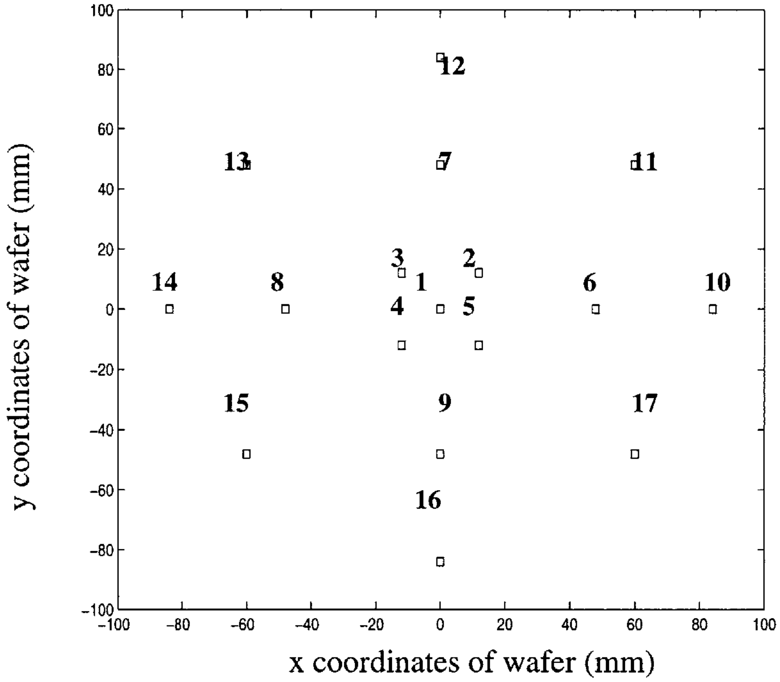


Figure 3.2: Die Positions on a Wafer

evolution of ILD thickness during CMP is as follows:

$$\begin{matrix} z = z_0 - \left(\dfrac{Kt}{\rho_0(x, y)}\right) & Kt < \rho_0 z_1 & \text{(nonlinear regime)} \\ z = z_0 - z_1 - Kt + \rho_0(x, y) z_1 & Kt > \rho_0 z_1 & \text{(linear regime)} \end{matrix} , \qquad (1)$$

$$\rho(x, y, z) = \begin{cases} \rho_0(x, y) & z > z_0 - z_1 \\ 1 & z < z_0 - z_1 \end{cases} . \qquad (1b)$$

where K is the blanket polish rate, $\rho(x, y, z)$ is the local pattern density, and z_0 and z_1 are defined as in Figure 3.3.

In the evaluation of pattern density, a simple vertical ILD material deposition is assumed. The effective density is evaluated in the following steps. First the density is evaluated in small square cells and the layout density is defined as the ratio of 'up' (metal) to total area of a cell. An elliptic filter is used to determine the effective pattern density across a die, where the density assigned to a point is the ratio of weighted raised area and the total

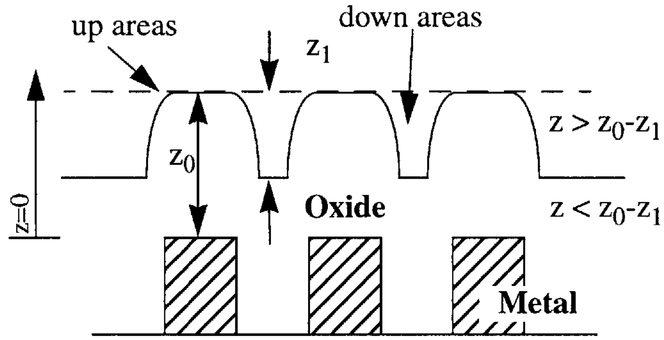


Figure 3.3: Definition of terms used in model

area of the filter window. The effective density is then obtained by summing the weighted local cell densities. The elliptic window was chosen because it has been shown to give the least root mean square error and relates to the physical properties of the pad [3], [6].

The planarization length is defined as the width (length scale) parameter in the elliptic elastic deformation function. For each process condition, the optimal response function length is determined and the response function which results in the overall least mean sum of square error between model and data is chosen. This procedure is summarized in Figure 3.4 [14].

In calculating the planarization length, care was taken to use different blanket removal rates at different die locations because the removal rate can vary significantly across a wafer, especially for large 8" wafers. A Matlab routine was used to find the proper blanket removal rate for a given die location, simultaneously with the extraction of planarization length.

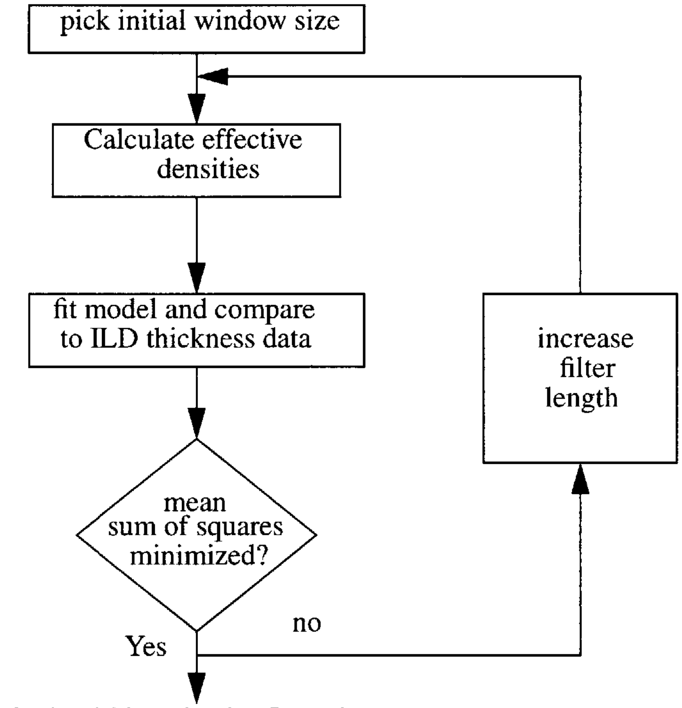


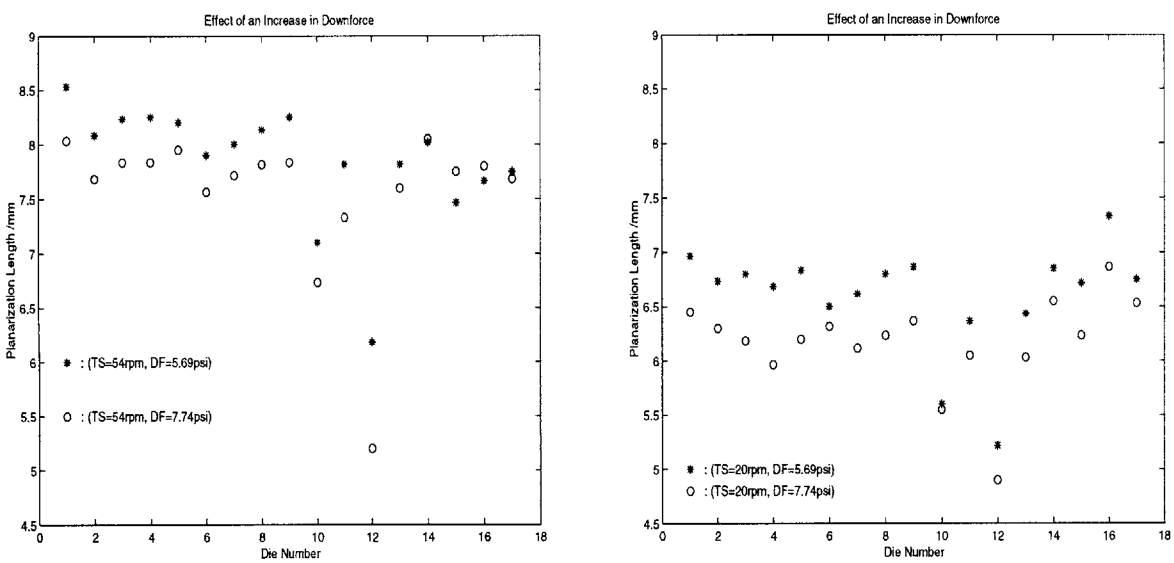
Figure 3.4: Experimental Extraction of Planarization Length

3.3 Analysis Results

Effect of Change in Table Speed and Down Force on Planarization Length

The planarization lengths of the 15 polished wafers are shown in Tables B.1 to B.5 of Appendix B. We noticed that the die with the lowest planarization length on each wafer was the die at the opposite end of the notch, corresponding to die 12 in Figure 3.2. Figures 3.5(a)-(f), which were obtained by taking the average of the planarization lengths of the three repetitions per process condition, shows dies 10 and 12 consistently had the lowest planarization lengths.

Upon analysis of these figures, the planarization length was found to increase with table speed and decrease with down force. This makes intuitive sense because as the down force is increased, the polishing pad tends to bend more and conform better to the pattern density structures and so the planarization length should decrease with down force. When the table speed is increased, we expect the planarization length to increase as well since at higher speeds, the pad has less time to flex and conform to different structures as the pad rotates past different pattern density structures. To verify our findings even further, we plotted the planarization lengths for scenarios in which there were two changes in process conditions instead of one; refer to Figures 3.5(e) and 3.5(f).

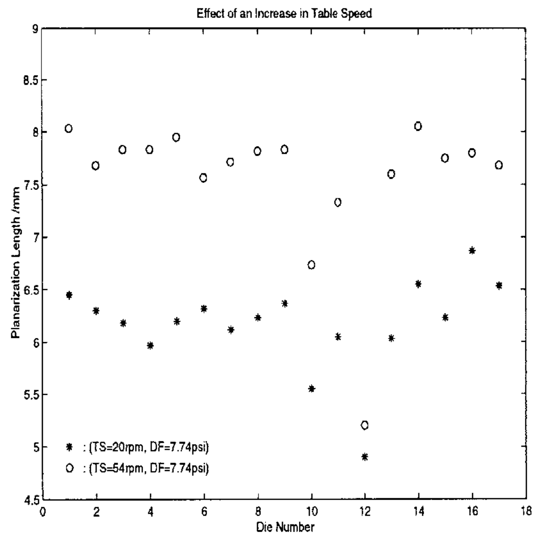


(a) **(b)**

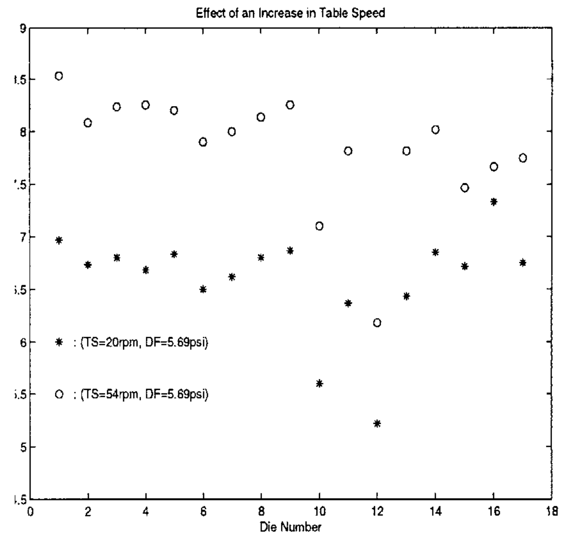
Figure 3.5: Effect of a Change in Table Speed and Down Force on Planarization Length

<u>Surface Interpolation of the Planarization Lengths for Different Process Conditions</u>

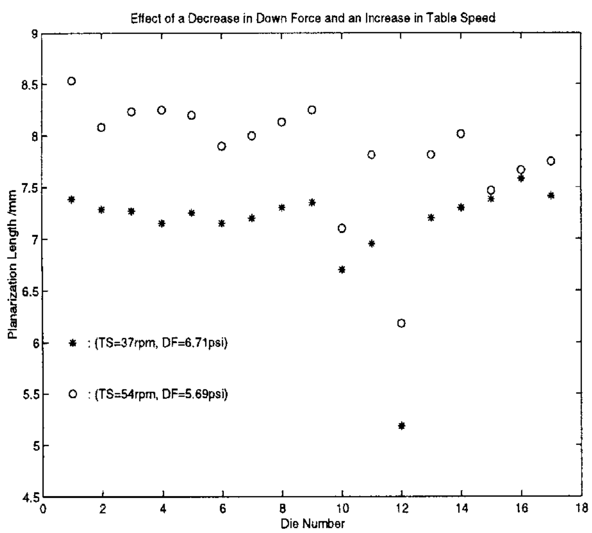
Figure 3.6 is an interpolated surface of the planarization lengths at different die positions and the non-uniformity in the planarization length is clear. The planarization lengths used are the average of three repetitions per process condition. This surface plot



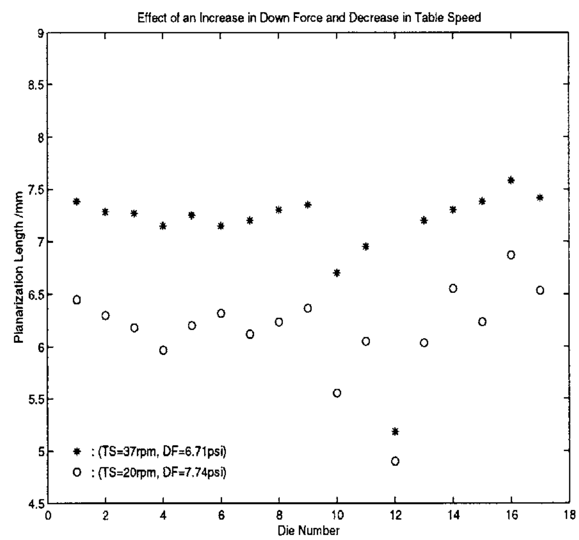
(c)



(d)



(e)



(f)

depicts the edge effects on planarization lengths and enables interpolation of planarization lengths at other die positions where experimental data is unavailable.

<u>Average and Range of Planarization Length for Different Process Conditions</u>

Figure 3.7 shows the planarization lengths that were calculated using the values in Tables B.2 and B.6. The method of presentation in Figure 3.7 clearly shows that for each

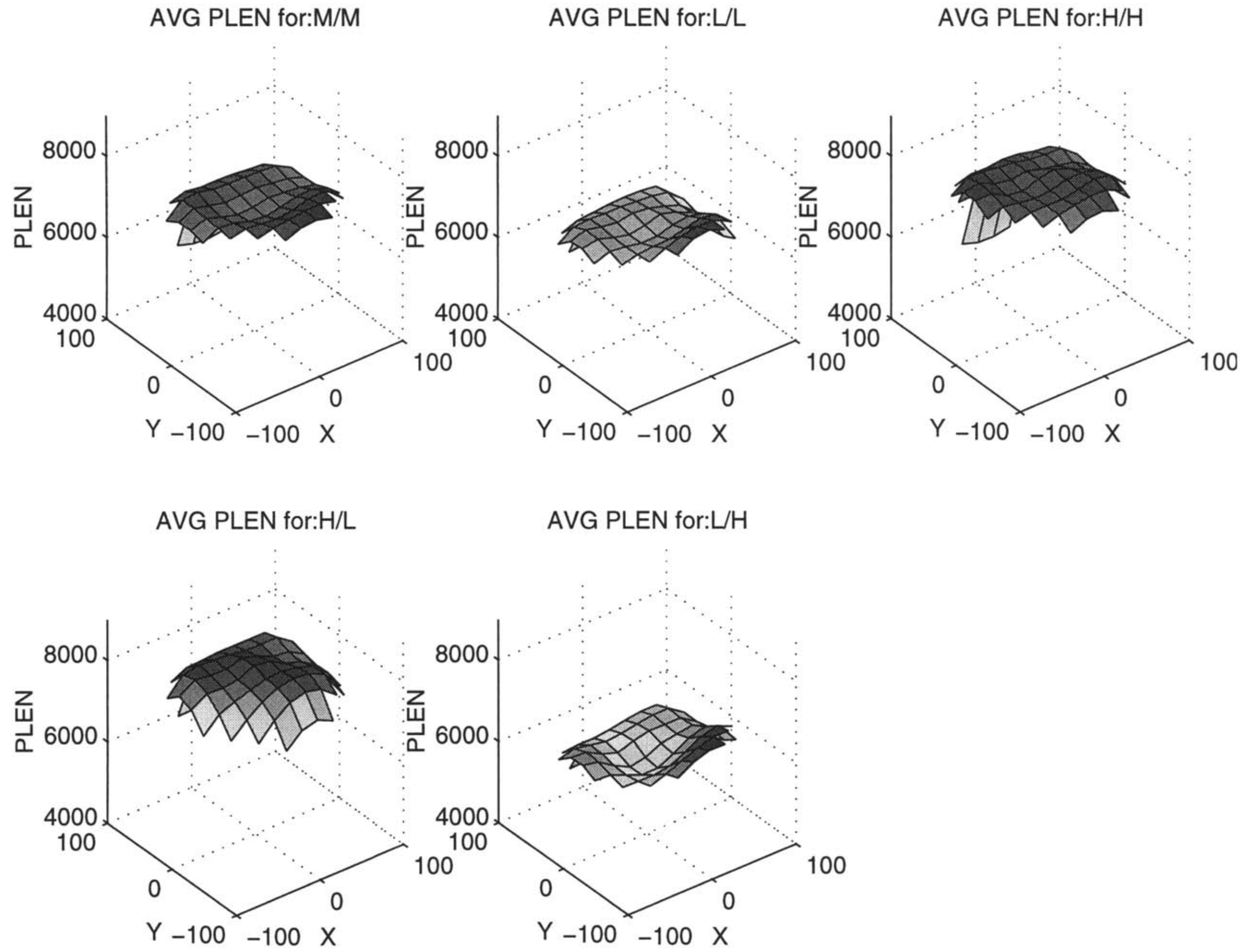
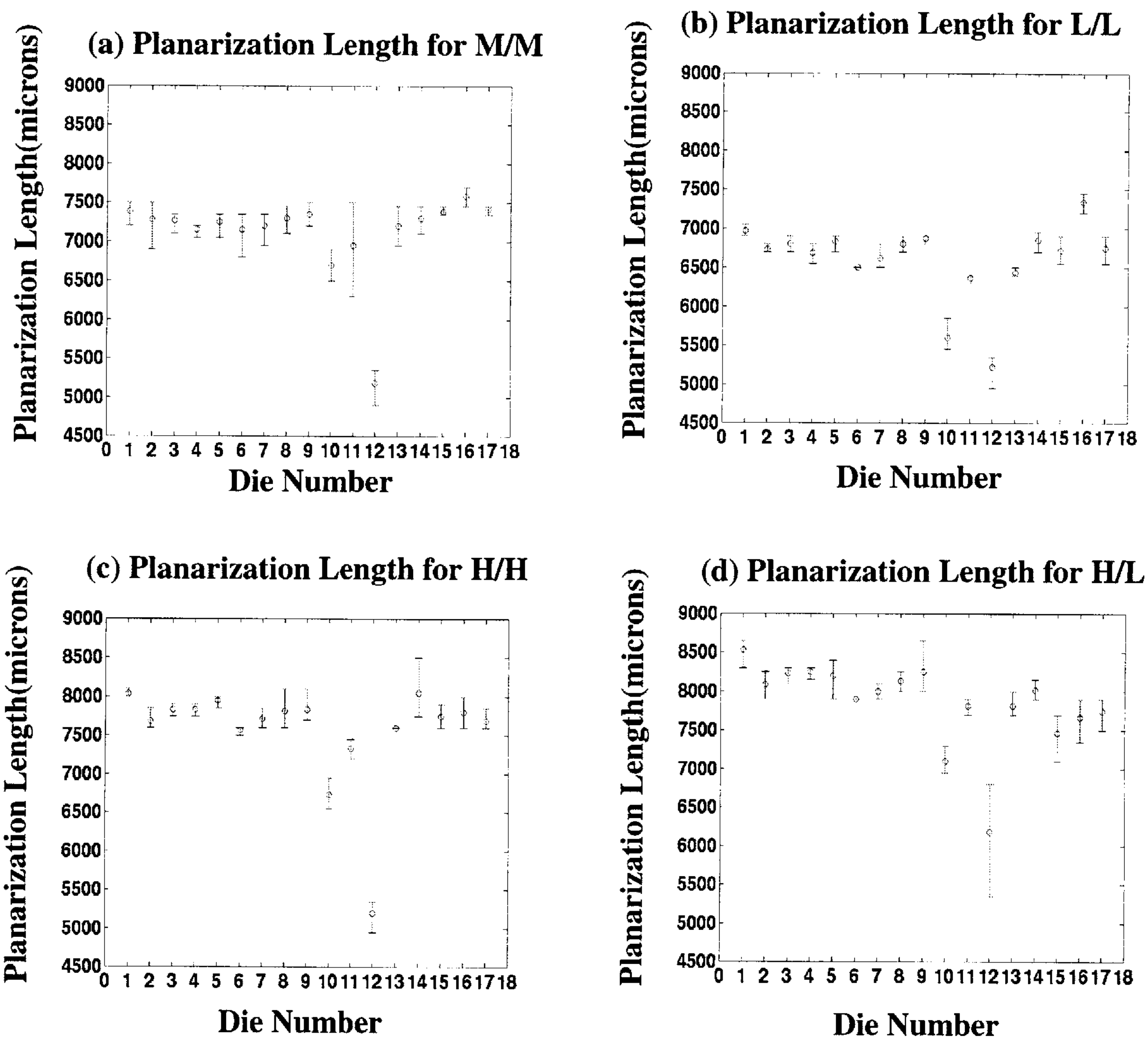


Figure 3.6: Surface Interpolation of Planarization Lengths (Table Speed/Down Force levels indicated)

process condition, the planarization length obtained varies somewhat from wafer to wafer. The vertical lines include the mean, high, and low extracted values for each process condition, and can be viewed as a measure of statistical variation in the planarization length. For example, in Figure 3.7c, the planarization lengths obtained for die number 14 ranged from 7.75mm to 8.5mm even though we used the same conditions in our three wafer replicates. Although we can assume all process conditions are the same for the three repetitions, this is not exactly true since the pad does not remain in the same condition after polishing. There is some pad wear as the pad is used to polish more wafers.



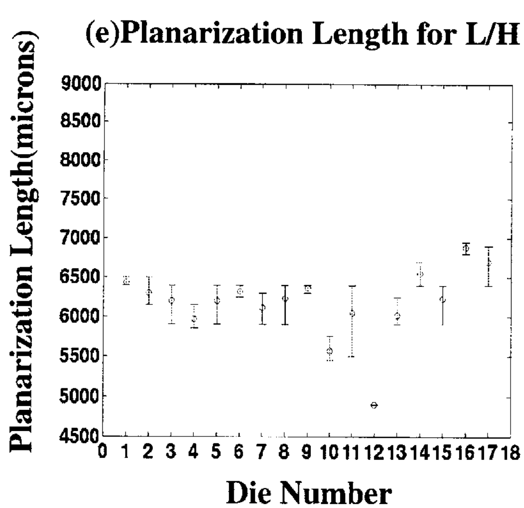


Figure 3.7: Process Condition Summary

M/M => 37 rpm, 6.71 psi
H/? => Table Speed = 54 rpm
L/? => Table Speed = 20 rpm
?/H => Down Force = 7.71 psi
?/L => Down Force = 5.69 psi
(e.g. H/H = 54 rpm, 7.71 psi)

Figure 3.7: Planarization length variation with process conditions

Figure 3.8 provides useful information about how planarization length can be improved. Specifically, increasing table speed or decreasing down force improves planarization length. Since the effect is cumulative, both previously mentioned changes would have the best effect when they are both applied to a process. In addition, Figure 3.8 b) shows that variation in table speed is more effective in improving the planarization length.

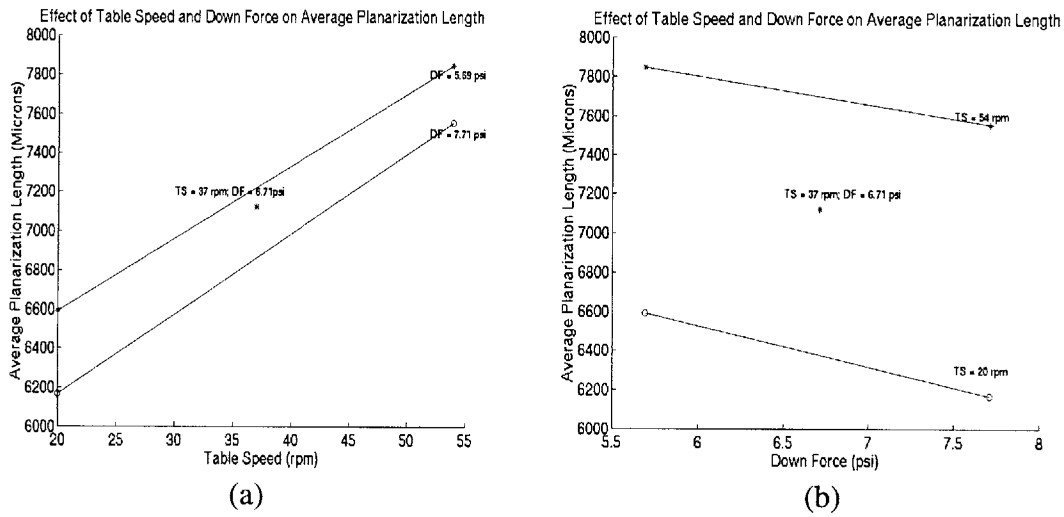
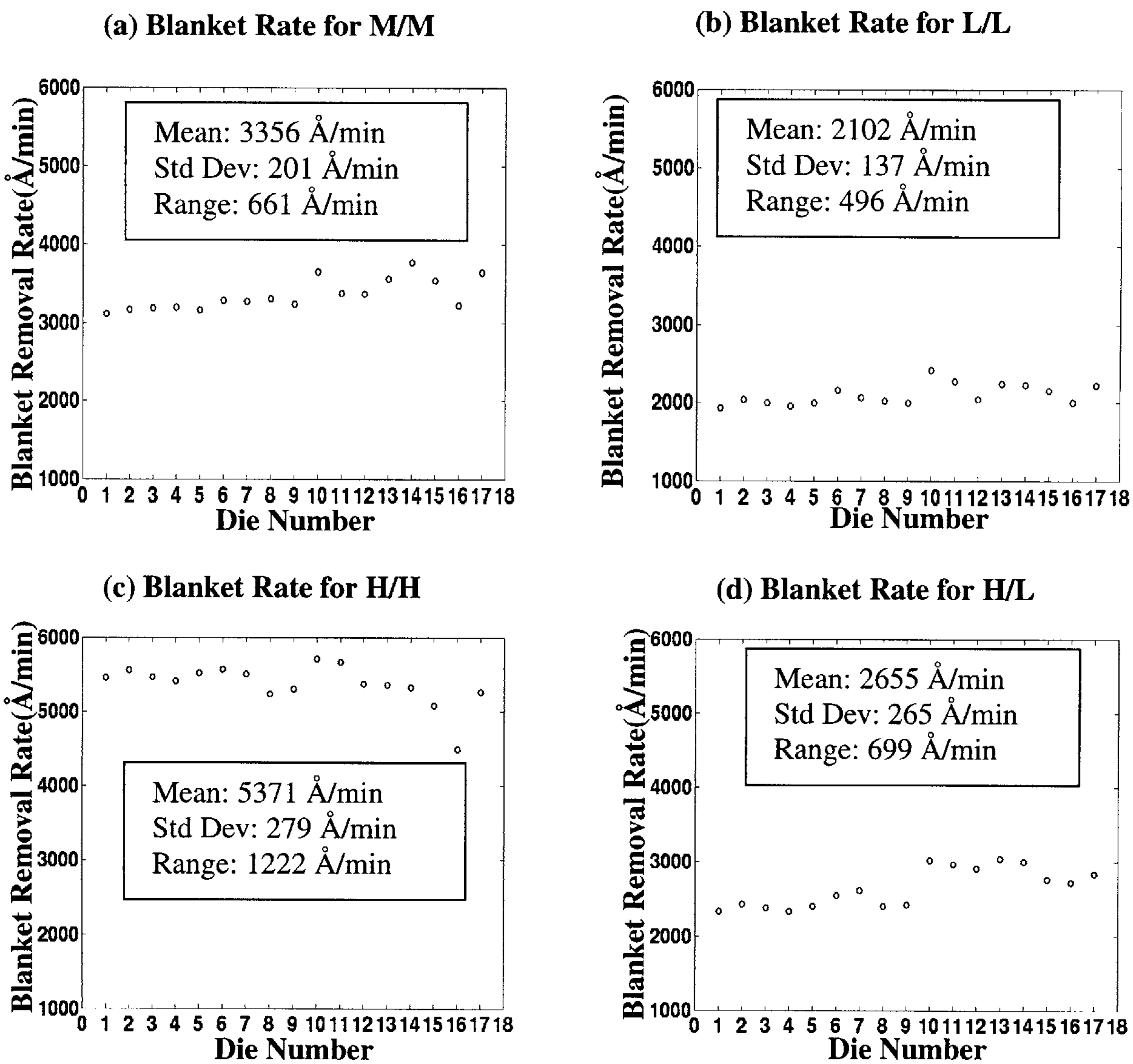


Figure 3.8: Summary of the Effect of Table Speed and Down Force on Average Planarization Length

<u>Blanket Removal Rates</u>

The planarization length extraction procedure incorporated a blanket removal rate extraction step. Blanket rates typically vary from die to die, and an error in the value of the blanket removal rate can introduce a constant offset between the model prediction and actual oxide thicknesses. The calculated blanket removal rates are shown in Figure 3.9.



Analysis of Figures 3.9(a) to 3.9(e) shows that the blanket rates are largest under process conditions of high speed and high down force, and lowest under low speed and low down force. This agrees with the classical Prestonian CMP model, where "blanket removal rate" is defined as a quantity which is directly proportional to both pressure (and thus, down force) and velocity [2].

For the values of down force and table speeds used in this experiment, a few other observations can be made. It can be seen from the graphs that at lower values of down force (5.69 psi), increasing the table speed increases the mean blanket rate from 2102 to

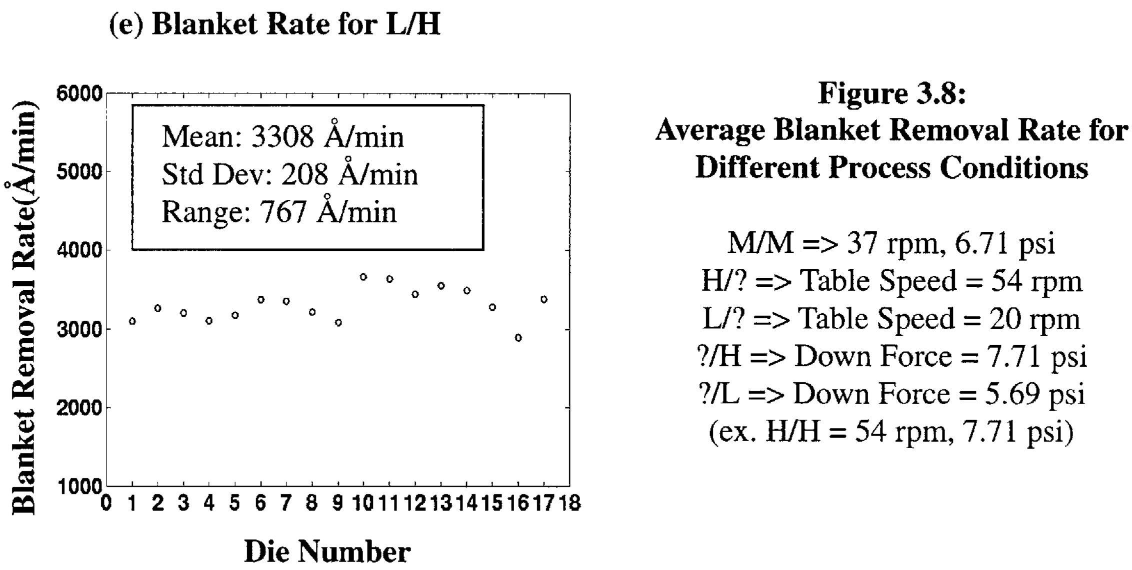


Figure 3.9: Blanket rates for different process conditions

2655 Å/min (Figures 3.9(b) to 3.9(d)). At higher down force (7.71 psi), it can be seen that the same increase in table speed causes a much higher increase in the mean blanket rate, from 3308 to 5371 Å/min (Figures 3.9(e) to 3.9(c)). However, higher down force blanket rates also exhibit larger within-wafer non-uniformity. Note that for the same values of table speed, a larger value of down force leads to a larger standard deviation and larger range of blanket rate values. For example, Figures 3.9(b) and 3.9(e) show that for a table speed of 20 rpm, a low down force gives a range of 496 Å and a standard deviation of 137 Å, while a high down force gives a range of 767 Å and a standard deviation of 208 Å. Thus it is possible to see that an increase in down force will increase the blanket rate, but also have a negative impact on the uniformity. This trade-off of increasing blanket rate while decreasing uniformity (and vice versa) is exhibited throughout the data set.

A similar observation can be made for increases in down force. At a lower value of table speed (20 rpm), an increase in down force results in an increase in mean blanket rate from 2102 to 3308 Å/min (Figures 3.9(b) to 3.9(e)). At the higher table speed of 54 rpm, the same increase in down force results in an increase in mean blanket rate from 2655 to 5371 Å/min (Figures 3.9(d) to 3.9(c)). However, increasing table speed also results in an increase in standard deviation (e.g., 137 Å to 201 Å for down force of 5.69 psi) and an increase in range (496 Å to 661 Å for 5.69 psi).

Analysis of Figure 3.8 also confirms that an increase in both table speed and down force will increase the blanket removal rate while also decreasing the uniformity (Figures 3.9(b), 3.9(a) and 3.9(c)).

The above observations are supported by the summary in Figure 3.10. However, more insight can be gained by further analysis of Figure 3.10. For example Figures 3.10 (a) and (b) show that an increase in either the down force or the table speed has a greater effect of increasing the mean removal rate at a higher table speed or down force respectively. This is because the slope of both graphs increase with an increase in the down force in Figure 3.10 (a) and an increase in table speed in Figure 3.10 (b). However, an examination of Figures 3.10 (c) and (d) show the opposite effect on wafer-level uniformity (as measured by the standard deviation) in the sense that the slopes decrease with an increase in table speed and down force.

3.4 Discussion

We know planarization length should vary strongly with pad type, relative speed and down force. Since the pad type remains relatively the same in our experiments (ignoring pad wear) and the relative speed is the same for symmetric dies, for example dies 10 and 14 and dies 12 and 16 in Figure 3.2, we expect similar results for these dies. However,

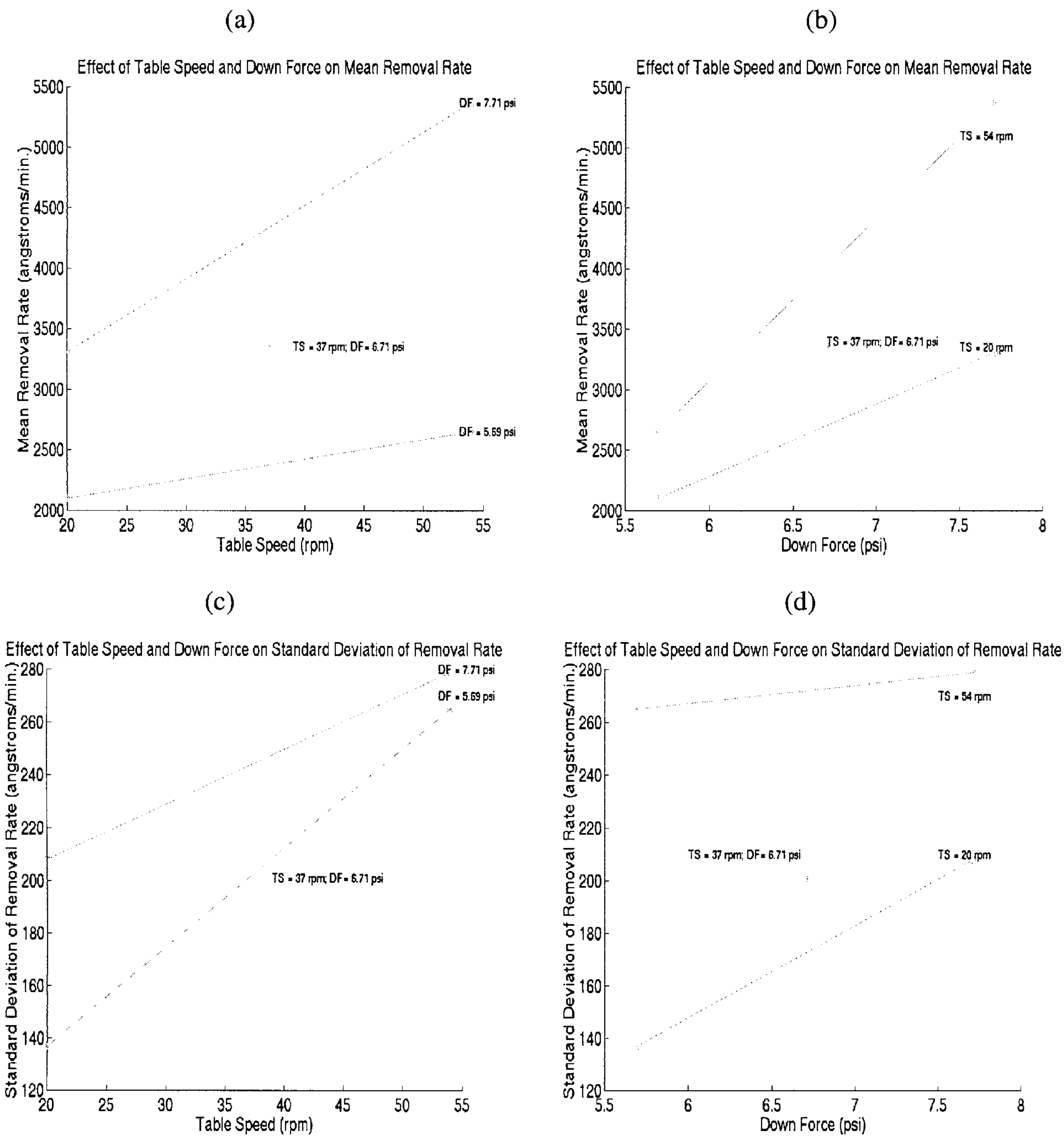
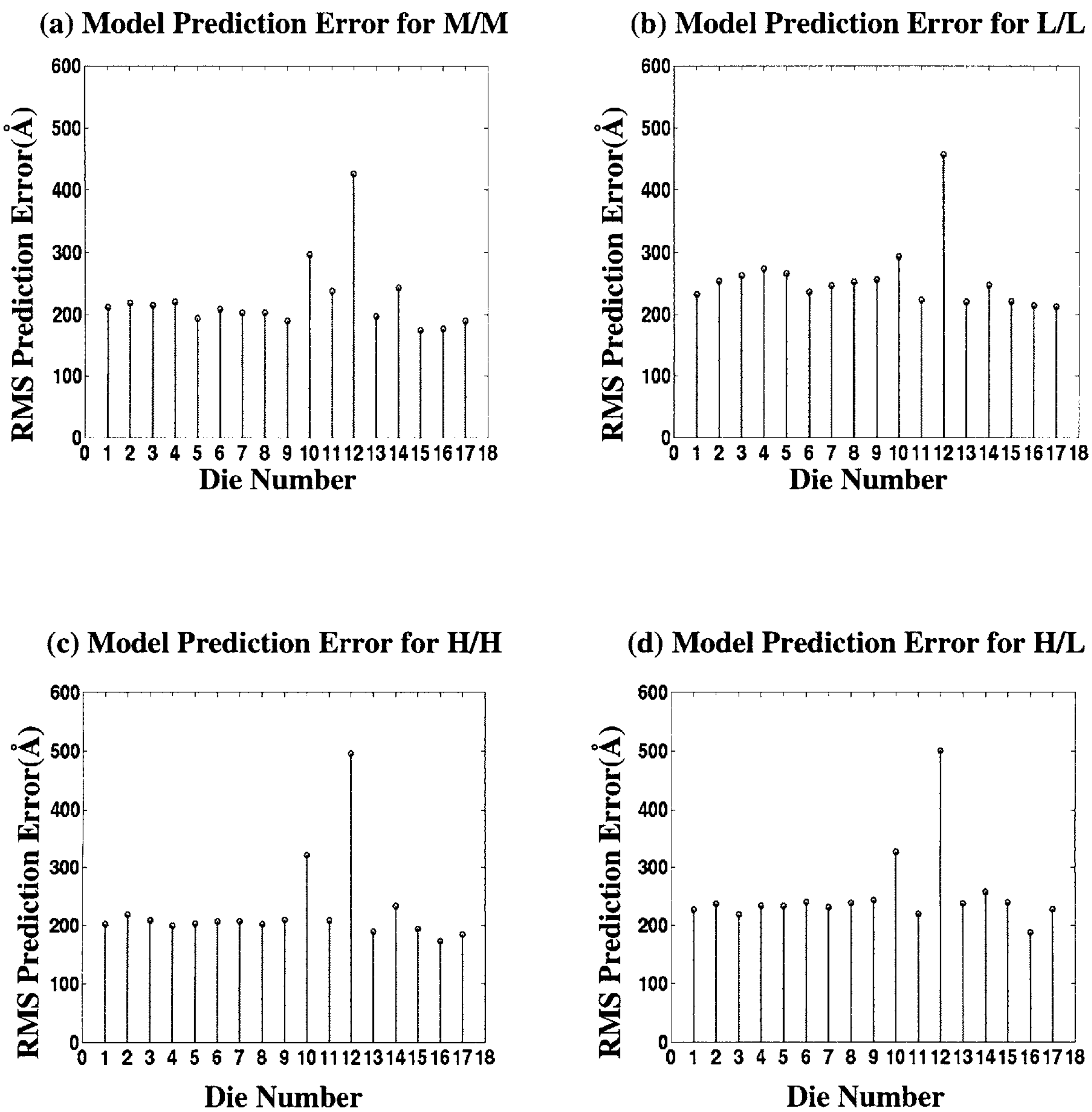


Figure 3.10: Summary of the Effect of Table Speed and Down Force on the Mean and Standard Deviation of Removal Rate

a look at Figures 3.5 and 3.7 shows that the planarization lengths for dies 10 and 14 are not similar. This also applies to dies 12 and 16. This discrepancy prompted an interest in investigating how well our model in Figure 3.3 performed for dies 12 and 10. Recall that the extracted planarization length is that which gives the best model fit. Thus large model fit errors could indicate poor estimates for planarization length.

In order to confirm that we do not have significant error in our modeling methodology, we have computed the root mean square error for each computation of the planarization length. An average of the three errors was taken for each process condition. This is shown in Figure 3.11.



The plots show that the prediction errors for die 12 are consistently the highest for

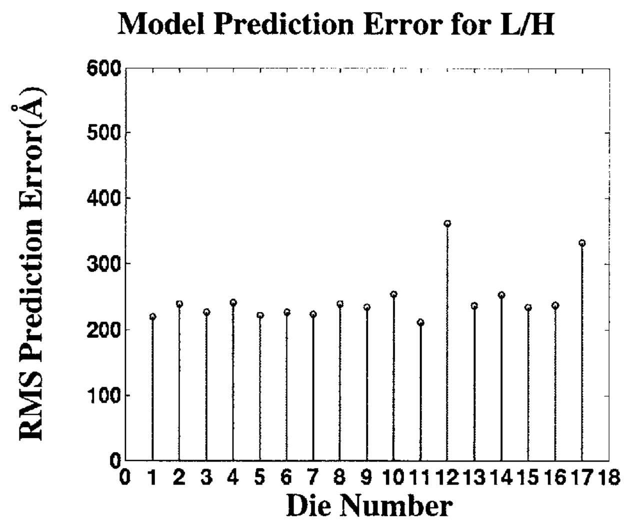


Figure 3.11: Root Mean Square Prediction Error

all the processed wafers. The next largest error corresponds to die 10 in Figures 3.11(a), 3.11(b), 3.11(c) and 3.11(d), and die 17 in Figure 3.11(e). The third largest error occurs in die 14 in all the figures except for Figure 3.11(b). One interesting observation is that all these errors occur with only dies that are at the edge of the wafers. And since our model worked well for most of the other dies then the polishing characteristics of the dies at the edges of the wafer must be significantly different from that of other dies.

However, in the worst case scenario, we can assume that the dies with relatively large errors such as dies 10, 12, 14 and 17 have erroneous planarization lengths. Even then, the planarization lengths of the remaining dies vary by as much as 0.5mm within the wafer. Hence the spatial location of a given die on a wafer does influence planarization length, and assumptions of a constant planarization length must be treated with caution.

A further analysis shows that die 12 exhibits characteristics of very high non-uniformity. The first sign of a suspicion is due to the fact that the extracted planarization length is much lower than the planarization length for other dies (See Figures 3.7(a) to

3.7(e)). Furthermore, we know that if the blanket rate is consistent across a die, then there is a single planarization length which captures the polish evolution well (i.e., with small error). However, the model prediction errors for die 12 are consistently and significantly higher than that of the other dies, which indicates a larger degree of scatter in the data set. The larger error indicates that the extracted planarization length may not valid, which means that there exists a large variation across the die which cannot be captured by pattern effect alone. Examination of the mean Total Indicated Range for each of the dies (averaged across all wafers) confirms this statement: the Mean TIR for die 12 is 6000Å, while the average mean TIR for all other dies on all other wafers is 5100 Å. The large variation leads one to believe that it cannot be just due to pattern effect alone. Examining the process and the die location, it is possible that some wafer edge effects may be the cause of the additional variation. Due to these edge effects, a non-uniform blanket removal rate exists in the dies closest to the edge.

Examining Figure 3.2 and Figure 3.1, it is possible to formulate another hypothesis to explain the source of the variation. Die 12 is at the edge of the wafer, with the region of high density structures close to the edge. The specific orientation of the die with respect to the edge, as well as its position on the wafer, may be the cause of the additional variation. Note that die 10 also exhibits a large value of prediction error; die 10 is also at the edge, and also has the region of high density structures closest to the edge. Dies 14 and 16, while also on the edge, and symmetrical in position to dies 10 and 12, do not exhibit such large error; this may be due to the fact that low density structures on the die are closest to the edge.

Large variations can be introduced if the edge of the wafer polishes slower than other regions of the wafer. Dies 10 and 12 will have high density regions polished at a slow rate, while lower density regions polish faster; this will lead to a larger variation in final oxide thickness. Dies 14 and 16, on the other hand, will have their high density regions polish faster, and their lower density regions polish slower, which may reduce the amount of variation in the final oxide thickness.

3.5 Conclusion and Future Work

We have analyzed the polish data for different process conditions and dies on a wafer. Our analysis shows that there is significant non-uniformity in the polishing of an 8" wafer. We discovered that certain data sets exhibited large variations which could not be explained by pattern effects alone; these data sets must also incorporate edge effects to explain the total variation. Ignoring dies which do not have valid extracted planarization lengths (i.e. dies 10 and 12), the planarization length varies in the range of 0.0 to 0.5 mm for our process. The planarization length also varied with process condition; it increased with table speed and decreased with down force.

The next phase of future analysis is to find out specifically how the orientation of the dies at the edge of the wafer affect their polish evolution. Furthermore, we plan to use the measurement data of the down areas to develop a pattern dependent model of the polishing characteristics of the down areas.

Chapter 4

Conclusions and Future Work

4.1 Summary

This thesis has shown that although CMP has the best planarization performance presently available, further research is necessary in order to learn more about and improve the uniformity issues in CMP. We have learned that certain measurement patterns are better than others in determining a wafer-level non-uniformity model and after a certain threshold number of measurements, there is very little improvement in the accuracy of our model. The grid pattern stood out in terms of performance; it required the fewest number of measurements in order to give a uniformity model that is as accurate as other models derived from measurements of a different distribution pattern.

Our analysis also shows that our previous assumption about the consistency of planarization length on a wafer that has undergone a particular process condition has limitations: the planarization length is typically not constant on an 8" wafer. The planarization length of dies in the interior of the wafer was found to vary by as much as 0.5mm in our experiments. The dies at the edge of the wafers had a different polish characteristic than other dies; the edge dies had the smallest planarization lengths and vary by as much as 3.2 mm compared to other die planarization lengths in our experiment. The knowledge of planarization length dependency on both process and spatial location should help in the development and optimization of CMP processes.

4.2 Improvements in Non-uniformity Modeling and Planarization Length Extraction

In this work, we used a sample standard deviation normalized to the mean as a sample uniformity metric. As mentioned in Chapter 2, thin plate splines are an alternative to appropriately weight the measurement data during spatial model development. More exploration of uniformity metrics and spatisl modeling would be valuable. It would also be interesting to try a few more patterns and see how the new patterns compare to the grid pattern.

If the within-die consistency of the polish characteristic is critical, it may be a good idea to use a hard pad and make the process condition as uniform as possible across the wafer. However, hard pads have a worse wafer-level uniformity so there is a trade-off to be considered. Although these suggestions are still to be proven, it is reasonable to presume that a hard pad would tend to polish more uniformly within a die than a soft pad because a soft pad bends and flexes more easily. A uniform process condition would obviously further avoid the possibility of non-uniform polish characteristics due to uneven process conditions across a wafer. The wafer-level removal rate and planarization length uniformity considerations as presented in this thesis could be applied to study hard pad tradeoffs between die-level and wafer-level performance.

4.3 Future Work

A reasonable extension of this thesis would be to incorporate thin plate splines into the methodology section in Chapter 2. This would ensure a correct weighting of the sampled data in the regression analysis and this would lead to more accurate models. To further investigate the non-uniform polish characteristic of the dies on a wafer, it would be interesting to find out if this difference can be attributed to pad hardness. It is reasonable to suspect that a soft pad will bend easily and so would polish the dies at the edge of a wafer differently. In the near future, the Statistical Metrology Group at MIT will develop a model to characterize the down area polishing mechanism and it would be interesting to see how the analysis in this thesis compares to the same analysis when down area measurements are used instead or in addition to up area measurements

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Experimental Removal Rate Data

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
1	0.0000	0.0000	2522.761	2567.910	1858.286	2106.000	3735.676	2154.007	2193.728	2207.317	1645.455
2	0.0000	9.5000	2569.030	2595.149	1804.857	2087.429	3750.811	2114.286	2203.833	2167.247	1651.843
3	-6.7175	6.7175	2574.254	2634.328	1811.714	2151.429	3720.000	2154.704	2165.505	2162.021	1640.541
4	-9.5000	0.0000	2558.209	2623.507	1832.571	2176.286	3697.297	2178.049	2157.143	2196.516	1616.708
5	-6.7175	-6.7175	2511.567	2619.403	1884.857	2168.571	3684.324	2197.561	2155.749	2226.829	1593.612
6	0.0000	-9.5000	2483.582	2591.418	1927.143	2116.857	3699.459	2177.003	2184.669	2257.491	1583.538
7	6.7175	-6.7175	2495.149	2567.537	1924.286	2059.429	3778.378	2155.401	2207.666	2253.659	1599.754
8	9.5000	0.0000	2525.746	2525.373	1905.714	2027.429	3820.541	2124.739	2203.833	2210.801	1620.639
9	6.7175	6.7175	2563.806	2564.552	1844.000	2033.714	3783.784	2107.666	2200.348	2171.777	1658.477
10	0.0000	19.0000	2585.448	2590.299	1808.286	2078.857	3723.784	2087.108	2178.397	2152.962	1651.597
11	-7.2710	17.5537	2592.537	2625.373	1801.714	2126.571	3692.432	2101.045	2154.007	2141.812	1645.209
12	-13.4350	13.4350	2604.851	2625.373	1806.857	2169.714	3655.676	2128.920	2136.585	2139.721	1607.862
13	-17.5537	7.2710	2608.955	2643.657	1812.857	2178.857	3637.838	2170.383	2127.178	2155.052	1590.909
14	-19.0000	0.0000	2576.493	2635.075	1817.143	2196.571	3651.892	2192.334	2139.373	2183.972	1551.843
15	-17.5537	-7.2710	2524.254	2623.881	1840.571	2191.714	3648.108	2190.244	2133.449	2207.317	1538.575
16	-13.4350	-13.4350	2486.567	2614.925	1882.571	2177.714	3643.243	2174.564	2139.024	2222.997	1511.057
17	-7.2710	-17.5537	2475.000	2595.149	1922.000	2146.286	3695.676	2163.763	2165.505	2238.676	1519.902
18	0.0000	-19.0000	2467.910	2570.149	1944.000	2096.571	3709.730	2151.568	2185.017	2240.418	1527.764
19	7.2710	-17.5537	2462.687	2538.060	1909.429	2037.143	3727.568	2144.251	2205.575	2219.861	1528.010
20	13.4350	-13.4350	2446.269	2516.418	1920.857	2009.429	3793.514	2123.693	2214.983	2214.286	1538.821
21	17.5537	-7.2710	2464.925	2504.478	1918.857	2005.714	3832.973	2088.502	2206.272	2212.544	1560.934
22	19.0000	0.0000	2499.627	2497.015	1903.714	1997.143	3834.054	2075.261	2201.742	2216.376	1590.909
23	17.5537	7.2710	2541.791	2490.299	1893.429	1996.571	3802.162	2076.307	2191.638	2179.094	1617.690
24	13.4350	13.4350	2580.970	2501.493	1854.286	1992.857	3748.108	2074.216	2181.882	2149.477	1641.278
25	7.2710	17.5537	2576.119	2540.672	1828.571	2017.714	3756.757	2070.035	2187.456	2156.446	1639.803
26	0.0000	28.5000	2552.612	2548.881	1788.286	2027.429	3700.541	2073.171	2165.854	2126.829	1562.654
27	-7.3763	27.5289	2572.761	2600.746	1764.571	2070.857	3680.541	2094.077	2154.355	2107.317	1543.980
28	-14.2500	24.6817	2581.343	2647.015	1758.286	2079.714	3661.081	2100.697	2141.812	2100.697	1533.170

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
29	-20.1525	20.1525	2588.433	2641.418	1779.714	2086.000	3629.730	2111.498	2117.422	2115.331	1534.398
30	-24.6817	14.2500	2600.746	2625.373	1784.857	2102.571	3612.432	2138.676	2111.847	2125.784	1531.695
31	-27.5289	7.3764	2596.269	2624.627	1806.857	2102.857	3646.486	2160.627	2121.254	2153.659	1528.993
32	-28.5000	0.0000	2600.000	2601.119	1820.857	2131.143	3647.568	2169.338	2125.436	2151.916	1510.565
33	-27.5289	-7.3763	2569.030	2575.746	1830.286	2118.571	3651.892	2165.854	2116.376	2177.003	1489.435
34	-24.6817	-14.2500	2508.955	2564.925	1833.429	2100.571	3670.811	2176.307	2113.240	2214.286	1488.452
35	-20.1525	-20.1525	2481.343	2576.119	1886.286	2102.286	3664.865	2145.645	2118.467	2227.875	1487.224
36	-14.2500	-24.6817	2481.716	2588.806	1923.429	2096.000	3691.351	2125.784	2126.829	2222.648	1493.612
37	-7.3763	-27.5289	2476.866	2580.970	1933.429	2085.714	3702.703	2117.422	2143.206	2217.770	1487.961
38	0.0000	-28.5000	2479.851	2551.493	1928.286	2062.857	3704.865	2111.847	2158.885	2218.467	1498.771
39	7.3763	-27.5289	2480.597	2523.881	1907.429	2024.286	3698.378	2112.544	2159.930	2202.091	1491.646
40	14.2500	-24.6817	2466.418	2498.881	1896.000	1998.571	3719.459	2104.530	2179.443	2180.488	1497.297
41	20.1525	-20.1525	2469.030	2492.910	1876.857	1996.000	3749.730	2083.972	2182.927	2177.003	1509.337
42	24.6817	-14.2500	2465.672	2501.493	1871.714	1979.143	3751.351	2048.780	2155.749	2180.836	1517.690
43	27.5289	-7.3764	2474.254	2487.313	1879.143	1988.571	3745.405	2040.418	2163.066	2178.397	1514.251
44	28.5000	0.0000	2474.254	2483.209	1880.000	1986.000	3748.649	2044.251	2163.763	2172.822	1534.152
45	27.5289	7.3764	2513.060	2477.985	1873.714	1979.714	3743.243	2059.233	2171.429	2168.990	1565.848
46	24.6817	14.2500	2560.075	2478.731	1856.286	1975.429	3710.270	2057.491	2149.826	2137.282	1572.236
47	20.1525	20.1525	2565.672	2486.567	1832.857	1955.429	3673.514	2050.174	2155.052	2125.087	1578.133
48	14.2500	24.6817	2569.403	2490.299	1807.429	1972.857	3690.811	2063.066	2149.129	2115.331	1585.504
49	7.3764	27.5289	2547.388	2534.328	1802.000	1993.714	3691.351	2065.157	2154.355	2121.603	1594.103
50	0.0000	38.0000	2482.090	2500.000	1796.286	1983.714	3668.649	2067.596	2169.338	2107.317	1521.376
51	-7.4134	37.2698	2505.224	2537.313	1783.429	2008.857	3685.405	2092.334	2173.171	2111.498	1506.634
52	-14.5420	35.1074	2527.612	2566.045	1791.429	2014.857	3671.351	2088.502	2156.446	2106.272	1491.400
53	-21.1117	31.5958	2539.925	2572.015	1793.714	2018.571	3658.919	2090.244	2135.192	2102.439	1483.047
54	-26.8701	26.8701	2549.254	2583.582	1785.714	2022.857	3642.703	2093.031	2130.314	2117.422	1481.572
55	-31.5958	21.1117	2569.030	2589.925	1801.429	2032.000	3656.216	2107.317	2134.843	2121.951	1499.754
56	-35.1074	14.5420	2600.373	2623.507	1803.714	2020.857	3663.784	2137.979	2140.767	2139.373	1521.130
57	-37.2698	7.4134	2602.612	2574.627	1805.714	2032.571	3661.081	2138.328	2122.648	2162.718	1515.725
58	-38.0000	0.0000	2597.015	2569.030	1813.143	2045.429	3662.162	2126.481	2115.331	2143.206	1516.462

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
59	-37.2698	-7.4134	2554.851	2563.060	1809.143	2023.429	3652.432	2129.268	2116.725	2144.948	1497.789
60	-35.1074	-14.5420	2532.090	2552.239	1800.000	2003.714	3669.189	2139.373	2116.725	2171.429	1483.538
61	-31.5958	-21.1117	2512.313	2540.672	1814.286	2011.429	3680.000	2129.965	2116.376	2203.136	1485.504
62	-26.8701	-26.8701	2499.254	2552.239	1862.857	2028.286	3705.405	2143.554	2111.150	2210.453	1489.681
63	-21.1117	-31.5958	2500.746	2573.881	1899.714	2046.571	3754.595	2116.028	2114.983	2195.470	1484.029
64	-14.5420	-35.1074	2511.567	2599.627	1910.857	2072.286	3764.865	2100.348	2130.662	2183.972	1484.029
65	-7.4134	-37.2698	2506.343	2565.299	1900.857	2065.143	3748.108	2084.321	2130.662	2183.275	1484.029
66	0.0000	-38.0000	2503.358	2542.910	1886.286	2049.714	3708.108	2075.958	2126.132	2184.669	1482.801
67	7.4134	-37.2698	2518.284	2537.687	1892.000	2034.286	3664.865	2081.533	2123.693	2184.321	1479.115
68	14.5420	-35.1074	2520.896	2517.910	1894.000	2014.571	3642.703	2086.760	2119.861	2177.003	1483.784
69	21.1117	-31.5958	2480.597	2526.866	1890.857	2010.286	3662.162	2085.366	2134.146	2164.808	1486.978
70	26.8701	-26.8701	2466.791	2513.060	1884.857	2010.286	3681.622	2063.415	2137.282	2164.460	1494.595
71	31.5958	-21.1117	2445.896	2512.313	1879.429	2007.429	3678.919	2051.220	2118.815	2159.582	1518.673
72	35.1074	-14.5420	2438.806	2493.657	1864.571	1998.286	3655.676	2032.753	2114.634	2158.537	1520.393
73	37.2698	-7.4134	2433.582	2489.925	1859.714	1981.714	3618.378	2046.690	2113.937	2171.080	1506.388
74	38.0000	0.0000	2432.836	2491.045	1863.143	1975.143	3628.649	2063.066	2128.571	2171.080	1510.565
75	37.2698	7.4134	2458.209	2475.746	1880.571	1958.286	3651.351	2060.279	2141.812	2167.247	1531.695
76	35.1074	14.5420	2494.403	2477.612	1867.429	1945.429	3670.811	2067.247	2141.463	2154.007	1535.627
77	31.5958	21.1117	2535.075	2476.119	1862.000	1930.286	3664.324	2057.143	2131.010	2140.070	1521.376
78	26.8701	26.8701	2522.015	2461.940	1822.571	1938.286	3636.757	2063.415	2136.585	2139.721	1509.091
79	21.1117	31.5958	2512.687	2474.627	1815.143	1933.429	3626.486	2067.247	2135.192	2141.115	1514.988
80	14.5420	35.1074	2500.373	2469.030	1804.857	1940.286	3634.595	2065.505	2142.160	2138.676	1528.747
81	7.4134	37.2698	2481.343	2466.418	1798.857	1951.714	3634.595	2067.247	2152.265	2114.983	1527.518
82	0.0000	47.5000	2448.881	2459.701	1825.714	1943.714	3660.000	2074.216	2191.289	2144.599	1508.108
83	-7.4306	46.9152	2476.866	2473.881	1827.143	1951.429	3721.081	2080.836	2197.561	2142.857	1497.297
84	-14.6783	45.1752	2498.881	2503.731	1800.286	1979.714	3737.297	2100.000	2190.592	2133.101	1489.926
85	-21.5645	42.3228	2511.567	2521.642	1818.286	1978.000	3701.081	2098.258	2166.899	2131.010	1475.430
86	-27.9198	38.4283	2525.373	2519.403	1813.429	1976.857	3669.189	2084.321	2159.233	2132.404	1463.391
87	-33.5876	33.5876	2544.403	2530.970	1830.286	1977.714	3664.324	2078.049	2153.310	2125.436	1467.076
88	-38.4283	27.9198	2554.104	2556.716	1832.571	1982.857	3657.297	2093.031	2169.338	2121.254	1481.327

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
89	-42.3228	21.5646	2561.940	2563.806	1825.714	1989.429	3667.027	2114.634	2170.035	2124.390	1502.457
90	-45.1752	14.6783	2576.866	2554.478	1806.286	1988.571	3707.568	2131.010	2160.976	2150.174	1527.027
91	-46.9152	7.4306	2592.164	2570.896	1812.286	1991.143	3677.297	2135.889	2147.735	2165.854	1542.506
92	-47.5000	0.0000	2595.149	2565.672	1825.143	1981.429	3670.811	2119.164	2133.798	2148.432	1531.450
93	-46.9152	-7.4306	2576.119	2555.224	1830.571	1979.429	3682.703	2106.620	2128.920	2139.373	1508.600
94	-45.1752	-14.6783	2541.418	2549.627	1822.286	1956.857	3682.703	2093.728	2131.707	2153.659	1494.840
95	-42.3228	-21.5646	2501.866	2539.179	1815.714	1959.714	3700.000	2111.150	2122.648	2176.307	1489.681
96	-38.4283	-27.9198	2489.925	2552.985	1832.286	1982.286	3726.486	2126.481	2132.753	2201.045	1492.138
97	-33.5876	-33.5876	2481.716	2569.030	1875.429	2007.714	3757.297	2135.889	2145.645	2218.467	1505.651
98	-27.9198	-38.4283	2491.045	2605.224	1905.143	2042.571	3791.892	2124.739	2135.192	2214.634	1507.862
99	-21.5646	-42.3228	2505.224	2626.493	1907.143	2063.714	3761.622	2114.983	2134.146	2186.411	1497.789
100	-14.6783	-45.1752	2526.119	2631.716	1891.429	2059.143	3777.838	2102.787	2142.160	2145.993	1495.086
101	-7.4306	-46.9152	2544.030	2605.597	1857.143	2051.429	3758.919	2094.425	2139.373	2148.432	1483.538
102	0.0000	-47.5000	2538.060	2580.970	1849.714	2024.286	3730.811	2075.610	2124.042	2151.916	1493.120
103	7.4306	-46.9152	2547.015	2560.448	1861.714	1993.429	3701.622	2075.610	2111.150	2166.551	1504.668
104	14.6783	-45.1752	2542.164	2538.060	1876.857	1979.714	3657.838	2094.077	2102.091	2181.533	1509.091
105	21.5645	-42.3228	2537.687	2536.567	1889.429	1981.143	3614.054	2127.526	2110.801	2180.139	1498.034
106	27.9198	-38.4283	2513.806	2537.313	1898.571	2001.714	3647.568	2136.934	2126.481	2184.321	1493.857
107	33.5876	-33.5876	2492.910	2539.179	1900.286	2007.714	3664.865	2102.091	2140.418	2177.352	1510.319
108	38.4283	-27.9198	2460.448	2536.194	1888.286	2029.714	3673.514	2093.380	2130.314	2173.171	1524.324
109	42.3228	-21.5646	2445.149	2530.597	1856.571	2021.714	3646.486	2067.944	2109.408	2170.732	1521.867
110	45.1752	-14.6783	2436.940	2516.791	1826.571	2009.714	3592.973	2058.188	2100.000	2178.746	1503.931
111	46.9152	-7.4306	2418.657	2528.358	1848.286	1988.286	3550.270	2067.596	2087.805	2197.213	1488.698
112	47.5000	0.0000	2408.955	2527.985	1849.714	1974.286	3542.162	2063.415	2102.091	2220.557	1486.241
113	46.9152	7.4306	2447.388	2525.746	1881.429	1946.000	3572.973	2079.094	2125.087	2212.195	1513.022
114	45.1752	14.6783	2461.194	2514.925	1904.857	1934.857	3597.297	2065.505	2135.192	2206.272	1530.713
115	42.3228	21.5645	2500.746	2496.642	1920.286	1929.429	3627.568	2072.822	2139.721	2174.564	1529.238
116	38.4283	27.9198	2520.522	2465.299	1889.429	1921.143	3644.324	2085.366	2134.146	2167.596	1508.845
117	33.5876	33.5876	2495.896	2469.030	1846.000	1917.429	3621.081	2086.760	2144.599	2167.944	1491.400
118	27.9198	38.4283	2467.910	2468.284	1828.857	1898.857	3616.757	2085.366	2140.418	2171.777	1497.789

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
119	21.5646	42.3228	2444.403	2476.866	1826.000	1899.429	3609.189	2096.167	2139.721	2175.958	1509.337
120	14.6783	45.1752	2455.224	2442.164	1813.143	1918.571	3599.459	2094.774	2144.599	2163.763	1519.902
121	7.4306	46.9152	2435.448	2442.164	1825.143	1933.429	3610.811	2079.443	2166.551	2152.265	1515.725
122	0.0000	57.0000	2455.224	2450.373	1843.143	1927.429	3685.946	2111.150	2215.679	2168.641	1518.919
123	-7.4400	56.5124	2480.970	2475.000	1856.286	1937.714	3724.324	2120.209	2217.422	2161.324	1508.108
124	-14.7527	55.0578	2501.493	2498.881	1833.143	1951.429	3787.568	2130.314	2215.679	2165.157	1496.560
125	-21.8130	52.6611	2512.313	2503.731	1844.000	1963.714	3768.108	2151.220	2213.937	2160.627	1493.366
126	-28.5000	49.3634	2521.269	2510.075	1858.571	1960.571	3753.514	2136.934	2204.530	2169.686	1480.098
127	-34.6994	45.2211	2530.597	2510.448	1850.857	1951.143	3722.703	2113.937	2195.819	2165.854	1465.602
128	-40.3051	40.3051	2525.746	2539.925	1865.143	1972.286	3700.000	2110.105	2189.895	2158.885	1466.585
129	-45.2211	34.6994	2533.209	2563.060	1869.143	1973.143	3714.054	2105.575	2194.077	2167.247	1478.870
130	-49.3634	28.5000	2564.925	2586.940	1870.286	1991.714	3701.622	2132.404	2195.122	2164.460	1505.405
131	-52.6611	21.8130	2555.597	2579.104	1852.286	1999.429	3735.135	2145.993	2195.122	2190.244	1530.958
132	-55.0578	14.7527	2588.806	2617.910	1846.571	1980.571	3741.622	2152.962	2204.530	2203.136	1554.054
133	-56.5124	7.4400	2606.716	2611.194	1841.429	1966.286	3744.324	2152.265	2188.502	2210.801	1568.305
134	-57.0000	0.0000	2622.015	2615.299	1864.000	1958.857	3728.108	2133.798	2170.035	2197.213	1564.373
135	-56.5124	-7.4400	2612.313	2611.194	1877.714	1952.571	3710.811	2135.192	2151.220	2182.578	1547.420
136	-55.0578	-14.7527	2552.612	2610.075	1881.143	1933.714	3685.946	2125.784	2153.659	2173.868	1530.467
137	-52.6611	-21.8130	2527.239	2592.164	1861.143	1936.857	3743.243	2131.010	2160.627	2204.181	1521.130
138	-49.3634	-28.5000	2516.791	2571.269	1852.857	1944.000	3752.432	2137.282	2168.641	2233.798	1524.324
139	-45.2211	-34.6994	2500.746	2563.060	1863.143	1971.143	3808.108	2157.840	2178.049	2257.840	1530.713
140	-40.3051	-40.3051	2495.522	2568.284	1888.571	2010.000	3847.027	2170.035	2174.564	2254.355	1546.683
141	-34.6994	-45.2211	2503.731	2588.060	1924.000	2038.286	3843.784	2165.157	2165.505	2232.404	1548.894
142	-28.5000	-49.3635	2526.119	2638.806	1911.714	2049.429	3849.730	2155.401	2165.505	2210.453	1532.924
143	-21.8130	-52.6611	2559.701	2659.701	1890.286	2067.429	3802.703	2147.038	2162.021	2177.352	1519.410
144	-14.7527	-55.0578	2570.896	2665.299	1868.286	2048.571	3814.054	2126.829	2172.125	2152.613	1515.971
145	-7.4400	-56.5124	2576.866	2646.642	1851.143	2030.000	3825.405	2113.937	2183.275	2150.174	1511.548
146	0.0000	-57.0000	2596.269	2602.612	1847.429	1999.429	3816.216	2102.091	2182.578	2153.310	1507.125
147	7.4400	-56.5124	2591.791	2559.701	1847.714	1972.000	3782.162	2094.774	2145.993	2169.338	1504.423
148	14.7527	-55.0578	2589.552	2546.269	1875.429	1961.714	3728.108	2107.666	2129.617	2181.882	1512.776

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
149	21.8129	-52.6611	2589.179	2545.149	1892.286	1976.000	3675.135	2139.024	2117.073	2204.878	1517.936
150	28.5000	-49.3634	2575.373	2533.955	1922.571	1966.000	3666.486	2149.826	2134.146	2212.544	1517.690
151	34.6994	-45.2211	2563.806	2552.612	1927.714	1997.429	3688.108	2153.310	2156.446	2217.073	1521.130
152	40.3051	-40.3051	2539.179	2574.627	1924.000	2012.571	3694.054	2157.143	2168.293	2218.118	1521.130
153	45.2211	-34.6994	2521.269	2586.194	1921.143	2038.000	3692.973	2141.115	2157.491	2207.317	1533.661
154	49.3634	-28.5000	2496.642	2591.045	1916.000	2059.143	3655.676	2111.498	2133.449	2202.091	1553.071
155	52.6611	-21.8130	2494.030	2580.597	1897.714	2065.714	3621.081	2102.787	2124.390	2197.909	1542.260
156	55.0578	-14.7527	2463.806	2583.955	1867.714	2029.429	3582.162	2103.484	2130.314	2211.847	1530.958
157	56.5124	-7.4400	2443.657	2583.209	1873.429	2015.429	3567.568	2101.394	2116.376	2240.418	1518.673
158	57.0000	0.0000	2441.791	2589.552	1875.714	1990.571	3550.270	2108.362	2121.951	2246.690	1512.531
159	56.5124	7.4400	2450.373	2586.194	1896.000	1964.286	3564.865	2114.983	2132.404	2249.826	1526.290
160	55.0578	14.7527	2467.164	2570.896	1929.143	1957.143	3583.243	2117.073	2149.129	2254.704	1541.278
161	52.6611	21.8129	2499.627	2548.881	1943.714	1944.857	3614.054	2111.498	2157.491	2241.463	1551.843
162	49.3634	28.5000	2522.761	2514.552	1955.143	1936.857	3661.081	2116.028	2178.049	2216.725	1532.432
163	45.2211	34.6994	2516.045	2495.149	1919.429	1922.571	3689.189	2119.861	2190.244	2198.606	1509.091
164	40.3051	40.3051	2494.403	2501.493	1872.857	1907.714	3668.649	2119.512	2198.955	2199.303	1503.686
165	34.6994	45.2211	2475.373	2520.522	1843.143	1890.000	3691.892	2122.300	2191.289	2203.833	1503.440
166	28.5000	49.3634	2445.149	2527.985	1833.143	1877.429	3656.757	2135.889	2173.519	2205.226	1510.811
167	21.8130	52.6611	2436.194	2504.478	1830.571	1905.143	3633.514	2138.676	2187.108	2210.453	1515.725
168	14.7527	55.0578	2416.791	2478.358	1829.143	1917.714	3641.081	2136.585	2182.230	2212.892	1525.799
169	7.4400	56.5124	2426.866	2449.254	1842.571	1922.000	3648.649	2128.571	2201.045	2189.547	1536.118
170	0.0000	66.5000	2508.955	2494.403	1905.429	1918.857	3765.946	2225.087	2258.537	2247.038	1561.671
171	-7.4456	66.0819	2532.836	2502.985	1885.429	1911.429	3807.568	2216.376	2272.822	2240.070	1552.088
172	-14.7976	64.8327	2554.104	2520.149	1898.857	1922.857	3848.108	2213.589	2273.171	2245.645	1540.049
173	-21.9636	62.7682	2561.194	2523.134	1898.857	1962.857	3858.919	2217.422	2279.443	2247.387	1550.369
174	-28.8533	59.9144	2567.537	2501.493	1901.714	1951.143	3864.865	2221.254	2266.899	2247.038	1561.179
175	-35.3801	56.3072	2572.388	2488.060	1914.571	1948.571	3819.459	2206.620	2254.355	2253.310	1572.973
176	-41.4621	51.9918	2581.716	2508.955	1926.857	1924.857	3783.784	2191.289	2243.206	2249.129	1557.985
177	-47.0226	47.0226	2574.627	2569.403	1937.143	1922.286	3751.351	2170.035	2231.010	2237.631	1545.209
178	-51.9918	41.4621	2552.239	2592.910	1948.286	1940.000	3747.027	2176.307	2234.495	2234.146	1546.683

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
179	-56.3072	35.3801	2535.075	2639.925	1943.429	1974.857	3740.000	2188.153	2225.087	2247.735	1560.688
180	-59.9144	28.8533	2534.328	2639.925	1941.714	1990.000	3757.297	2196.516	2256.794	2260.627	1586.978
181	-62.7682	21.9636	2542.537	2667.537	1932.286	1975.714	3775.676	2213.240	2269.686	2288.502	1601.720
182	-64.8327	14.7976	2583.209	2687.687	1954.000	1978.000	3807.027	2195.470	2270.035	2304.530	1637.592
183	-66.0819	7.4456	2642.164	2691.791	1962.857	1957.143	3820.000	2179.094	2255.749	2303.136	1640.786
184	-66.5000	0.0000	2657.463	2693.284	1960.571	1942.857	3805.405	2172.822	2232.056	2284.321	1633.170
185	-66.0819	-7.4456	2658.582	2684.328	1971.714	1936.000	3808.649	2200.000	2214.286	2272.822	1603.194
186	-64.8327	-14.7976	2612.313	2673.881	1974.571	1929.714	3776.757	2211.498	2209.756	2266.202	1591.646
187	-62.7682	-21.9636	2578.731	2679.104	1955.143	1927.143	3779.459	2197.909	2226.481	2284.669	1586.978
188	-59.9144	-28.8533	2547.388	2658.209	1936.571	1934.571	3810.811	2219.512	2249.129	2302.787	1593.120
189	-56.3072	-35.3801	2539.179	2648.134	1936.000	1941.429	3837.297	2224.739	2258.537	2306.969	1609.091
190	-51.9918	-41.4621	2541.791	2629.478	1945.714	1936.000	3886.486	2240.767	2261.324	2333.101	1615.725
191	-47.0226	-47.0226	2552.985	2612.687	1946.571	1962.000	3899.459	2240.418	2247.735	2301.394	1630.958
192	-41.4621	-51.9918	2549.627	2624.627	1960.286	1998.286	3893.514	2228.223	2220.557	2257.143	1630.221
193	-35.3801	-56.3072	2570.522	2643.657	1948.286	2030.286	3877.838	2222.997	2217.770	2248.432	1607.617
194	-28.8533	-59.9144	2590.299	2670.522	1920.000	2058.571	3863.784	2216.028	2214.983	2234.146	1594.595
195	-21.9636	-62.7682	2603.358	2692.537	1874.000	2056.000	3855.135	2203.484	2241.812	2225.784	1575.921
196	-14.7976	-64.8327	2615.299	2678.358	1854.571	2043.143	3895.676	2191.289	2260.279	2193.728	1571.253
197	-7.4456	-66.0819	2628.731	2660.075	1862.571	2040.286	3868.108	2191.986	2265.157	2194.774	1559.705
198	0.0000	-66.5000	2639.552	2625.746	1865.143	2007.714	3868.649	2162.718	2258.537	2210.453	1554.300
199	7.4456	-66.0819	2637.687	2565.672	1866.857	1998.857	3848.108	2148.084	2222.648	2222.300	1543.489
200	14.7976	-64.8327	2639.179	2556.343	1882.571	2003.714	3817.838	2142.509	2189.547	2237.631	1540.541
201	21.9636	-62.7682	2626.493	2571.642	1913.714	1990.857	3738.919	2151.568	2172.125	2255.401	1539.066
202	28.8533	-59.9144	2626.866	2559.701	1919.714	2004.286	3723.784	2176.307	2184.321	2265.854	1539.803
203	35.3801	-56.3072	2633.209	2572.388	1957.429	2018.000	3699.459	2196.516	2217.770	2273.868	1556.265
204	41.4621	-51.9918	2617.537	2607.836	1969.714	2023.714	3737.838	2211.847	2213.937	2290.592	1570.516
205	47.0226	-47.0226	2608.955	2651.493	1958.857	2048.000	3729.730	2216.725	2216.725	2283.972	1580.098
206	51.9918	-41.4621	2592.164	2689.925	1963.143	2090.286	3732.432	2201.394	2204.878	2282.927	1588.206
207	56.3072	-35.3801	2574.254	2691.045	1960.857	2106.857	3700.000	2181.185	2181.533	2273.171	1594.103
208	59.9144	-28.8533	2547.388	2685.821	1957.714	2129.429	3645.405	2154.355	2178.746	2266.899	1615.971

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
209	62.7682	-21.9636	2539.925	2676.866	1942.571	2111.429	3608.649	2172.125	2184.669	2253.659	1605.897
210	64.8327	-14.7976	2523.881	2674.627	1911.429	2087.143	3625.946	2176.655	2202.787	2247.735	1595.823
211	66.0819	-7.4456	2533.209	2679.851	1900.857	2057.143	3638.919	2178.049	2209.408	2270.383	1574.939
212	66.5000	0.0000	2531.343	2701.866	1894.286	2029.143	3629.730	2204.530	2214.634	2283.624	1567.813
213	66.0819	7.4456	2528.358	2684.328	1890.286	2036.571	3632.973	2209.756	2210.105	2296.167	1575.676
214	64.8327	14.7976	2532.463	2680.970	1916.000	2028.286	3660.000	2220.557	2214.983	2297.213	1566.339
215	62.7682	21.9635	2567.537	2664.925	1958.571	2012.857	3677.297	2209.756	2244.948	2282.927	1587.224
216	59.9144	28.8533	2572.015	2644.403	1981.143	1992.000	3747.027	2204.530	2255.749	2261.672	1572.727
217	56.3072	35.3801	2557.836	2628.731	1979.429	1956.857	3776.216	2197.561	2274.564	2235.192	1543.243
218	51.9918	41.4621	2548.507	2610.821	1924.286	1914.000	3830.270	2201.394	2284.669	2251.916	1528.256
219	47.0226	47.0226	2516.791	2602.985	1879.143	1892.571	3834.595	2206.620	2286.760	2237.282	1538.329
220	41.4621	51.9918	2490.299	2596.642	1858.857	1886.571	3822.703	2210.801	2268.990	2236.585	1552.334
221	35.3801	56.3072	2453.731	2597.761	1854.286	1893.143	3814.054	2207.317	2262.369	2248.432	1553.563
222	28.8533	59.9144	2435.821	2579.478	1853.714	1909.714	3799.459	2214.634	2244.948	2273.171	1566.339
223	21.9636	62.7682	2420.149	2559.328	1856.571	1923.714	3763.784	2219.861	2242.857	2298.955	1570.762
224	14.7977	64.8327	2451.866	2515.672	1888.000	1915.429	3729.730	2212.195	2242.160	2278.397	1579.115
225	7.4456	66.0819	2475.000	2491.045	1898.286	1917.143	3737.838	2208.014	2247.038	2266.202	1580.344
226	0.0000	76.0000	2521.642	2555.224	1971.429	1883.429	3834.054	2338.328	2292.334	2315.679	1651.843
227	-7.4493	75.6340	2556.716	2577.239	1983.429	1881.429	3856.216	2334.146	2303.484	2324.390	1639.558
228	-14.8269	74.5397	2590.672	2613.433	1964.000	1896.571	3852.973	2340.767	2312.544	2321.603	1617.936
229	-22.0616	72.7275	2604.478	2595.896	1966.286	1900.000	3887.027	2333.798	2316.028	2339.721	1624.816
230	-29.0839	70.2148	2604.478	2577.239	1967.429	1906.000	3915.135	2323.345	2324.390	2343.902	1641.769
231	-35.8261	67.0260	2614.179	2545.149	1976.571	1900.857	3890.811	2314.634	2294.774	2355.401	1669.533
232	-42.2233	63.1917	2611.940	2529.478	1997.429	1870.857	3849.730	2304.878	2277.352	2340.767	1685.504
233	-48.2139	58.7488	2592.164	2539.179	1996.000	1858.000	3781.081	2291.986	2275.958	2318.118	1664.128
234	-53.7401	53.7401	2566.418	2588.806	2031.429	1870.571	3790.270	2280.139	2266.202	2307.666	1649.631
235	-58.7488	48.2139	2545.896	2640.299	2038.571	1881.429	3760.000	2272.125	2256.446	2315.679	1642.506
236	-63.1917	42.2233	2525.000	2672.388	2026.286	1914.286	3747.568	2289.199	2258.188	2338.676	1647.912
237	-67.0260	35.8262	2504.104	2676.866	2002.857	1937.143	3775.135	2311.150	2275.610	2360.976	1657.248
238	-70.2148	29.0839	2491.045	2685.448	2022.857	1943.143	3787.027	2312.892	2293.380	2387.108	1663.882

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
239	-72.7275	22.0616	2519.776	2711.567	2034.857	1956.286	3848.108	2301.045	2318.815	2403.833	1706.388
240	-74.5397	14.8269	2550.373	2737.687	2048.286	1941.429	3877.838	2286.063	2321.951	2409.408	1735.872
241	-75.6340	7.4493	2600.000	2754.478	2064.571	1938.571	3889.189	2262.718	2311.150	2400.348	1733.661
242	-76.0000	0.0000	2630.224	2740.672	2071.429	1942.857	3895.676	2247.735	2286.411	2379.443	1715.971
243	-75.6340	-7.4493	2639.925	2726.493	2059.714	1946.286	3850.270	2272.125	2278.397	2371.429	1698.034
244	-74.5397	-14.8269	2604.851	2704.851	2049.429	1938.286	3816.757	2299.652	2279.094	2366.551	1690.418
245	-72.7275	-22.0616	2591.791	2697.015	2045.429	1930.286	3813.514	2317.770	2287.805	2368.641	1681.081
246	-70.2148	-29.0839	2566.791	2702.239	2025.143	1923.429	3828.649	2313.937	2308.014	2395.470	1677.641
247	-67.0260	-35.8262	2552.612	2696.642	2016.571	1922.000	3862.162	2304.878	2311.847	2416.725	1697.297
248	-63.1917	-42.2233	2555.597	2674.627	1983.714	1914.000	3894.054	2327.178	2322.648	2432.753	1729.730
249	-58.7488	-48.2139	2563.806	2640.672	1995.429	1916.286	3904.865	2363.066	2315.679	2421.254	1736.118
250	-53.7401	-53.7401	2564.552	2621.269	2030.286	1926.857	3894.595	2366.202	2306.272	2377.003	1732.432
251	-48.2139	-58.7488	2559.701	2615.672	2024.857	1953.714	3884.324	2327.526	2287.456	2322.300	1729.484
252	-42.2234	-63.1917	2567.537	2621.269	2009.143	1985.429	3868.108	2305.923	2282.578	2281.185	1714.005
253	-35.8261	-67.0260	2589.179	2627.239	1988.857	2010.000	3851.892	2295.470	2297.909	2272.822	1686.732
254	-29.0840	-70.2148	2601.493	2649.254	1941.143	2019.714	3851.892	2276.655	2318.118	2272.125	1656.757
255	-22.0616	-72.7275	2625.746	2672.761	1890.571	2021.143	3885.405	2271.777	2328.571	2278.397	1648.649
256	-14.8269	-74.5397	2652.985	2685.075	1893.143	2007.714	3885.405	2283.624	2340.767	2272.822	1645.455
257	-7.4493	-75.6340	2662.313	2677.612	1906.857	1991.429	3900.000	2272.822	2332.056	2253.659	1634.152
258	0.0000	-76.0000	2658.209	2637.313	1924.571	1983.143	3885.946	2248.084	2317.422	2252.613	1610.319
259	7.4493	-75.6340	2666.045	2597.761	1935.143	1986.571	3850.811	2220.906	2301.394	2285.366	1607.125
260	14.8269	-74.5397	2673.134	2589.925	1946.286	1988.000	3836.757	2207.666	2273.868	2304.181	1596.560
261	22.0616	-72.7275	2671.269	2579.478	1958.571	1981.714	3805.946	2218.118	2265.157	2346.690	1594.595
262	29.0839	-70.2149	2672.761	2560.821	1987.714	1991.714	3769.189	2214.286	2258.537	2350.174	1590.418
263	35.8261	-67.0260	2668.284	2566.045	2012.000	2010.571	3747.027	2221.951	2279.094	2350.871	1609.337
264	42.2233	-63.1917	2652.985	2583.209	2011.714	2014.571	3756.757	2246.690	2293.380	2337.282	1640.049
265	48.2139	-58.7488	2646.642	2638.806	2006.857	2023.143	3818.919	2279.094	2296.864	2336.934	1650.123
266	53.7401	-53.7401	2644.776	2687.687	2007.429	2042.286	3825.946	2284.321	2298.606	2335.540	1642.998
267	58.7488	-48.2139	2617.164	2741.418	1994.000	2063.143	3798.919	2264.460	2266.551	2337.282	1650.369
268	63.1917	-42.2233	2591.418	2753.731	1981.714	2111.714	3761.622	2247.735	2247.387	2326.132	1658.968

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
269	67.0260	-35.8262	2577.985	2736.194	2002.286	2117.143	3704.324	2248.780	2235.540	2300.000	1654.545
270	70.2148	-29.0839	2574.627	2740.672	2008.857	2118.286	3642.703	2255.401	2249.826	2293.728	1648.894
271	72.7275	-22.0616	2582.090	2740.672	2006.000	2111.429	3651.351	2258.885	2270.383	2290.592	1665.356
272	74.5397	-14.8269	2585.075	2752.985	1973.143	2088.571	3676.216	2250.871	2279.094	2307.317	1649.631
273	75.6340	-7.4493	2563.433	2775.373	1968.286	2061.714	3704.865	2262.718	2286.411	2309.408	1628.010
274	76.0000	0.0000	2555.970	2775.746	1928.857	2040.286	3712.432	2277.700	2179.443	2322.648	1611.548
275	75.6340	7.4493	2563.806	2781.716	1927.429	2028.000	3706.486	2296.864	2294.077	2335.889	1626.290
276	74.5397	14.8268	2579.478	2769.776	1934.857	2026.286	3725.405	2343.554	2304.530	2355.401	1644.717
277	72.7275	22.0616	2604.104	2764.552	1952.286	2003.429	3765.405	2359.582	2325.436	2332.753	1652.580
278	70.2149	29.0839	2615.672	2733.209	1985.714	1983.429	3847.027	2338.676	2351.220	2312.195	1633.415
279	67.0260	35.8261	2607.463	2717.164	1986.857	1967.143	3880.541	2291.289	2353.310	2290.244	1610.074
280	63.1917	42.2233	2596.642	2716.045	1979.143	1935.143	3904.324	2320.557	2351.916	2278.746	1586.978
281	58.7488	48.2139	2570.522	2723.881	1936.571	1904.571	3947.027	2328.920	2355.052	2269.686	1572.973
282	53.7401	53.7401	2524.627	2718.284	1889.714	1870.000	3919.459	2327.526	2349.826	2262.369	1577.641
283	48.2139	58.7488	2466.418	2718.657	1881.714	1876.286	3914.595	2318.815	2336.237	2281.533	1621.867
284	42.2233	63.1917	2446.642	2681.343	1872.286	1878.571	3895.676	2334.495	2316.725	2286.063	1648.157
285	35.8262	67.0260	2411.567	2645.896	1861.429	1876.286	3904.865	2344.948	2299.303	2312.544	1661.425
286	29.0840	70.2148	2414.925	2614.179	1872.286	1883.714	3864.865	2329.965	2294.425	2332.404	1653.563
287	22.0616	72.7275	2417.164	2594.403	1889.143	1890.571	3850.811	2318.815	2280.488	2359.930	1663.636
288	14.8269	74.5397	2453.731	2564.925	1927.714	1884.000	3815.135	2314.634	2286.063	2365.505	1683.047
289	7.4493	75.6340	2492.537	2542.537	1956.000	1903.429	3809.189	2334.495	2292.683	2334.495	1683.292
290	0.0000	85.5000	2454.851	2503.731	1988.000	1782.571	3669.189	2383.275	2237.979	2317.770	1708.354
291	-7.4518	85.1746	2479.851	2555.597	1994.571	1791.143	3658.919	2371.080	2248.780	2328.223	1700.983
292	-14.8469	84.2011	2516.045	2591.045	1958.571	1809.143	3655.676	2374.216	2258.885	2333.101	1698.034
293	-22.1290	82.5867	2526.866	2612.313	1951.143	1801.714	3676.757	2395.470	2271.080	2332.056	1683.292
294	-29.2427	80.3437	2513.433	2600.746	1982.857	1796.571	3702.703	2377.003	2299.303	2342.160	1670.762
295	-36.1339	77.4893	2519.030	2571.269	2004.571	1806.000	3717.838	2323.345	2288.153	2345.993	1700.983
296	-42.7500	74.0452	2539.552	2543.657	1989.429	1802.286	3709.189	2303.484	2260.279	2340.070	1748.403
297	-49.0408	70.0375	2507.836	2535.821	1977.714	1790.857	3645.405	2320.906	2238.328	2326.132	1752.580
298	-54.9583	65.4968	2477.239	2547.388	1987.714	1780.857	3621.622	2316.028	2253.310	2287.805	1711.057

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
299	-60.4576	60.4576	2449.627	2587.687	2025.143	1775.714	3628.108	2303.833	2248.084	2295.819	1686.732
300	-65.4968	54.9583	2426.119	2608.955	2012.571	1806.000	3636.216	2289.199	2240.767	2302.787	1681.572
301	-70.0375	49.0408	2428.358	2648.881	1999.143	1842.286	3620.000	2317.422	2216.028	2318.467	1676.904
302	-74.0452	42.7500	2409.701	2663.060	1963.714	1864.571	3606.486	2363.066	2229.268	2330.662	1670.516
303	-77.4893	36.1339	2383.955	2675.373	1955.429	1865.429	3633.514	2392.683	2244.251	2335.192	1655.528
304	-80.3437	29.2427	2367.910	2678.358	1978.571	1876.857	3686.486	2378.397	2265.505	2360.976	1661.671
305	-82.5867	22.1290	2398.881	2702.239	1980.857	1890.571	3757.838	2337.979	2277.700	2350.523	1706.143
306	-84.2011	14.8469	2416.418	2715.672	1983.714	1904.286	3764.324	2327.178	2275.958	2339.721	1735.135
307	-85.1746	7.4518	2432.836	2713.060	2004.571	1886.286	3804.865	2302.787	2280.836	2316.725	1706.634
308	-85.5000	0.0000	2470.522	2695.522	2020.857	1888.000	3785.946	2279.791	2278.397	2306.272	1679.115
309	-85.1746	-7.4518	2506.343	2677.985	2022.000	1886.857	3784.324	2284.321	2275.958	2307.666	1677.150
310	-84.2011	-14.8469	2495.149	2652.985	1983.429	1890.571	3761.622	2308.711	2267.596	2306.272	1688.452
311	-82.5867	-22.1290	2485.075	2639.179	1964.000	1864.286	3781.622	2356.794	2268.293	2314.286	1674.201
312	-80.3437	-29.2427	2480.597	2662.313	1984.000	1827.714	3795.676	2372.125	2290.941	2339.721	1646.437
313	-77.4893	-36.1339	2445.522	2658.955	1972.286	1835.429	3806.486	2352.962	2290.244	2374.564	1653.808
314	-74.0452	-42.7500	2450.373	2632.836	1964.857	1821.429	3834.595	2331.359	2295.819	2392.334	1695.577
315	-70.0375	-49.0408	2429.478	2615.299	1949.714	1832.571	3840.541	2375.610	2275.261	2384.321	1710.811
316	-65.4968	-54.9583	2429.478	2583.582	1986.571	1804.000	3846.486	2401.045	2283.624	2366.202	1699.017
317	-60.4576	-60.4576	2433.582	2576.866	2027.143	1793.714	3798.378	2399.303	2275.261	2334.495	1694.595
318	-54.9583	-65.4968	2452.239	2563.060	2025.143	1820.286	3778.378	2343.902	2266.202	2280.139	1716.216
319	-49.0408	-70.0375	2488.806	2552.985	2011.143	1847.143	3758.378	2327.178	2250.523	2250.871	1733.661
320	-42.7500	-74.0452	2504.851	2558.209	1981.143	1870.286	3769.730	2344.251	2263.066	2233.449	1691.892
321	-36.1339	-77.4893	2514.925	2551.493	1944.857	1873.429	3761.622	2321.254	2280.488	2247.038	1655.283
322	-29.2427	-80.3437	2535.821	2569.403	1909.714	1873.429	3790.811	2288.502	2304.181	2249.477	1651.597
323	-22.1290	-82.5867	2572.761	2598.507	1887.429	1881.143	3794.595	2309.756	2305.923	2250.174	1675.430
324	-14.8469	-84.2011	2583.955	2616.045	1898.000	1880.571	3839.459	2343.206	2299.303	2251.220	1670.762
325	-7.4518	-85.1746	2604.478	2631.716	1916.857	1864.286	3845.405	2338.328	2283.972	2248.780	1651.843
326	0.0000	-85.5000	2600.746	2588.060	1966.286	1846.571	3816.216	2295.122	2265.854	2242.509	1624.816
327	7.4518	-85.1746	2627.239	2543.657	1986.000	1856.000	3789.189	2252.962	2249.826	2288.502	1633.907
328	14.8469	-84.2011	2658.955	2520.149	1993.429	1872.571	3783.784	2254.355	2241.463	2325.784	1651.597

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
329	22.1290	-82.5867	2650.746	2521.269	2012.286	1850.571	3755.135	2259.930	2225.784	2338.328	1635.872
330	29.2427	-80.3437	2632.463	2508.582	2064.857	1824.857	3755.676	2254.007	2233.798	2352.962	1617.936
331	36.1339	-77.4893	2629.104	2509.328	2091.714	1847.429	3729.189	2222.300	2251.220	2344.251	1625.061
332	42.7500	-74.0452	2635.448	2516.418	2066.286	1876.000	3745.405	2218.467	2282.230	2335.540	1672.482
333	49.0408	-70.0375	2612.313	2551.119	2022.286	1890.571	3803.784	2261.324	2298.606	2302.787	1709.828
334	54.9583	-65.4968	2593.284	2601.493	2028.000	1878.000	3875.676	2293.380	2299.303	2294.077	1705.160
335	60.4576	-60.4576	2553.731	2628.358	2021.143	1904.286	3885.405	2290.941	2289.895	2297.909	1693.612
336	65.4968	-54.9584	2537.313	2662.687	2003.143	1944.000	3823.784	2272.822	2263.415	2302.091	1698.526
337	70.0375	-49.0408	2506.716	2686.567	1967.143	1974.000	3750.270	2273.171	2237.631	2289.895	1717.936
338	74.0452	-42.7500	2485.448	2686.567	1972.000	1983.143	3715.135	2289.895	2217.073	2263.763	1697.052
339	77.4893	-36.1339	2492.164	2694.030	1998.857	1977.143	3639.459	2295.819	2224.390	2262.021	1662.654
340	80.3437	-29.2427	2473.134	2703.731	2013.143	1969.143	3581.622	2275.958	2243.206	2253.310	1662.899
341	82.5867	-22.1290	2475.373	2716.791	1986.286	1974.000	3601.622	2248.780	2238.328	2255.401	1680.344
342	84.2011	-14.8469	2479.478	2722.761	1973.714	1966.857	3626.486	2266.202	2249.477	2259.233	1677.887
343	85.1746	-7.4518	2484.328	2730.597	1977.143	1940.286	3661.622	2286.411	2261.324	2254.355	1630.467
344	85.5000	0.0000	2465.672	2739.925	1960.286	1928.000	3671.892	2286.760	2268.641	2266.899	1597.297
345	85.1747	7.4518	2473.134	2725.746	1932.000	1906.286	3672.973	2290.592	2279.791	2290.941	1634.152
346	84.2011	14.8469	2502.239	2713.433	1908.857	1917.143	3698.919	2342.509	2298.606	2317.422	1695.086
347	82.5867	22.1290	2533.955	2679.104	1899.143	1894.286	3742.162	2383.275	2314.634	2326.132	1718.919
348	80.3437	29.2427	2538.433	2685.448	1927.143	1874.857	3778.919	2392.683	2317.422	2304.181	1702.457
349	77.4893	36.1339	2555.597	2671.642	1976.571	1848.571	3799.459	2361.672	2323.693	2283.624	1689.926
350	74.0452	42.7500	2554.478	2644.403	1988.857	1850.857	3804.324	2339.721	2311.498	2274.913	1685.504
351	70.0375	49.0408	2512.313	2638.433	1975.714	1824.000	3817.838	2367.247	2284.669	2268.293	1654.300
352	65.4968	54.9583	2460.075	2651.119	1926.571	1800.000	3807.027	2397.213	2282.230	2270.383	1617.445
353	60.4576	60.4576	2418.284	2643.657	1902.857	1781.714	3777.297	2387.108	2292.334	2252.265	1617.936
354	54.9583	65.4968	2399.627	2658.209	1879.143	1773.429	3756.216	2357.840	2293.031	2256.098	1679.115
355	49.0408	70.0375	2395.896	2621.269	1855.429	1781.143	3785.405	2374.913	2275.958	2266.202	1723.587
356	42.7500	74.0452	2366.791	2589.179	1839.429	1768.000	3789.730	2404.181	2268.293	2266.202	1726.536
357	36.1339	77.4893	2351.866	2543.657	1848.286	1758.571	3749.730	2400.000	2267.247	2290.244	1700.737
358	29.2427	80.3437	2348.507	2523.134	1868.286	1754.000	3724.324	2345.993	2260.976	2324.739	1708.354

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
359	22.1290	82.5867	2368.657	2509.701	1879.143	1787.429	3691.892	2323.693	2260.627	2350.523	1731.941
360	14.8469	84.2011	2414.179	2494.776	1897.429	1804.571	3683.243	2343.902	2238.328	2351.568	1757.494
361	7.4518	85.1746	2434.328	2483.582	1936.286	1794.857	3676.757	2372.125	2235.889	2325.087	1741.278
362	0.0000	95.0000	1983.209	2098.881	1614.000	1331.143	2936.216	2131.707	1914.634	2019.512	1483.047
363	-7.4536	94.7071	1988.806	2151.493	1660.000	1349.143	2902.162	2091.638	1925.436	2026.132	1504.668
364	-14.8613	93.8304	1997.761	2198.134	1624.571	1362.571	2868.649	2101.045	1924.390	2049.826	1522.850
365	-22.1773	92.3751	2002.239	2192.164	1588.571	1367.429	2917.838	2163.763	1938.676	2055.052	1511.057
366	-29.3566	90.3504	1999.627	2186.194	1631.714	1357.143	2941.622	2162.369	1972.822	2048.084	1472.482
367	-36.3549	87.7686	1981.343	2180.597	1673.429	1336.857	2976.216	2113.240	1997.213	2037.631	1444.472
368	-43.1291	84.6456	1967.164	2160.075	1683.143	1358.000	2988.649	2020.906	1975.261	2031.359	1508.108
369	-49.6374	81.0008	1983.209	2133.582	1655.429	1373.143	2957.838	2018.118	1947.038	2011.847	1549.140
370	-55.8396	76.8566	1973.134	2124.254	1606.571	1359.143	2963.784	2059.582	1935.889	1992.334	1524.079
371	-61.6976	72.2386	1930.224	2129.478	1642.857	1335.429	2940.000	2080.139	1948.432	1963.066	1466.093
372	-67.1751	67.1751	1901.493	2137.313	1682.286	1332.857	2932.973	2053.310	1943.902	1961.324	1421.867
373	-72.2386	61.6976	1898.507	2173.881	1666.000	1364.286	2923.243	2023.345	1932.056	1963.415	1449.631
374	-76.8566	55.8396	1900.746	2184.328	1625.429	1397.143	2885.405	2052.613	1913.589	1982.578	1474.447
375	-81.0008	49.6374	1895.149	2210.448	1578.000	1422.286	2924.324	2138.676	1890.592	1995.122	1463.145
376	-84.6456	43.1291	1874.627	2219.403	1602.000	1420.000	2938.919	2183.624	1904.530	1989.895	1420.885
377	-87.7686	36.3549	1853.358	2204.478	1648.857	1424.857	2964.324	2183.624	1930.662	2009.756	1405.405
378	-90.3504	29.3566	1861.940	2235.821	1636.000	1444.000	2975.676	2134.843	1935.889	2004.878	1451.597
379	-92.3751	22.1773	1882.463	2253.731	1621.143	1466.000	3015.676	2098.955	1939.024	2002.787	1488.452
380	-93.8304	14.8613	1907.463	2276.119	1589.429	1458.571	3050.270	2125.436	1956.794	1991.986	1505.405
381	-94.7071	7.4536	1922.388	2251.866	1637.714	1432.571	3120.000	2098.955	1969.338	1952.265	1465.111
382	-95.0000	0.0000	1925.746	2221.269	1677.143	1428.857	3140.541	2074.216	1988.153	1947.387	1427.518
383	-94.7071	-7.4536	1973.507	2206.343	1681.714	1434.000	3152.432	2034.146	2003.833	1944.948	1460.197
384	-93.8304	-14.8613	2004.478	2189.552	1640.286	1446.000	3143.243	2060.976	1990.941	1954.007	1481.327
385	-92.3751	-22.1773	2015.672	2180.597	1566.857	1422.000	3195.676	2111.847	1975.261	1958.537	1477.641
386	-90.3504	-29.3566	1963.433	2180.597	1603.714	1373.429	3169.730	2135.192	1980.139	1955.749	1428.993
387	-87.7686	-36.3549	1934.701	2181.343	1627.429	1340.857	3181.081	2119.164	1984.669	1990.941	1400.491
388	-84.6456	-43.1291	1923.507	2174.627	1622.857	1351.143	3174.595	2057.491	1957.491	2021.254	1444.963

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
389	-81.0008	-49.6374	1916.045	2135.821	1603.429	1353.714	3104.865	2067.596	1944.251	2027.178	1471.744
390	-76.8566	-55.8396	1905.970	2102.612	1582.857	1311.714	3101.622	2111.150	1914.634	2013.937	1475.676
391	-72.2386	-61.6976	1897.388	2055.224	1630.857	1302.286	3102.703	2140.070	1916.725	1970.383	1414.005
392	-67.1751	-67.1751	1883.955	2055.970	1663.714	1271.143	3061.081	2109.059	1910.105	1939.721	1389.926
393	-61.6976	-72.2385	1907.463	2057.463	1688.571	1298.286	3016.757	2042.857	1922.997	1905.923	1432.187
394	-55.8396	-76.8566	1944.776	2045.896	1650.571	1334.571	3036.757	2038.328	1911.847	1895.122	1485.749
395	-49.6374	-81.0008	1956.716	2028.358	1593.429	1344.000	3048.649	2079.443	1910.105	1892.683	1489.681
396	-43.1291	-84.6456	1981.343	2016.045	1592.857	1346.857	3012.432	2079.094	1913.589	1882.927	1448.403
397	-36.3549	-87.7685	2019.403	2044.030	1605.714	1362.286	3030.811	2033.449	1928.223	1884.669	1413.022
398	-29.3566	-90.3504	2051.866	2053.731	1595.143	1360.000	3050.811	2012.544	1949.477	1898.955	1454.545
399	-22.1773	-92.3751	2087.313	2072.015	1574.571	1380.000	3019.459	2048.780	1951.220	1898.955	1503.440
400	-14.8613	-93.8304	2127.612	2111.567	1553.429	1374.000	3084.324	2100.697	1940.418	1889.895	1504.914
401	-7.4536	-94.7071	2101.119	2101.493	1587.143	1337.429	3077.297	2085.017	1922.300	1867.596	1441.769
402	0.0000	-95.0000	2139.925	2073.507	1650.286	1360.000	3107.027	1937.631	1818.815	1809.756	1336.609
403	7.4536	-94.7071	2152.239	2055.597	1681.429	1357.714	3054.595	1967.247	1885.017	1904.530	1434.889
404	14.8613	-93.8304	2200.746	2039.552	1705.143	1374.000	3035.676	1963.066	1892.334	1946.341	1472.482
405	22.1773	-92.3751	2209.701	2023.881	1681.143	1366.286	3072.432	1999.303	1893.380	1945.993	1458.968
406	29.3566	-90.3504	2180.970	2022.761	1719.714	1352.857	3075.676	1985.714	1908.362	1921.951	1401.966
407	36.3549	-87.7686	2154.851	2024.254	1760.000	1336.286	3038.919	1951.220	1914.286	1907.666	1369.042
408	43.1291	-84.6456	2124.254	2017.164	1747.714	1360.286	3013.514	1893.728	1920.557	1909.059	1412.285
409	49.6373	-81.0008	2097.761	2028.358	1679.143	1375.429	3017.838	1889.547	1956.098	1868.990	1447.912
410	55.8396	-76.8566	2075.746	2035.821	1608.286	1389.714	3091.351	1926.829	1959.930	1822.300	1456.265
411	61.6976	-72.2386	2030.224	2044.776	1617.429	1394.857	3177.297	1961.324	1945.993	1811.498	1427.273
412	67.1751	-67.1752	1992.164	2059.328	1622.000	1388.000	3175.135	1949.129	1925.784	1842.160	1393.612
413	72.2386	-61.6976	1956.343	2095.149	1595.143	1432.571	3093.514	1916.028	1917.770	1847.387	1426.536
414	76.8566	-55.8396	1941.791	2114.925	1542.571	1476.000	3018.378	1955.749	1907.317	1842.857	1472.973
415	81.0008	-49.6374	1945.522	2159.328	1520.571	1496.571	2973.514	2001.394	1896.516	1835.889	1469.533
416	84.6456	-43.1291	1932.836	2147.015	1538.000	1475.143	2962.703	2010.105	1903.833	1799.303	1406.143
417	87.7686	-36.3549	1916.418	2154.851	1582.857	1464.000	2924.865	1988.502	1907.666	1806.620	1373.464
418	90.3504	-29.3566	1916.791	2190.299	1589.429	1482.286	2907.568	1939.721	1913.937	1816.376	1415.233

Table A.1: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angstroms per Minute)								
			Wafer #3	Wafer#4	Wafer #5	Wafer#6	Wafer#7	Wafer#10	Wafer#11	Wafer#12	Wafer#13
419	92.3751	-22.1773	1921.642	2216.418	1584.571	1503.714	2915.676	1943.206	1909.059	1836.585	1446.192
420	93.8304	-14.8613	1910.821	2245.522	1560.571	1510.286	2968.649	2014.983	1902.439	1834.495	1441.032
421	94.7071	-7.4536	1900.000	2255.224	1576.571	1474.286	3017.838	2028.920	1919.512	1839.024	1385.258
422	95.0000	0.0000	1874.627	2229.851	1570.571	1432.857	3021.081	2005.923	1945.993	1843.206	1348.649
423	94.7071	7.4536	1910.448	2242.164	1542.286	1451.143	3036.757	1969.686	1960.279	1878.397	1415.479
424	93.8304	14.8613	1949.254	2214.552	1499.143	1457.714	3002.703	1997.213	1971.429	1904.878	1500.246
425	92.3751	22.1773	1994.030	2198.507	1458.000	1423.143	3054.595	2080.139	1974.564	1918.118	1530.958
426	90.3504	29.3566	1996.642	2198.507	1490.571	1388.571	3075.135	2124.739	1977.700	1907.666	1489.681
427	87.7686	36.3549	1983.955	2176.119	1547.143	1368.000	3090.811	2119.861	1948.780	1902.439	1433.415
428	84.6456	43.1291	1988.806	2163.433	1580.857	1355.143	3068.649	2075.610	1945.296	1908.362	1466.339
429	81.0008	49.6374	1983.209	2159.701	1593.143	1370.286	3009.189	2090.244	1918.467	1918.467	1478.624
430	76.8566	55.8396	1960.075	2140.672	1542.857	1352.000	3016.216	2141.812	1900.697	1883.624	1456.757
431	72.2386	61.6976	1932.463	2130.970	1528.857	1328.857	2996.216	2168.990	1916.376	1879.094	1392.875
432	67.1751	67.1751	1892.164	2120.149	1524.571	1291.714	2961.622	2136.585	1920.209	1867.596	1357.494
433	61.6976	72.2386	1887.313	2138.806	1530.857	1290.571	2923.243	2092.334	1935.540	1857.491	1434.889
434	55.8396	76.8566	1886.940	2132.090	1488.286	1287.429	2941.622	2106.620	1921.951	1891.638	1499.017
435	49.6374	81.0008	1891.418	2104.851	1444.286	1278.857	2984.865	2154.007	1911.847	1882.927	1517.690
436	43.1291	84.6456	1880.224	2066.045	1466.286	1267.143	2972.973	2182.927	1917.073	1890.244	1481.327
437	36.3550	87.7685	1880.224	2047.388	1494.000	1278.000	2962.703	2148.780	1925.087	1906.272	1450.614
438	29.3566	90.3504	1889.552	2050.746	1522.000	1299.429	2940.000	2061.672	1946.690	1955.052	1500.737
439	22.1773	92.3751	1929.478	2057.090	1499.429	1329.714	2932.973	2082.927	1929.268	1988.153	1562.654
440	14.8613	93.8304	1951.866	2066.418	1479.429	1334.571	2957.838	2106.272	1911.847	2013.589	1574.693
441	7.4536	94.7071	1973.881	2069.403	1533.714	1343.714	2958.378	2150.523	1904.530	2015.679	1541.769

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
1	0.0000	0.0000	2696.203	1105.9337	3410.000	2321.254	2020.209	2251.568	2212.195	1394.5122	1311.585

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
2	0.0000	9.5000	2613.502	1124.0838	3370.526	2362.718	2047.735	2294.425	2260.627	1381.0976	1306.098
3	-6.7175	6.7175	2656.118	1120.2443	3464.737	2320.557	2022.648	2305.923	2224.042	1345.5285	1289.431
4	-9.5000	0.0000	2709.705	1099.3019	3558.947	2328.920	2006.620	2275.610	2163.066	1356.0976	1279.878
5	-6.7175	-6.7175	2730.802	1082.8970	3551.053	2280.139	1987.456	2229.965	2137.979	1373.1707	1291.260
6	0.0000	-9.5000	2756.118	1074.6946	3441.579	2254.704	1980.139	2183.275	2158.885	1411.1789	1304.065
7	6.7175	-6.7175	2745.992	1079.9302	3322.105	2241.115	2004.878	2197.561	2161.672	1425.4065	1326.016
8	9.5000	0.0000	2681.435	1093.8918	3342.632	2268.293	2019.861	2211.847	2210.453	1414.4309	1333.537
9	6.7175	6.7175	2624.895	1110.8202	3336.316	2342.509	2039.721	2260.279	2237.979	1399.3902	1315.244
10	0.0000	19.0000	2633.755	1122.6876	3317.895	2341.463	2070.732	2305.923	2218.815	1353.8618	1293.902
11	-7.2710	17.5537	2627.004	1117.4520	3386.316	2330.314	2048.780	2275.610	2201.394	1322.9675	1285.163
12	-13.4350	13.4350	2631.646	1118.1501	3473.158	2323.345	2036.585	2264.111	2169.338	1319.7154	1271.138
13	-17.5537	7.2710	2665.401	1108.0279	3558.421	2306.969	2011.498	2247.735	2116.376	1321.3415	1266.870
14	-19.0000	0.0000	2711.814	1085.1658	3571.579	2319.861	1988.153	2236.237	2090.244	1332.9268	1271.138
15	-17.5537	-7.2710	2732.489	1069.6335	3565.789	2259.233	1965.854	2191.638	2091.638	1343.9024	1264.431
16	-13.4350	-13.4350	2728.692	1060.0349	3542.632	2210.453	1968.293	2136.934	2099.303	1364.0244	1276.626
17	-7.2710	-17.5537	2749.789	1055.6719	3467.368	2206.272	1968.293	2121.603	2093.728	1408.3333	1290.650
18	0.0000	-19.0000	2737.131	1059.5113	3401.579	2196.167	1967.247	2120.209	2097.909	1419.1057	1307.724
19	7.2710	-17.5537	2699.578	1057.9407	3283.158	2185.366	1963.763	2126.481	2095.470	1414.8374	1319.512
20	13.4350	-13.4350	2696.624	1064.9215	3212.632	2188.502	1970.732	2141.812	2109.408	1407.9268	1323.171
21	17.5537	-7.2710	2670.886	1077.1379	3218.947	2194.077	1982.578	2152.265	2142.857	1395.7317	1323.984
22	19.0000	0.0000	2650.211	1093.3682	3230.000	2228.223	2015.331	2174.913	2176.307	1399.3902	1321.138
23	17.5537	7.2710	2605.485	1109.4241	3230.526	2283.275	2042.509	2220.906	2225.087	1379.0650	1318.496
24	13.4350	13.4350	2577.215	1120.7679	3250.526	2319.164	2064.808	2254.007	2257.840	1360.1626	1318.089
25	7.2710	17.5537	2608.439	1123.9092	3274.737	2337.631	2084.669	2280.836	2251.916	1358.1301	1313.821
26	0.0000	28.5000	2576.371	1106.4572	3250.526	2294.774	2061.324	2241.463	2132.056	1338.6179	1279.472
27	-7.3763	27.5289	2597.468	1095.4625	3331.053	2290.941	2030.662	2224.042	2128.571	1326.6260	1268.293
28	-14.2500	24.6817	2569.620	1095.8115	3367.368	2283.972	2022.997	2228.571	2120.557	1312.6016	1260.569
29	-20.1525	20.1525	2589.873	1093.5428	3399.474	2268.990	2011.498	2202.787	2111.498	1304.4715	1263.415
30	-24.6817	14.2500	2629.536	1098.2548	3420.526	2243.902	2006.969	2167.596	2090.941	1302.4390	1268.089
31	-27.5289	7.3764	2664.557	1088.8307	3435.789	2250.871	1992.334	2170.732	2051.568	1309.1463	1261.789

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
32	-28.5000	0.0000	2672.574	1078.1850	3414.211	2224.042	1968.990	2162.369	2036.934	1316.8699	1253.252
33	-27.5289	-7.3763	2685.654	1069.4590	3392.105	2201.742	1947.038	2163.415	2043.902	1313.6179	1252.439
34	-24.6817	-14.2500	2696.624	1058.9878	3353.684	2166.899	1947.387	2140.418	2064.460	1323.7805	1253.252
35	-20.1525	-20.1525	2694.937	1056.5445	3356.316	2154.704	1948.084	2104.530	2063.763	1338.2114	1257.927
36	-14.2500	-24.6817	2707.595	1058.6387	3389.474	2140.070	1940.767	2100.697	2059.233	1355.6911	1264.024
37	-7.3763	-27.5289	2727.426	1061.4311	3408.947	2152.962	1940.418	2112.544	2068.990	1365.6504	1276.220
38	0.0000	-28.5000	2717.722	1055.6719	3362.105	2167.944	1939.721	2110.105	2068.293	1374.3902	1283.943
39	7.3763	-27.5289	2683.966	1048.6911	3261.579	2178.746	1953.310	2102.787	2079.791	1363.4146	1297.561
40	14.2500	-24.6817	2664.135	1056.0209	3231.579	2172.125	1964.111	2104.181	2096.864	1353.6585	1301.626
41	20.1525	-20.1525	2648.523	1052.1815	3198.947	2168.293	1976.307	2112.544	2077.700	1359.3496	1296.138
42	24.6817	-14.2500	2636.287	1064.5724	3180.526	2172.822	1968.641	2126.829	2067.596	1373.9837	1296.138
43	27.5289	-7.3764	2633.755	1066.1431	3179.474	2172.125	1975.610	2144.948	2093.380	1375.4065	1297.967
44	28.5000	0.0000	2627.848	1073.1239	3189.474	2198.606	2006.272	2168.990	2126.481	1375.4065	1294.715
45	27.5289	7.3764	2586.076	1087.6091	3221.053	2214.286	2024.739	2179.094	2157.840	1359.7561	1291.870
46	24.6817	14.2500	2543.038	1098.4293	3252.632	2238.328	2041.115	2199.303	2158.188	1351.6260	1294.106
47	20.1525	20.1525	2543.460	1098.9529	3233.684	2267.247	2063.066	2228.223	2182.927	1338.8211	1297.561
48	14.2500	24.6817	2572.152	1100.0000	3231.579	2284.669	2079.791	2247.735	2170.732	1341.6667	1295.935
49	7.3764	27.5289	2585.654	1103.8394	3222.632	2289.895	2078.746	2255.052	2140.070	1349.7967	1293.902
50	0.0000	38.0000	2554.430	1087.4346	3249.474	2236.934	2043.902	2167.247	2058.885	1336.5854	1280.488
51	-7.4134	37.2698	2569.620	1087.6091	3296.316	2260.627	2024.739	2162.718	2059.582	1325.0000	1266.260
52	-14.5420	35.1074	2562.447	1079.4066	3332.105	2260.976	2020.906	2170.035	2056.446	1309.9593	1265.041
53	-21.1117	31.5958	2580.169	1082.7225	3348.421	2245.296	2014.634	2149.477	2073.519	1307.9268	1271.545
54	-26.8701	26.8701	2604.641	1082.7225	3308.421	2234.146	2025.784	2128.920	2103.484	1317.6829	1272.764
55	-31.5958	21.1117	2627.426	1088.4817	3288.421	2208.711	2017.422	2110.453	2083.972	1309.3496	1269.512
56	-35.1074	14.5420	2635.021	1089.1798	3277.368	2193.728	2013.937	2097.213	2078.397	1307.3171	1268.496
57	-37.2698	7.4134	2638.397	1097.5567	3275.263	2188.502	1996.516	2102.787	2062.718	1309.1463	1258.537
58	-38.0000	0.0000	2645.992	1083.4206	3264.737	2174.913	1966.551	2125.784	2040.070	1306.9106	1255.285
59	-37.2698	-7.4134	2639.241	1070.3316	3267.368	2182.578	1960.627	2147.038	2052.265	1313.2114	1256.504
60	-35.1074	-14.5420	2643.038	1060.9075	3241.579	2177.700	1947.038	2151.220	2064.460	1320.9350	1256.707
61	-31.5958	-21.1117	2654.008	1066.4921	3233.158	2163.066	1946.690	2131.359	2058.188	1321.5447	1256.301

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
62	-26.8701	-26.8701	2661.181	1074.1710	3260.526	2147.387	1942.509	2132.056	2054.704	1327.4390	1259.959
63	-21.1117	-31.5958	2643.882	1080.6283	3313.158	2156.098	1936.934	2123.345	2058.537	1343.4959	1266.870
64	-14.5420	-35.1074	2675.527	1074.8691	3375.789	2177.700	1943.554	2121.603	2063.066	1330.8943	1267.480
65	-7.4134	-37.2698	2702.532	1069.8080	3396.316	2193.031	1941.812	2128.223	2064.808	1331.9106	1264.228
66	0.0000	-38.0000	2707.595	1073.1239	3365.789	2184.669	1939.721	2134.843	2068.293	1320.7317	1262.805
67	7.4134	-37.2698	2688.608	1071.9023	3307.895	2179.791	1956.098	2120.906	2077.700	1316.0569	1277.236
68	14.5420	-35.1074	2647.679	1075.5672	3262.632	2172.822	1968.990	2122.300	2101.742	1317.6829	1284.350
69	21.1117	-31.5958	2626.160	1073.1239	3206.842	2168.990	1974.564	2118.118	2110.453	1308.3333	1279.675
70	26.8701	-26.8701	2648.945	1066.4921	3195.789	2159.930	1971.429	2118.815	2100.000	1317.8862	1274.390
71	31.5958	-21.1117	2665.823	1065.0960	3182.632	2162.021	1962.718	2121.254	2069.686	1335.5691	1274.390
72	35.1074	-14.5420	2670.042	1067.1902	3196.316	2157.143	1959.233	2110.801	2074.564	1345.7317	1281.911
73	37.2698	-7.4134	2681.857	1063.8743	3193.158	2158.188	1941.463	2127.875	2083.275	1370.5285	1284.350
74	38.0000	0.0000	2667.932	1060.3839	3180.000	2183.275	1957.491	2156.794	2090.592	1372.5610	1290.854
75	37.2698	7.4134	2640.506	1060.0349	3203.684	2168.641	1979.791	2157.491	2104.530	1357.5203	1287.602
76	35.1074	14.5420	2596.203	1072.4258	3213.684	2177.700	1991.638	2169.686	2108.014	1348.1707	1284.146
77	31.5958	21.1117	2556.540	1075.2182	3211.053	2180.836	2009.756	2172.125	2105.575	1340.6504	1292.683
78	26.8701	26.8701	2566.245	1070.6806	3226.316	2210.105	2008.014	2198.258	2122.300	1341.4634	1292.886
79	21.1117	31.5958	2570.886	1066.4921	3250.526	2238.328	2039.721	2214.634	2114.634	1339.4309	1287.195
80	14.5420	35.1074	2559.916	1069.4590	3222.632	2241.115	2058.537	2203.833	2097.213	1337.6016	1298.374
81	7.4134	37.2698	2559.916	1080.8028	3227.895	2247.387	2049.129	2183.624	2073.519	1337.8049	1289.431
82	0.0000	47.5000	2558.650	1078.0105	3193.684	2190.592	2044.599	2150.174	2040.418	1318.6992	1298.984
83	-7.4306	46.9152	2573.418	1083.9442	3245.263	2201.045	2029.268	2148.432	2017.770	1319.5122	1280.488
84	-14.6783	45.1752	2589.030	1086.3874	3301.053	2214.983	2012.892	2159.582	2012.195	1318.2927	1273.780
85	-21.5645	42.3228	2594.093	1081.6754	3331.579	2228.223	2010.453	2155.052	2036.585	1330.0813	1281.707
86	-27.9198	38.4283	2602.532	1086.5620	3318.421	2228.571	2014.634	2139.721	2058.537	1330.8943	1286.585
87	-33.5876	33.5876	2612.658	1080.8028	3273.158	2209.408	2019.164	2112.892	2112.195	1338.0081	1288.618
88	-38.4283	27.9198	2621.519	1089.7033	3235.263	2198.606	2034.843	2100.697	2142.857	1318.4959	1286.585
89	-42.3228	21.5646	2620.675	1090.5759	3213.684	2188.502	2041.463	2094.425	2122.648	1309.9593	1276.016
90	-45.1752	14.6783	2637.975	1099.4764	3214.737	2188.502	2040.418	2073.868	2098.955	1303.2520	1279.472
91	-46.9152	7.4306	2629.536	1104.1885	3220.526	2161.324	2014.634	2076.655	2068.293	1297.7642	1277.033

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
92	-47.5000	0.0000	2618.143	1098.9529	3228.421	2162.369	1987.456	2091.986	2084.669	1302.4390	1259.350
93	-46.9152	-7.4306	2616.456	1088.8307	3236.842	2182.927	1976.307	2131.010	2059.930	1306.0976	1260.163
94	-45.1752	-14.6783	2648.101	1075.5672	3218.421	2208.711	1968.990	2164.111	2068.293	1329.8780	1261.179
95	-42.3228	-21.5646	2677.215	1074.8691	3188.947	2206.969	1960.627	2168.293	2075.610	1332.9268	1259.756
96	-38.4283	-27.9198	2687.342	1077.8360	3191.053	2187.456	1969.338	2153.310	2066.202	1346.3415	1256.707
97	-33.5876	-33.5876	2656.540	1086.3874	3201.053	2175.261	1974.564	2150.871	2066.202	1346.9512	1268.293
98	-27.9198	-38.4283	2652.743	1089.5288	3251.579	2168.641	1962.369	2151.220	2067.944	1340.4472	1266.260
99	-21.5646	-42.3228	2640.506	1094.0663	3319.474	2181.882	1957.143	2148.432	2073.171	1313.2114	1271.951
100	-14.6783	-45.1752	2646.835	1092.4956	3413.684	2189.199	1955.401	2141.812	2064.460	1308.7398	1261.992
101	-7.4306	-46.9152	2677.215	1087.0855	3438.947	2189.547	1962.369	2162.021	2084.669	1298.9837	1253.252
102	0.0000	-47.5000	2696.624	1091.4485	3418.947	2190.941	1976.307	2159.582	2097.909	1302.2358	1255.081
103	7.4306	-46.9152	2698.734	1092.4956	3354.737	2180.488	1984.321	2159.233	2074.913	1298.5772	1265.041
104	14.6783	-45.1752	2688.608	1093.7173	3312.632	2178.049	1992.334	2142.160	2090.244	1301.0163	1282.927
105	21.5645	-42.3228	2694.093	1090.0524	3254.737	2166.899	1988.850	2134.843	2112.892	1302.2358	1278.862
106	27.9198	-38.4283	2688.186	1089.1798	3211.053	2166.551	1985.714	2139.721	2099.303	1305.6911	1268.089
107	33.5876	-33.5876	2702.532	1078.0105	3215.789	2170.035	1993.728	2141.115	2088.850	1305.4878	1261.585
108	38.4283	-27.9198	2685.232	1076.7888	3214.737	2169.686	1990.941	2134.146	2071.080	1310.1626	1252.236
109	42.3228	-21.5646	2663.713	1080.9773	3210.000	2175.610	1980.488	2129.617	2069.338	1330.4878	1260.163
110	45.1752	-14.6783	2677.215	1080.9773	3205.789	2162.021	1961.672	2108.014	2068.990	1347.7642	1262.398
111	46.9152	-7.4306	2694.093	1068.2373	3216.316	2160.976	1952.613	2126.829	2086.411	1360.1626	1278.252
112	47.5000	0.0000	2674.684	1058.6387	3230.526	2181.882	1952.265	2139.721	2106.969	1364.2276	1286.179
113	46.9152	7.4306	2664.557	1055.4974	3221.053	2193.728	1975.610	2147.387	2092.334	1359.1463	1286.992
114	45.1752	14.6783	2618.987	1064.3979	3222.105	2189.547	1986.760	2142.509	2079.443	1352.0325	1288.618
115	42.3228	21.5645	2616.034	1075.0436	3252.105	2171.080	1993.380	2144.251	2069.338	1351.0163	1286.992
116	38.4283	27.9198	2617.300	1078.8831	3221.579	2165.854	1982.927	2151.220	2077.700	1357.1138	1290.650
117	33.5876	33.5876	2620.253	1073.9965	3222.105	2205.226	1988.153	2168.990	2088.850	1351.4228	1290.650
118	27.9198	38.4283	2629.536	1062.3037	3225.789	2222.997	1993.031	2199.303	2106.969	1343.0894	1295.528
119	21.5646	42.3228	2628.270	1050.6108	3217.368	2232.056	2021.951	2206.272	2104.878	1331.0976	1300.407
120	14.6783	45.1752	2594.937	1055.4974	3201.053	2222.648	2045.296	2200.348	2078.049	1333.5366	1311.992

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
121	7.4306	46.9152	2579.747	1068.7609	3191.053	2215.679	2056.446	2165.854	2055.749	1329.4715	1311.992
122	0.0000	57.0000	2587.342	1078.8831	3234.737	2225.784	2064.111	2166.551	2060.976	1309.7561	1304.065
123	-7.4400	56.5124	2600.000	1087.2600	3285.263	2224.739	2062.718	2158.537	2052.613	1319.9187	1285.976
124	-14.7527	55.0578	2629.114	1090.9250	3340.000	2231.707	2066.551	2149.826	2027.875	1329.4715	1273.374
125	-21.8130	52.6611	2641.772	1088.8307	3342.632	2235.192	2057.840	2163.066	2047.735	1340.8537	1286.585
126	-28.5000	49.3634	2650.633	1092.6702	3315.789	2244.948	2046.341	2158.537	2075.610	1348.7805	1288.821
127	-34.6994	45.2211	2632.068	1097.3822	3272.105	2243.206	2053.310	2157.143	2109.408	1356.9106	1294.106
128	-40.3051	40.3051	2631.224	1093.8918	3218.421	2236.585	2061.324	2134.843	2166.899	1364.2276	1304.065
129	-45.2211	34.6994	2640.506	1102.9668	3191.579	2233.449	2079.443	2120.209	2189.895	1354.8780	1306.707
130	-49.3634	28.5000	2665.401	1104.1885	3186.842	2218.815	2080.488	2108.014	2202.091	1352.8455	1305.081
131	-52.6611	21.8130	2691.983	1109.9476	3210.000	2216.725	2081.185	2094.077	2176.307	1339.2276	1292.276
132	-55.0578	14.7527	2705.907	1116.2304	3200.526	2178.746	2067.247	2078.746	2136.237	1328.0488	1281.504
133	-56.5124	7.4400	2682.700	1120.9424	3218.947	2179.443	2056.446	2092.334	2124.042	1323.5772	1276.829
134	-57.0000	0.0000	2656.962	1120.2443	3236.316	2181.882	2017.422	2127.178	2111.847	1319.9187	1280.488
135	-56.5124	-7.4400	2674.684	1104.7120	3261.053	2196.167	1991.289	2165.157	2128.223	1336.7886	1287.195
136	-55.0578	-14.7527	2686.076	1098.2548	3244.737	2204.181	1986.063	2193.380	2125.436	1351.4228	1285.163
137	-52.6611	-21.8130	2727.848	1091.4485	3220.000	2203.484	1988.153	2203.833	2122.300	1358.1301	1290.650
138	-49.3634	-28.5000	2749.367	1093.8918	3192.105	2204.530	1998.955	2214.286	2120.557	1346.7480	1281.707
139	-45.2211	-34.6994	2732.911	1097.5567	3149.474	2202.091	2009.408	2217.770	2112.544	1344.7154	1289.634
140	-40.3051	-40.3051	2719.409	1105.2356	3178.947	2182.927	2013.240	2202.091	2094.077	1347.3577	1283.537
141	-34.6994	-45.2211	2716.456	1111.5183	3216.842	2187.108	2010.105	2196.864	2086.063	1333.7398	1291.870
142	-28.5000	-49.3635	2694.937	1121.9895	3262.105	2190.592	2000.000	2192.683	2106.969	1328.2520	1304.268
143	-21.8130	-52.6611	2717.722	1121.1169	3333.684	2198.258	1985.366	2193.380	2114.983	1325.0000	1291.870
144	-14.7527	-55.0578	2706.329	1109.5986	3414.737	2197.561	1982.578	2196.864	2099.303	1305.0813	1280.894
145	-7.4400	-56.5124	2694.093	1102.6178	3471.579	2219.861	1998.955	2208.014	2105.575	1296.3415	1265.244
146	0.0000	-57.0000	2682.700	1104.7120	3465.789	2227.875	2012.544	2225.784	2121.951	1283.7398	1261.585
147	7.4400	-56.5124	2692.405	1105.9337	3392.105	2231.010	2025.087	2201.394	2126.829	1287.8049	1272.358
148	14.7527	-55.0578	2710.549	1110.4712	3320.526	2212.544	2018.118	2183.972	2120.209	1298.9837	1278.659
149	21.8129	-52.6611	2728.270	1109.5986	3263.684	2201.742	2024.390	2177.700	2121.951	1310.3659	1276.220
150	28.5000	-49.3634	2732.068	1109.9476	3248.421	2200.348	2026.132	2170.383	2139.721	1306.7073	1270.732

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
151	34.6994	-45.2211	2725.738	1100.6981	3238.421	2197.909	2025.436	2177.352	2162.021	1311.5854	1254.878
152	40.3051	-40.3051	2727.426	1096.3351	3253.684	2214.983	2021.951	2186.063	2164.111	1318.4959	1259.350
153	45.2211	-34.6994	2740.506	1098.6038	3283.684	2226.829	2035.889	2196.864	2151.220	1328.4553	1256.098
154	49.3634	-28.5000	2731.224	1104.5375	3295.263	2213.240	2040.767	2189.199	2124.739	1339.4309	1257.520
155	52.6611	-21.8130	2734.599	1112.7400	3287.368	2199.652	2020.906	2162.718	2104.878	1352.8455	1264.228
156	55.0578	-14.7527	2755.274	1109.9476	3282.632	2186.063	2007.666	2163.066	2117.770	1354.6748	1270.325
157	56.5124	-7.4400	2737.553	1099.4764	3264.211	2182.578	1981.185	2160.976	2127.875	1362.6016	1285.976
158	57.0000	0.0000	2725.316	1084.4677	3273.158	2218.815	1987.456	2179.443	2126.829	1369.7154	1298.171
159	56.5124	7.4400	2703.797	1072.7749	3271.053	2236.585	1990.592	2200.697	2108.711	1360.3659	1309.350
160	55.0578	14.7527	2693.249	1070.6806	3253.158	2245.993	2008.711	2203.833	2080.836	1358.3333	1309.146
161	52.6611	21.8129	2689.873	1084.2932	3257.895	2203.484	2012.195	2189.895	2081.185	1363.6179	1317.073
162	49.3634	28.5000	2678.059	1090.0524	3271.579	2173.868	1998.955	2180.836	2069.338	1369.1057	1315.447
163	45.2211	34.6994	2660.338	1091.9721	3278.421	2177.352	1999.303	2180.139	2068.641	1375.0000	1301.423
164	40.3051	40.3051	2666.245	1078.5340	3266.316	2194.077	2009.756	2213.589	2086.063	1371.3415	1296.138
165	34.6994	45.2211	2675.527	1068.2373	3244.211	2220.557	2014.983	2239.373	2093.031	1357.5203	1301.220
166	28.5000	49.3634	2686.920	1061.2565	3235.789	2234.495	2029.617	2245.296	2107.666	1351.4228	1309.350
167	21.8130	52.6611	2662.025	1058.6387	3244.211	2233.449	2048.780	2232.404	2094.774	1338.0081	1318.902
168	14.7527	55.0578	2640.084	1061.7801	3254.211	2226.481	2056.446	2199.303	2076.655	1318.4959	1321.138
169	7.4400	56.5124	2615.612	1067.7138	3243.684	2227.178	2059.930	2183.275	2063.763	1312.3984	1316.260
170	0.0000	66.5000	2658.228	1105.2356	3308.947	2297.213	2129.268	2198.955	2156.446	1327.6423	1317.683
171	-7.4456	66.0819	2674.684	1114.1361	3326.842	2288.502	2121.951	2190.941	2176.655	1325.8130	1293.496
172	-14.7976	64.8327	2687.764	1123.5602	3359.474	2312.892	2125.087	2190.941	2178.049	1339.0244	1276.016
173	-21.9636	62.7682	2725.316	1130.1920	3390.526	2298.606	2137.282	2193.031	2150.523	1361.5854	1277.033
174	-28.8533	59.9144	2746.414	1132.4607	3353.158	2318.467	2139.024	2191.986	2159.582	1369.3089	1279.065
175	-35.3801	56.3072	2745.992	1138.3944	3271.053	2317.073	2131.359	2186.411	2160.976	1372.3577	1287.805
176	-41.4621	51.9918	2732.068	1146.2478	3222.632	2298.955	2116.376	2199.652	2203.136	1369.3089	1305.488
177	-47.0226	47.0226	2729.958	1150.6108	3165.263	2286.760	2124.390	2185.366	2249.129	1364.2276	1326.626
178	-51.9918	41.4621	2756.962	1144.8517	3158.421	2283.275	2124.042	2187.456	2292.334	1373.3740	1343.496
179	-56.3072	35.3801	2772.152	1141.5358	3177.368	2275.610	2141.812	2190.592	2317.770	1380.2846	1343.089
180	-59.9144	28.8533	2813.924	1145.5497	3185.789	2274.564	2143.206	2184.669	2306.272	1381.9106	1339.024

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
181	-62.7682	21.9636	2843.038	1149.0401	3199.474	2264.111	2136.237	2186.063	2269.338	1372.3577	1327.033
182	-64.8327	14.7976	2832.489	1156.3700	3203.684	2245.993	2120.557	2180.836	2217.422	1359.9593	1321.138
183	-66.0819	7.4456	2807.173	1149.9127	3219.474	2231.010	2099.652	2190.941	2218.467	1352.0325	1330.488
184	-66.5000	0.0000	2793.249	1152.8796	3230.526	2211.498	2066.202	2207.666	2221.951	1355.6911	1331.098
185	-66.0819	-7.4456	2789.451	1149.5637	3254.211	2205.226	2019.512	2220.906	2227.178	1363.8211	1334.350
186	-64.8327	-14.7976	2804.641	1138.0454	3271.053	2223.693	2010.105	2265.854	2236.934	1376.4228	1341.870
187	-62.7682	-21.9636	2856.540	1118.4991	3283.684	2245.645	2019.164	2283.972	2241.115	1380.6911	1335.569
188	-59.9144	-28.8533	2875.105	1116.9284	3298.421	2249.826	2029.268	2306.272	2239.373	1374.7967	1330.081
189	-56.3072	-35.3801	2860.338	1114.4852	3288.421	2245.296	2041.115	2319.512	2231.010	1363.8211	1332.724
190	-51.9918	-41.4621	2817.300	1121.6405	3279.474	2242.857	2065.854	2306.272	2209.756	1356.0976	1330.488
191	-47.0226	-47.0226	2791.561	1126.3525	3283.684	2232.404	2075.261	2285.714	2189.895	1350.8130	1335.772
192	-41.4621	-51.9918	2772.996	1144.1536	3262.632	2208.362	2075.610	2280.836	2178.746	1342.8862	1351.220
193	-35.3801	-56.3072	2780.169	1154.9738	3287.368	2228.571	2064.111	2285.366	2176.307	1339.2276	1356.911
194	-28.8533	-59.9144	2796.624	1155.3229	3329.474	2229.268	2059.930	2271.429	2160.627	1339.2276	1365.244
195	-21.9636	-62.7682	2788.608	1141.7103	3437.368	2234.495	2042.160	2266.899	2141.463	1326.0163	1347.358
196	-14.7976	-64.8327	2766.667	1137.5218	3530.526	2256.794	2040.767	2277.003	2139.024	1304.6748	1323.374
197	-7.4456	-66.0819	2754.008	1122.6876	3600.526	2292.683	2058.188	2288.153	2145.645	1290.2439	1307.927
198	0.0000	-66.5000	2734.599	1116.4049	3572.105	2311.150	2073.519	2300.348	2153.659	1286.5854	1300.203
199	7.4456	-66.0819	2732.911	1123.5602	3485.263	2301.742	2075.610	2279.791	2173.868	1295.3252	1304.878
200	14.7976	-64.8327	2740.506	1130.5410	3392.632	2290.941	2072.822	2255.749	2174.913	1310.9756	1304.675
201	21.9636	-62.7682	2760.759	1132.8098	3347.368	2268.293	2078.049	2231.010	2186.063	1317.4797	1305.488
202	28.8533	-59.9144	2774.262	1133.6824	3331.579	2260.627	2076.655	2221.603	2195.819	1327.0325	1284.350
203	35.3801	-56.3072	2781.013	1134.3805	3328.947	2265.505	2076.307	2210.453	2201.394	1331.9106	1269.715
204	41.4621	-51.9918	2789.451	1124.0838	3322.105	2267.596	2093.728	2236.934	2217.770	1334.9593	1261.789
205	47.0226	-47.0226	2800.000	1121.2914	3360.000	2284.669	2106.272	2246.341	2218.815	1350.0000	1268.902
206	51.9918	-41.4621	2789.451	1136.3002	3406.316	2294.774	2107.317	2242.857	2226.132	1359.7561	1280.488
207	56.3072	-35.3801	2791.983	1139.2670	3390.526	2293.728	2115.331	2244.251	2216.376	1371.7480	1285.569
208	59.9144	-28.8533	2812.658	1150.2618	3412.632	2286.760	2124.739	2215.331	2197.213	1378.8618	1291.057
209	62.7682	-21.9636	2830.380	1153.0541	3418.421	2277.003	2101.394	2207.666	2178.746	1392.4797	1289.228
210	64.8327	-14.7976	2838.819	1150.2618	3419.474	2279.791	2084.669	2212.195	2179.791	1394.7154	1300.407

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
211	66.0819	-7.4456	2832.911	1135.9511	3399.474	2290.941	2076.307	2226.132	2187.805	1407.3171	1313.211
212	66.5000	0.0000	2795.359	1113.2635	3384.737	2298.955	2066.551	2235.192	2173.171	1417.4797	1330.894
213	66.0819	7.4456	2792.827	1098.7784	3366.842	2314.634	2069.338	2250.871	2155.401	1403.0488	1340.244
214	64.8327	14.7976	2772.996	1096.6841	3356.316	2321.254	2067.247	2258.885	2124.739	1413.8211	1352.033
215	62.7682	21.9635	2748.101	1106.2827	3343.158	2307.317	2073.868	2242.857	2120.209	1426.8293	1353.049
216	59.9144	28.8533	2741.350	1104.1885	3348.421	2269.338	2055.052	2215.679	2141.115	1425.8130	1349.797
217	56.3072	35.3801	2732.911	1100.8726	3357.368	2243.902	2045.993	2209.408	2146.341	1416.8699	1349.593
218	51.9918	41.4621	2711.814	1095.8115	3344.737	2234.495	2055.749	2217.073	2133.101	1408.3333	1337.602
219	47.0226	47.0226	2706.751	1082.7225	3357.368	2264.111	2064.111	2237.979	2138.328	1395.3252	1324.390
220	41.4621	51.9918	2714.346	1075.9162	3333.684	2281.185	2078.049	2252.265	2165.854	1381.0976	1320.528
221	35.3801	56.3072	2748.945	1077.3124	3322.105	2285.017	2089.547	2260.627	2181.882	1376.0163	1320.122
222	28.8533	59.9144	2772.996	1090.0524	3322.105	2287.456	2098.606	2243.206	2171.429	1368.6992	1332.724
223	21.9636	62.7682	2760.759	1089.0052	3335.789	2265.505	2112.195	2201.742	2146.690	1366.4634	1334.959
224	14.7977	64.8327	2732.911	1089.7033	3325.789	2267.596	2115.331	2183.624	2126.132	1347.1545	1335.772
225	7.4456	66.0819	2680.591	1095.9860	3313.684	2283.624	2125.087	2189.547	2124.390	1333.7398	1332.927
226	0.0000	76.0000	2768.776	1152.5305	3316.842	2379.791	2204.530	2237.631	2284.321	1345.1220	1338.618
227	-7.4493	75.6340	2777.215	1161.0820	3331.579	2418.118	2194.077	2262.021	2324.042	1353.0488	1317.276
228	-14.8269	74.5397	2797.046	1169.2845	3378.421	2410.801	2207.666	2248.084	2358.885	1358.1301	1295.325
229	-22.0616	72.7275	2806.329	1167.7138	3413.684	2388.850	2212.544	2244.599	2337.282	1364.8374	1295.732
230	-29.0839	70.2148	2829.536	1162.8272	3384.211	2388.850	2219.164	2268.990	2333.449	1371.7480	1286.992
231	-35.8261	67.0260	2829.114	1172.7749	3320.000	2408.711	2212.195	2281.882	2331.010	1372.5610	1304.268
232	-42.2233	63.1917	2838.819	1176.9634	3239.474	2391.638	2193.031	2284.321	2349.826	1370.9350	1317.886
233	-48.2139	58.7488	2828.270	1188.8307	3128.947	2364.111	2182.927	2287.108	2366.551	1367.6829	1336.992
234	-53.7401	53.7401	2864.135	1196.1606	3122.105	2354.355	2180.139	2290.592	2400.348	1371.5447	1363.821
235	-58.7488	48.2139	2886.076	1191.6230	3148.947	2346.341	2191.986	2277.700	2444.948	1374.1870	1383.943
236	-63.1917	42.2233	2908.861	1188.4817	3166.842	2324.042	2189.199	2280.139	2491.986	1385.1626	1398.780
237	-67.0260	35.8262	2929.536	1186.3874	3212.105	2330.662	2182.927	2287.108	2486.760	1386.7886	1398.984
238	-70.2148	29.0839	2954.430	1186.7365	3250.526	2336.934	2186.411	2293.380	2444.599	1388.6179	1384.350
239	-72.7275	22.0616	2964.135	1193.7173	3276.842	2347.387	2173.171	2286.760	2391.638	1375.0000	1373.374
240	-74.5397	14.8269	2960.338	1188.3072	3288.421	2320.209	2162.369	2281.185	2382.927	1366.0569	1372.764

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
241	-75.6340	7.4493	2966.245	1196.1606	3325.263	2297.561	2131.359	2281.533	2381.882	1362.3984	1375.610
242	-76.0000	0.0000	2934.177	1199.6510	3347.368	2281.533	2094.077	2292.334	2379.094	1365.4472	1377.033
243	-75.6340	-7.4493	2923.629	1196.6841	3343.684	2275.610	2058.188	2290.592	2387.108	1365.6504	1389.024
244	-74.5397	-14.8269	2937.131	1177.8360	3364.211	2273.519	2055.401	2317.422	2396.864	1371.3415	1389.228
245	-72.7275	-22.0616	2968.354	1155.8464	3364.737	2281.533	2056.446	2332.753	2396.516	1377.6423	1392.480
246	-70.2148	-29.0839	2991.561	1156.1955	3381.053	2302.091	2060.279	2371.080	2388.502	1374.3902	1383.333
247	-67.0260	-35.8262	3008.017	1152.8796	3401.579	2321.951	2055.052	2406.272	2388.850	1362.1951	1375.813
248	-63.1917	-42.2233	2977.637	1148.6911	3357.895	2317.770	2088.153	2414.983	2359.233	1349.3902	1377.846
249	-58.7488	-48.2139	2924.051	1157.2426	3328.947	2300.000	2108.711	2388.153	2308.362	1342.6829	1385.366
250	-53.7401	-53.7401	2854.430	1156.5445	3312.632	2286.411	2131.359	2356.794	2280.836	1343.2927	1402.033
251	-48.2139	-58.7488	2809.283	1166.8412	3320.526	2289.895	2140.070	2362.369	2282.927	1344.1057	1414.634
252	-42.2234	-63.1917	2828.692	1180.1047	3328.947	2295.470	2134.146	2356.098	2289.895	1350.2033	1414.228
253	-35.8261	-67.0260	2839.241	1187.0855	3333.684	2280.488	2118.467	2344.599	2278.049	1339.4309	1402.033
254	-29.0840	-70.2148	2847.679	1179.9302	3424.737	2290.244	2105.575	2319.164	2251.916	1332.3171	1392.886
255	-22.0616	-72.7275	2822.363	1178.8831	3506.842	2311.150	2110.105	2314.286	2237.979	1320.1220	1376.220
256	-14.8269	-74.5397	2804.641	1163.5253	3602.632	2342.509	2119.512	2322.300	2232.056	1306.5041	1358.333
257	-7.4493	-75.6340	2792.827	1153.5777	3648.421	2374.564	2122.648	2352.962	2235.889	1303.4553	1348.984
258	0.0000	-76.0000	2806.329	1143.4555	3634.211	2405.923	2122.997	2351.568	2231.707	1298.1707	1345.325
259	7.4493	-75.6340	2831.224	1145.7243	3544.737	2431.359	2136.585	2340.070	2263.763	1304.4715	1355.285
260	14.8269	-74.5397	2817.722	1152.1815	3437.368	2421.951	2123.693	2325.784	2277.352	1315.4472	1352.846
261	22.0616	-72.7275	2836.709	1159.5113	3393.684	2395.122	2127.875	2284.321	2297.909	1318.6992	1354.268
262	29.0839	-70.2149	2840.084	1159.1623	3379.474	2376.307	2123.345	2259.930	2293.031	1334.9593	1338.008
263	35.8261	-67.0260	2844.304	1154.7993	3370.000	2395.470	2142.857	2256.098	2298.606	1336.1789	1323.984
264	42.2233	-63.1917	2866.667	1151.1344	3356.316	2405.226	2163.763	2255.749	2295.470	1350.4065	1288.415
265	48.2139	-58.7488	2869.198	1149.3892	3398.947	2394.077	2175.958	2256.446	2299.652	1354.6748	1283.537
266	53.7401	-53.7401	2840.506	1149.5637	3456.316	2403.136	2190.941	2277.700	2293.031	1360.7724	1291.057
267	58.7488	-48.2139	2821.519	1156.1955	3485.789	2402.787	2198.258	2278.397	2312.195	1372.3577	1312.805
268	63.1917	-42.2233	2824.051	1164.5724	3490.526	2385.714	2202.439	2273.171	2319.164	1389.6341	1330.894
269	67.0260	-35.8262	2857.806	1172.6003	3477.368	2356.098	2195.470	2249.826	2293.728	1397.1545	1330.081
270	70.2148	-29.0839	2860.759	1178.0105	3460.526	2354.355	2192.334	2238.328	2270.732	1411.1789	1330.894

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
271	72.7275	-22.0616	2875.949	1168.5864	3471.579	2361.672	2183.972	2256.098	2271.080	1435.3659	1325.813
272	74.5397	-14.8269	2876.371	1158.6387	3443.158	2387.108	2164.808	2268.641	2285.017	1437.6016	1345.325
273	75.6340	-7.4493	2875.527	1150.6108	3464.737	2395.819	2147.038	2280.488	2291.986	1445.7317	1353.659
274	76.0000	0.0000	2876.371	1139.2670	3499.474	2396.167	2158.885	2285.714	2277.352	1446.3415	1365.244
275	75.6340	7.4493	2879.747	1123.0366	3494.211	2390.592	2171.080	2284.669	2255.052	1450.0000	1369.512
276	74.5397	14.8268	2825.316	1120.4188	3487.368	2375.261	2170.383	2276.307	2206.620	1450.2033	1375.000
277	72.7275	22.0616	2779.325	1129.6684	3473.684	2359.233	2155.401	2268.641	2183.972	1454.8780	1366.057
278	70.2149	29.0839	2767.932	1139.7906	3446.842	2360.279	2132.056	2252.962	2200.348	1453.8618	1372.967
279	67.0260	35.8261	2766.245	1137.1728	3427.368	2349.129	2114.634	2229.965	2226.829	1453.8618	1379.065
280	63.1917	42.2233	2746.414	1132.8098	3403.684	2320.557	2105.923	2222.997	2265.854	1438.0081	1371.951
281	58.7488	48.2139	2722.785	1115.0087	3398.947	2326.481	2124.739	2235.889	2272.474	1415.2439	1361.585
282	53.7401	53.7401	2741.772	1099.3019	3405.263	2363.415	2154.704	2266.899	2266.551	1399.7967	1344.919
283	48.2139	58.7488	2766.667	1098.6038	3428.947	2388.502	2165.854	2286.063	2281.185	1387.6016	1341.870
284	42.2233	63.1917	2805.485	1102.7923	3424.737	2412.195	2171.429	2278.049	2317.770	1379.0650	1339.024
285	35.8262	67.0260	2836.287	1111.5183	3400.000	2383.972	2177.003	2253.659	2319.512	1374.5935	1339.024
286	29.0840	70.2148	2870.464	1121.2914	3391.579	2358.537	2175.261	2220.557	2295.470	1359.7561	1347.154
287	22.0616	72.7275	2843.882	1125.4799	3391.053	2337.282	2193.728	2196.516	2262.021	1356.3008	1342.276
288	14.8269	74.5397	2814.768	1121.2914	3368.947	2341.463	2204.530	2200.000	2249.477	1356.5041	1350.407
289	7.4493	75.6340	2771.308	1139.9651	3351.053	2355.401	2206.969	2214.983	2259.930	1351.4228	1350.000
290	0.0000	85.5000	2821.941	1176.6143	3197.368	2403.833	2207.666	2279.791	2352.962	1301.2195	1336.382
291	-7.4518	85.1746	2832.068	1182.5480	3264.737	2433.101	2216.028	2296.167	2418.118	1308.1301	1318.902
292	-14.8469	84.2011	2827.426	1173.2984	3320.526	2442.160	2212.892	2290.592	2479.094	1315.0407	1298.780
293	-22.1290	82.5867	2821.941	1167.3647	3395.263	2431.359	2213.937	2288.153	2466.551	1326.2195	1294.106
294	-29.2427	80.3437	2805.907	1165.7941	3405.789	2421.603	2225.784	2272.822	2415.679	1335.3659	1284.553
295	-36.1339	77.4893	2815.190	1161.6056	3382.105	2465.157	2217.422	2312.195	2390.244	1345.7317	1288.211
296	-42.7500	74.0452	2817.722	1158.2897	3316.842	2476.307	2208.711	2313.937	2401.742	1351.4228	1291.870
297	-49.0408	70.0375	2823.629	1172.9494	3234.737	2450.174	2205.575	2308.711	2421.254	1346.3415	1302.033
298	-54.9583	65.4968	2814.768	1179.7557	3189.474	2399.303	2183.275	2293.380	2408.711	1338.0081	1315.244
299	-60.4576	60.4576	2817.300	1177.4869	3158.947	2389.547	2183.972	2293.380	2404.530	1333.7398	1340.447
300	-65.4968	54.9583	2856.118	1172.9494	3162.105	2387.805	2186.411	2282.927	2423.345	1332.5203	1363.821

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
301	-70.0375	49.0408	2884.388	1169.9825	3173.684	2374.216	2166.551	2277.352	2489.547	1336.1789	1378.862
302	-74.0452	42.7500	2879.325	1166.8412	3203.684	2355.749	2164.460	2275.610	2490.592	1337.1951	1380.285
303	-77.4893	36.1339	2887.764	1164.7469	3267.368	2376.307	2162.369	2288.153	2449.826	1331.5041	1373.171
304	-80.3437	29.2427	2891.561	1162.8272	3320.000	2385.017	2161.672	2269.338	2396.516	1321.3415	1363.211
305	-82.5867	22.1290	2865.823	1153.9267	3344.211	2380.139	2159.930	2264.111	2398.258	1320.5285	1363.415
306	-84.2011	14.8469	2836.709	1145.7243	3366.842	2343.206	2141.463	2250.871	2398.606	1315.6504	1369.309
307	-85.1746	7.4518	2829.114	1151.6579	3337.895	2312.195	2121.951	2241.463	2375.610	1314.4309	1367.276
308	-85.5000	0.0000	2826.582	1158.4642	3325.263	2295.819	2085.366	2242.857	2351.220	1318.0894	1368.089
309	-85.1746	-7.4518	2809.705	1152.8796	3330.526	2291.638	2058.188	2247.387	2377.700	1322.7642	1362.805
310	-84.2011	-14.8469	2817.722	1142.5829	3301.053	2283.972	2052.962	2233.449	2390.244	1342.8862	1368.293
311	-82.5867	-22.1290	2827.426	1127.9232	3271.053	2276.307	2051.568	2226.481	2380.836	1349.5935	1363.211
312	-80.3437	-29.2427	2860.338	1119.3717	3313.158	2280.836	2033.798	2254.704	2368.990	1341.4634	1362.195
313	-77.4893	-36.1339	2881.435	1115.1832	3305.789	2305.226	2041.812	2292.334	2367.944	1336.5854	1349.797
314	-74.0452	-42.7500	2891.561	1118.8482	3296.316	2319.164	2054.704	2317.073	2400.697	1329.2683	1359.959
315	-70.0375	-49.0408	2866.245	1120.0698	3227.895	2301.045	2071.429	2317.073	2394.425	1317.2764	1358.943
316	-65.4968	-54.9583	2815.612	1122.5131	3202.632	2298.258	2085.017	2290.244	2335.889	1303.2520	1369.919
317	-60.4576	-60.4576	2741.772	1120.5934	3196.316	2282.927	2099.303	2266.899	2292.334	1294.5122	1373.984
318	-54.9583	-65.4968	2710.127	1136.3002	3220.000	2297.213	2115.331	2259.233	2320.906	1299.5935	1374.593
319	-49.0408	-70.0375	2710.127	1145.3752	3243.684	2297.561	2119.512	2267.596	2357.491	1291.6667	1379.472
320	-42.7500	-74.0452	2725.316	1161.9546	3221.053	2273.171	2116.376	2255.749	2367.596	1300.8130	1371.341
321	-36.1339	-77.4893	2715.612	1170.3316	3232.632	2271.777	2104.530	2233.449	2310.105	1291.0569	1359.959
322	-29.2427	-80.3437	2725.316	1167.1902	3272.105	2308.014	2106.969	2223.693	2298.606	1281.3008	1346.138
323	-22.1290	-82.5867	2716.034	1156.5445	3312.632	2302.787	2118.467	2241.463	2322.997	1286.5854	1336.992
324	-14.8469	-84.2011	2716.878	1155.3229	3376.316	2309.059	2129.617	2245.296	2334.495	1285.7724	1329.268
325	-7.4518	-85.1746	2747.679	1152.0070	3428.947	2334.843	2128.920	2257.491	2313.240	1267.8862	1335.366
326	0.0000	-85.5000	2760.759	1153.0541	3455.789	2391.289	2132.753	2281.882	2297.213	1271.3415	1339.024
327	7.4518	-85.1746	2797.890	1159.6859	3379.474	2419.164	2135.192	2291.289	2336.934	1284.5528	1355.285
328	14.8469	-84.2011	2823.207	1160.5585	3293.158	2411.498	2131.359	2273.171	2362.021	1290.6504	1365.041
329	22.1290	-82.5867	2823.207	1169.8080	3210.000	2394.077	2098.955	2255.401	2379.791	1294.9187	1370.325
330	29.2427	-80.3437	2848.523	1169.2845	3201.053	2397.561	2092.334	2237.979	2348.432	1293.2927	1360.163

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
331	36.1339	-77.4893	2820.675	1160.9075	3211.053	2423.693	2114.634	2235.540	2351.568	1301.0163	1339.228
332	42.7500	-74.0452	2861.181	1149.7382	3188.421	2441.115	2128.920	2242.509	2380.139	1315.6504	1313.211
333	49.0408	-70.0375	2877.637	1143.2810	3157.368	2411.498	2148.432	2240.767	2386.063	1314.6341	1288.211
334	54.9583	-65.4968	2877.637	1138.5689	3200.000	2388.153	2153.310	2251.916	2340.070	1312.3984	1293.496
335	60.4576	-60.4576	2837.553	1145.2007	3237.895	2398.258	2158.537	2263.415	2313.937	1313.4146	1301.016
336	65.4968	-54.9584	2812.236	1150.6108	3283.684	2398.258	2162.021	2255.401	2340.767	1315.6504	1315.244
337	70.0375	-49.0408	2802.110	1150.2618	3292.632	2365.157	2164.111	2229.617	2356.794	1327.6423	1325.000
338	74.0452	-42.7500	2797.046	1156.8935	3310.526	2325.784	2143.554	2223.693	2333.449	1337.8049	1327.642
339	77.4893	-36.1339	2798.734	1161.2565	3311.579	2303.833	2144.599	2219.164	2294.077	1337.1951	1323.374
340	80.3437	-29.2427	2786.920	1162.8272	3325.263	2315.679	2142.160	2233.449	2294.425	1344.9187	1321.341
341	82.5867	-22.1290	2780.169	1154.4503	3341.579	2324.739	2141.115	2242.509	2365.157	1362.6016	1341.260
342	84.2011	-14.8469	2784.388	1143.2810	3358.947	2339.721	2125.436	2262.718	2418.118	1361.1789	1351.016
343	85.1746	-7.4518	2792.405	1146.9459	3369.474	2339.373	2122.648	2271.080	2388.850	1359.9593	1357.520
344	85.5000	0.0000	2807.173	1142.0593	3420.526	2364.111	2127.178	2289.547	2356.446	1355.0813	1360.772
345	85.1747	7.4518	2809.705	1131.4136	3465.789	2351.916	2162.718	2300.348	2351.916	1349.7967	1357.317
346	84.2011	14.8469	2799.156	1127.7487	3443.684	2332.404	2164.808	2271.777	2336.237	1347.9675	1362.805
347	82.5867	22.1290	2788.608	1138.2199	3442.632	2303.833	2152.613	2265.505	2296.167	1353.6585	1354.878
348	80.3437	29.2427	2784.810	1160.3839	3444.211	2304.530	2137.631	2255.401	2268.990	1352.4390	1349.593
349	77.4893	36.1339	2794.937	1159.6859	3452.632	2342.857	2109.059	2256.794	2284.669	1352.6423	1365.041
350	74.0452	42.7500	2764.979	1159.8604	3447.368	2347.038	2102.439	2233.101	2344.948	1350.8130	1378.659
351	70.0375	49.0408	2756.540	1155.6719	3384.737	2333.101	2101.045	2211.498	2378.049	1336.1789	1369.309
352	65.4968	54.9583	2739.662	1138.5689	3370.000	2333.449	2129.617	2236.934	2362.718	1315.8537	1356.301
353	60.4576	60.4576	2748.523	1122.8621	3373.684	2360.976	2152.613	2270.035	2350.174	1293.6992	1348.577
354	54.9583	65.4968	2736.287	1123.3857	3400.000	2421.254	2158.188	2306.620	2385.017	1291.6667	1347.154
355	49.0408	70.0375	2793.671	1126.8761	3383.158	2440.070	2175.261	2293.031	2448.432	1291.8699	1342.276
356	42.7500	74.0452	2830.802	1134.3805	3363.684	2421.603	2187.108	2272.822	2481.185	1282.1138	1341.057
357	36.1339	77.4893	2843.882	1140.4887	3354.211	2396.516	2189.547	2245.296	2417.422	1280.2846	1348.780
358	29.2427	80.3437	2822.363	1150.0873	3322.105	2383.275	2192.683	2219.512	2371.080	1281.3008	1344.106
359	22.1290	82.5867	2812.658	1151.4834	3298.421	2360.627	2211.498	2218.815	2367.944	1287.3984	1345.122
360	14.8469	84.2011	2787.342	1153.9267	3266.842	2340.767	2217.073	2235.192	2375.610	1297.9675	1344.106

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
361	7.4518	85.1746	2809.283	1164.7469	3235.789	2354.704	2214.634	2254.355	2340.418	1293.4959	1348.577
362	0.0000	95.0000	2478.903	1052.3560	2584.737	2122.300	1953.659	1920.906	2095.819	1053.2520	1156.504
363	-7.4536	94.7071	2481.435	1048.3421	2652.105	2166.551	1938.676	1939.721	2174.564	1065.4472	1137.805
364	-14.8613	93.8304	2445.570	1021.4660	2716.842	2181.533	1950.174	1937.282	2260.279	1084.5528	1126.016
365	-22.1773	92.3751	2423.207	1005.9337	2750.000	2142.509	1953.659	1920.209	2248.084	1084.9593	1117.480
366	-29.3566	90.3504	2416.034	1001.9197	2806.842	2137.979	1957.840	1933.449	2175.261	1085.7724	1116.463
367	-36.3549	87.7686	2394.937	990.7504	2787.368	2186.063	1959.582	1960.627	2102.091	1088.0081	1102.236
368	-43.1291	84.6456	2381.857	982.5480	2756.842	2234.495	1962.021	1979.443	2164.808	1098.5772	1108.740
369	-49.6374	81.0008	2378.481	981.3264	2708.947	2227.178	1934.146	1958.188	2194.077	1109.5528	1120.732
370	-55.8396	76.8566	2384.388	995.6370	2656.842	2140.418	1914.286	1920.906	2186.411	1103.0488	1119.715
371	-61.6976	72.2386	2361.603	1004.3630	2618.421	2081.882	1888.502	1899.652	2126.481	1090.8537	1121.951
372	-67.1751	67.1751	2379.747	1004.0140	2620.526	2120.209	1900.000	1904.878	2072.125	1083.3333	1123.577
373	-72.2386	61.6976	2396.203	992.1466	2584.737	2126.132	1886.063	1893.031	2121.603	1075.4065	1132.724
374	-76.8566	55.8396	2414.346	982.8970	2608.947	2085.017	1871.429	1889.199	2204.530	1077.2358	1153.455
375	-81.0008	49.6374	2427.426	977.6614	2615.789	2059.582	1879.094	1874.564	2221.254	1078.6585	1170.732
376	-84.6456	43.1291	2438.397	981.5009	2686.842	2084.321	1879.791	1910.105	2176.307	1080.2846	1177.642
377	-87.7686	36.3549	2442.616	979.2321	2732.105	2123.693	1881.533	1923.345	2104.878	1071.7480	1179.065
378	-90.3504	29.3566	2426.160	966.8412	2765.789	2140.418	1890.941	1901.394	2157.143	1061.9919	1184.146
379	-92.3751	22.1773	2381.857	954.1012	2792.632	2109.408	1902.091	1879.791	2185.366	1075.2033	1189.024
380	-93.8304	14.8613	2363.291	951.4834	2798.421	2055.749	1908.014	1860.627	2196.864	1079.8780	1193.699
381	-94.7071	7.4536	2385.654	960.3839	2744.211	2040.767	1883.624	1873.171	2132.056	1066.6667	1185.772
382	-95.0000	0.0000	2375.527	968.4119	2685.789	2040.070	1856.446	1873.519	2060.976	1070.7317	1175.203
383	-94.7071	-7.4536	2381.435	977.8360	2586.842	2011.150	1827.875	1833.798	2109.756	1073.9837	1176.220
384	-93.8304	-14.8613	2378.481	975.2182	2572.632	1990.244	1827.875	1821.254	2181.882	1079.2683	1168.089
385	-92.3751	-22.1773	2375.949	961.0820	2557.368	1978.397	1817.422	1788.502	2163.415	1097.9675	1168.089
386	-90.3504	-29.3566	2396.624	954.9738	2544.737	1966.202	1792.334	1807.317	2080.488	1081.9106	1149.187
387	-87.7686	-36.3549	2402.954	949.5637	2584.211	1993.728	1789.547	1841.115	2011.847	1051.8293	1135.366
388	-84.6456	-43.1291	2429.536	942.0593	2560.000	2004.530	1800.348	1850.523	2088.850	1062.1951	1144.919
389	-81.0008	-49.6374	2400.000	933.6824	2550.526	2016.725	1772.474	1875.261	2159.233	1056.7073	1151.626
390	-76.8566	-55.8396	2372.574	928.2723	2482.105	1982.578	1764.111	1854.355	2145.993	1037.6016	1148.984

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
391	-72.2386	-61.6976	2328.692	927.3997	2458.947	1949.129	1758.885	1848.780	2094.077	1014.2276	1141.667
392	-67.1751	-67.1751	2271.308	936.4747	2442.105	1952.265	1781.882	1842.160	2026.481	996.5447	1122.764
393	-61.6976	-72.2385	2262.869	936.8237	2474.737	1962.369	1789.199	1824.739	2086.411	998.5772	1124.797
394	-55.8396	-76.8566	2260.759	934.3805	2502.105	1960.976	1827.178	1801.742	2140.767	1006.7073	1133.740
395	-49.6374	-81.0008	2266.245	947.2949	2482.632	1928.920	1840.070	1800.000	2145.296	1013.0081	1142.480
396	-43.1291	-84.6456	2265.823	970.6806	2443.684	1912.892	1856.098	1803.136	2083.972	1008.1301	1135.366
397	-36.3549	-87.7685	2258.650	978.8831	2425.789	1960.627	1870.035	1817.422	2035.540	1003.2520	1124.797
398	-29.3566	-90.3504	2251.899	991.6230	2427.895	1992.683	1871.429	1834.843	2077.700	1021.1382	1127.846
399	-22.1773	-92.3751	2285.232	984.9913	2505.263	1980.139	1881.882	1831.707	2124.739	1039.2276	1117.480
400	-14.8613	-93.8304	2292.405	992.8447	2570.000	1955.052	1882.927	1807.666	2113.240	1037.1951	1117.276
401	-7.4536	-94.7071	2294.093	995.8115	2610.526	1943.206	1834.495	1812.544	2040.070	1018.0894	1113.211
402	0.0000	-95.0000	2206.751	960.2094	2588.421	1918.815	1780.836	1765.157	1921.254	972.3577	1073.984
403	7.4536	-94.7071	2307.595	1008.5515	2611.053	2072.822	1849.826	1851.916	2051.568	1013.2114	1141.667
404	14.8613	-93.8304	2335.443	997.7312	2576.842	2107.666	1852.613	1874.216	2101.394	1043.2927	1174.797
405	22.1773	-92.3751	2332.911	994.0663	2488.947	2080.836	1811.150	1848.780	2096.864	1047.7642	1181.504
406	29.3566	-90.3504	2323.207	991.7976	2494.211	2071.777	1791.638	1863.415	2052.613	1033.7398	1174.593
407	36.3549	-87.7686	2303.797	987.4346	2491.053	2123.345	1806.969	1879.094	1989.199	1027.6423	1147.561
408	43.1291	-84.6456	2296.624	971.3787	2461.579	2142.160	1819.861	1887.108	2034.843	1028.2520	1124.593
409	49.6373	-81.0008	2308.017	955.8464	2428.947	2123.345	1834.495	1875.610	2095.470	1032.1138	1105.081
410	55.8396	-76.8566	2308.017	951.6579	2437.895	2053.659	1824.390	1855.052	2089.199	1027.6423	1092.886
411	61.6976	-72.2386	2305.485	954.6248	2468.421	2010.453	1809.408	1839.721	1998.606	1026.0163	1086.585
412	67.1751	-67.1752	2273.840	954.7993	2482.105	2045.296	1816.725	1854.704	1931.359	1022.1545	1087.805
413	72.2386	-61.6976	2258.228	950.6108	2532.105	2051.568	1841.812	1841.812	1981.882	1029.0650	1099.390
414	76.8566	-55.8396	2250.633	949.2147	2538.421	2033.798	1822.300	1812.195	2035.889	1035.3659	1111.585
415	81.0008	-49.6374	2256.540	946.9459	2567.368	1972.474	1818.815	1799.652	2019.861	1038.0081	1110.366
416	84.6456	-43.1291	2257.384	958.8133	2604.211	1938.676	1797.909	1794.774	1964.460	1046.5447	1105.691
417	87.7686	-36.3549	2229.114	970.8551	2649.474	1982.927	1806.969	1819.512	1934.146	1045.5285	1107.520
418	90.3504	-29.3566	2240.506	965.9686	2667.368	2014.634	1824.390	1839.024	2004.530	1048.7805	1119.715
419	92.3751	-22.1773	2234.177	955.8464	2713.158	1996.516	1825.784	1828.223	2109.756	1063.4146	1130.081
420	93.8304	-14.8613	2244.304	956.0209	2725.789	1991.986	1833.798	1820.557	2146.690	1069.1057	1153.049

Table A.2: Experimental Data (Removal Rates) for all the Wafers

Site #	x-coordinate	y-coordinate	Removal Rate (Angtroms per Minute)								
			Wafer #14	Wafer #15	Wafer #16	Wafer #17	Wafer #18	Wafer #19	Wafer #20	Wafer #21	Wafer #22
421	94.7071	-7.4536	2295.781	966.1431	2758.947	1989.547	1829.965	1830.662	2094.425	1065.2439	1150.000
422	95.0000	0.0000	2336.709	971.5532	2813.684	2044.948	1873.171	1881.533	2026.132	1060.1626	1145.528
423	94.7071	7.4536	2356.962	970.8551	2824.737	2058.188	1891.289	1900.348	2049.477	1051.2195	1143.089
424	93.8304	14.8613	2332.489	967.1902	2807.895	2021.254	1904.181	1871.429	2064.808	1056.0976	1130.894
425	92.3751	22.1773	2349.367	974.5201	2814.211	1978.397	1892.334	1836.585	2051.568	1062.8049	1129.878
426	90.3504	29.3566	2344.304	1001.2216	2785.263	1951.220	1855.401	1816.376	2006.969	1046.9512	1115.650
427	87.7686	36.3549	2334.599	1016.2304	2748.421	2000.000	1847.038	1824.739	1948.432	1045.1220	1127.033
428	84.6456	43.1291	2323.629	1006.8063	2710.000	2042.509	1826.132	1816.376	2028.571	1045.3252	1143.902
429	81.0008	49.6374	2310.127	1005.5846	2702.105	2041.115	1812.544	1790.941	2102.787	1044.7154	1154.268
430	76.8566	55.8396	2280.169	996.1606	2681.579	2031.010	1823.345	1791.986	2127.875	1041.8699	1152.033
431	72.2386	61.6976	2283.122	982.5480	2657.895	2015.679	1813.240	1833.101	2093.031	1031.0976	1138.821
432	67.1751	67.1751	2269.620	981.3264	2651.053	2068.293	1844.251	1874.564	2055.401	1012.1951	1125.000
433	61.6976	72.2386	2267.932	972.7749	2623.684	2124.739	1855.401	1908.014	2101.045	1013.4146	1131.301
434	55.8396	76.8566	2261.181	979.0576	2636.316	2135.192	1854.007	1897.561	2200.697	1019.9187	1132.927
435	49.6374	81.0008	2318.565	975.7417	2644.737	2114.634	1885.366	1855.401	2215.679	1019.1057	1127.033
436	43.1291	84.6456	2355.696	986.9110	2615.263	2077.003	1897.909	1833.449	2157.491	1011.5854	1128.862
437	36.3550	87.7685	2377.215	993.0192	2608.421	2093.728	1927.526	1837.282	2089.547	1009.5528	1129.675
438	29.3566	90.3504	2409.283	1006.6318	2585.789	2105.226	1952.265	1868.990	2125.784	1023.9837	1131.707
439	22.1773	92.3751	2413.924	1002.9668	2566.842	2082.230	1968.293	1886.411	2179.443	1044.9187	1141.260
440	14.8613	93.8304	2431.646	1011.3438	2545.263	2057.491	1963.763	1880.139	2167.247	1050.4065	1150.610
441	7.4536	94.7071	2465.401	1035.4276	2556.316	2068.990	1948.780	1903.833	2114.634	1053.0488	1165.650

Planarization Length Data

The data below is a tabulation of the planarization lengths from the different process conditions in Chapter 3.

Table B.1: Planarization Lengths on Different Dies Per Wafer for M/M Process Condition

Die number	Die Position		Planarization Length (Using Matlab CMP Toolbox) /µm		
	x- coordinate	y- coordinate	Wafer		
			335-1	335-2	335-3
1	0	0	7450	7200	7500
2	12	12	7500	6900	7450
3	-12	12	7350	7100	7350
4	-12	-12	7200	7050	7200
5	12	-12	7350	7050	7350
6	48	0	7300	6800	7350
7	0	48	7350	6950	7300
8	-48	0	7450	7100	7350
9	0	-48	7350	7200	7500
10	84	0	6900	6500	6700
11	60	48	7500	6300	7050
12	0	84	5350	5300	4900
13	-60	48	7450	6950	7200
14	-84	0	7100	7450	7350
15	-60	-48	7350	7350	7450
16	0	-84	7700	7450	7600
17	60	-48	7350	7450	7450

Table B.2: Planarization Lengths on Different Dies Per Wafer for L/L Process Condition

Die number	Die Position		Planarization Length (Using Matlab CMP Toolbox)/µm		
	x- coordinate	y- coordinate	Wafer		
			335-4	335-5	335-6
1	0	0	6900	7050	6950
2	12	12	6700	6800	6700
3	-12	12	6700	6800	6900
4	-12	-12	6550	6800	6700
5	12	-12	6700	6900	6900
6	48	0	6500	6500	6500
7	0	48	6550	6800	6500
8	-48	0	6900	6700	6800
9	0	-48	6900	6800	6900
10	84	0	5850	5500	5450
11	60	48	6400	6300	6400
12	0	84	4950	5350	5350
13	-60	48	6400	6400	6500
14	-84	0	6900	6700	6950
15	-60	-48	6700	6550	6900
16	0	-84	7450	7200	7350
17	60	-48	6800	6550	6900

Table B.3: Planarization Lengths on Different Dies Per Wafer for H/H Process Condition

Die number	Die Position		Planarization Length (Using Matlab CMP Toolbox)/μm		
			Wafer		
	x- coordinate	y- coordinate	335-7	335-8	335-9
1	0	0	8000	8100	8000
2	12	12	7600	7600	7850
3	-12	12	7850	7750	7900
4	-12	-12	7850	7900	7750
5	12	-12	8000	8000	7850
6	48	0	7500	7600	7600
7	0	48	7700	7850	7600
8	-48	0	7600	8100	7750
9	0	-48	7700	7700	8100
10	84	0	6550	6950	6700
11	60	48	7200	7450	7350
12	0	84	4950	5350	5300
13	-60	48	7600	7600	7600
14	-84	0	7750	7900	8500
15	-60	-48	7600	7900	7750
16	0	-84	7600	8000	n/a
17	60	-48	7850	7600	7600

Table B.4: Planarization Lengths on Different Dies Per Wafer for H/L Process Condition

Die number	Die Position		Planarization Length (Using Matlab CMP Toolbox)/µm		
	x- coordinate	y- coordinate	Wafer		
			335-10	335-11	335-12
1	0	0	8650	8650	8300
2	12	12	7900	8250	8100
3	-12	12	8300	8300	8100
4	-12	-12	8300	8300	8150
5	12	-12	8300	8400	7900
6	48	0	7900	7900	7900
7	0	48	8100	8000	7900
8	-48	0	8250	8000	8150
9	0	-48	8100	8650	8000
10	84	0	7300	6950	7050
11	60	48	7850	7700	7900
12	0	84	6400	6800	5350
13	-60	48	8000	7700	7750
14	-84	0	7900	8150	8000
15	-60	-48	7100	7600	7700
16	0	-84	7900	7750	7350
17	60	-48	7900	7500	7850

Table B.5: Planarization Lengths on Different Dies Per Wafer for L/H Process Condition

Die number	Die Position		Planarization Length (Using Matlab CMP Toolbox)/μm		
	x- coordinate	y- coordinate	Wafer		
			335-13	335-14	335-15
1	0	0	6400	6400	6550
2	12	12	6250	6150	6500
3	-12	12	6250	5900	6400
4	-12	-12	5850	5900	6150
5	12	-12	6300	5900	6400
6	48	0	6300	6250	6400
7	0	48	6300	5900	6150
8	-48	0	5900	6400	6400
9	0	-48	6300	6400	6400
10	84	0	5500	5450	5700
11	60	48	6250	5500	6400
12	0	84	4900	4900	4900
13	-60	48	5900	5900	6300
14	-84	0	6400	6700	6550
15	-60	-48	5900	6400	6400
16	0	-84	6800	6950	6800
17	60	-48	6400	6400	6800