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Abstract
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Keywords
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Influence of flow rate, nozzle speed, pitch and the number of passes on the thickness of S1805 photoresist in SUSS MicroTec AS8 spray coater

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S1805 positive photoresist has been deposited on single crystalline Si wafers using a Suss MicroTec Alta Spray. The influence of flow rate, nozzle speed, pitch and number of passes on the thickness of the photoresist was studied. Results show that the thickness of S1805 is linearly proportional to the flow rate and number of passes, and inversely proportional to the nozzle speed and pitch.

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I. Introduction

Photoresists are light sensitive materials commonly used in lithography process to create desired patterns on substrates at nanoscale and microscale. It is important for a substrate to have a uniform coating of photoresist to obtain the desired features since the non-uniform coating leads to variation in diffraction which eventually causes inaccurate feature sizes after the exposure and development processes in lithography. Conventionally, the spin coating process has been widely used to deposit photoresist on a flat substrate. This inexpensive and straightforward process includes dispensing the photoresist onto the center of a substrate and spinning the substrate at high speed to achieve the uniform coating by centrifugal force. However, spin coating often presents several challenges in applications particularly that have non-planar surfaces such as microelectromechanical systems (MEMS), trenches, and concave and convex structures. It is difficult to obtain uniformity and conformality on substrates with deep features by spin coating.[1,2]

Spray coating is a complementary technique to spin coating. The spray coater usually uses photoresists diluted with certain solvent. The diluted photoresist sprayed by nitrogen gas at the end of nozzle turns to many small size snowball-like diluted photoresist droplets. While these droplets are flying, most of solvent evaporates. The condensed photoresist droplets stick not only on the top substrate but also on the sidewalls.

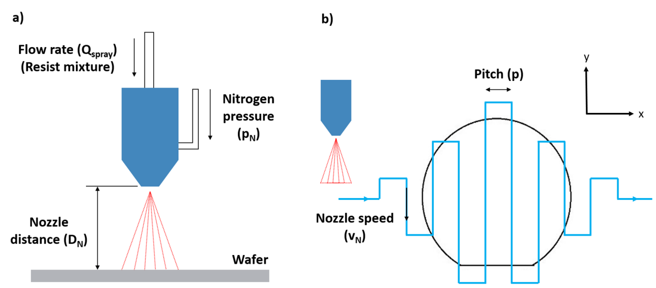

FIG. 1. (a) Front view of the nozzle coating the photoresist on the wafer. The mixture of photoresist and solvent is dispensed with a volume flow rate of Q_{spray} and a fixed distance D_N between nozzle and a wafer. (b) Top view of the wafer showing the meander movement of the nozzle. V_S in the speed of the nozzle and pitch is the distance between consecutive vertical strokes for making meander

FIG. 2. SUSS MicroTec AS8 spray coater[3,4]

The spray coating provides many advantages over spin coating. First, the spray coating gives very good uniformity of photoresist. In the case of spin coating, photore-

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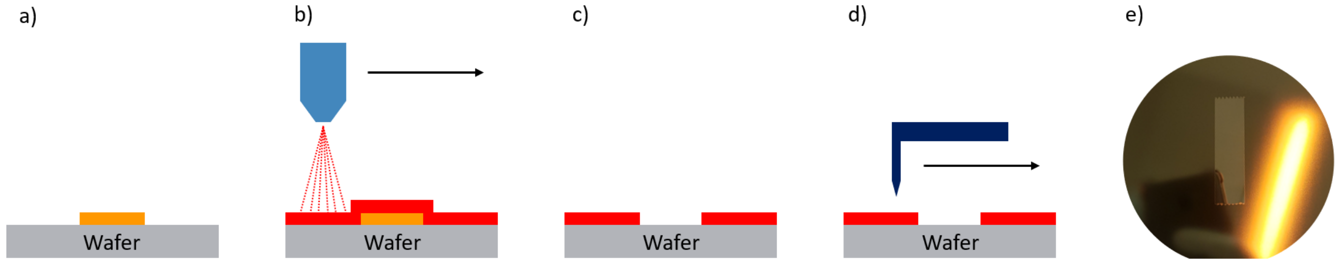

FIG. 3. (a) Blank Si Wafer covered with Kapton film in center, (b) Spray coat S1805 positive photoresist, (c) Kapton film peeled off, (d) Photoresist coating step height measured using stylus profilometer and (e) Deposited S1805 layer

sists with lower viscosity which is used for thick coating are often not uniform even on the flat surface. To to contrary, spray coating uses diluted photoresist to make a unit thickness, and the final thickness of photoresist can be simply increased by adding the number of spray passes. Second, the spray coating enables conformal coating of substrate. As described above, droplets can stick to sidewall of substrates. Third, this technique shows lower probability of edge beads. Forth, the resist consumption can be reduced.

There are parameters that affect the behavior of spray coating as shown in Fig. 1 (a) and (b); photoresist dilution, temperature of chunk, nitrogen pressure (P_N), working distance between nozzle and sample (D_N), flow rate of photoresist (Q_{spray}), speed of nozzle (V_N), pitch (P) and the number of passes. Fig. 1 (b) shows how the spray nozzle actuates. The nozzle moves along a meander path to cover entire substrate. Once one meander completed, so-called 'pass', chuck rotates 90 degree and another pass starts. One cycle typically consists of 4 passes.

In this study, we study the influence of flow rate, speed of nozzle, pitch and number of passes on the thickness of photoresist using the SUSS MicroTec AS8 spray coater (Fig.2). This is to provide guidelines for optimal recipe to obtain desired photoresist thickness.

II. Experiment

The process flow for fabrication and characterization of the photoresist is illustrated in Fig. 3. A bottle of S1805 photoresist was diluted with acetone, where the volume ratio of S1805 to acetone was 1:8. A Kapton film was adhered to the center of bare silicon wafer. The wafer was then placed on the chuck in the spray coater chamber. The temperature of chuck was fixed at 60°C. The spray coating was performed with a nitrogen pressure of 20 ± 2.5 l/min and the working distance between nozzle and sample surface was 12mm. After spraying, the wafer was baked at 90°C for 2 minutes. The Kapton film was removed to measure the thickness of photoresist using profilometer (KLA Tencor P7 profilometer) with an applied force of 1 mg, scan speed of 50 μm/s and sampling rate of 200 Hz. The mean and standard deviation of thickness were calculated with 4 measurement data.

Four parameters, flow rate of photoresist, nozzle speed, pitch and number of passes were varied. The influence of each parameter on the thickness of photoresist was analysed by conducting a parametric study wherein the individual parameter was varied while keeping the other three parameters constant. An exhaustive set of recipes used in this experiment is provided in Table I. The averages of the set of results for each parameter are plotted in Fig. 4 - 7.

III. Results and Discussion

A. Flow rate

The flow rate was increased from 0.5 ml/min to 2 ml/min with the increment of 0.5 ml/min while the nozzle speed, pitch and number of passes were kept constant at 90 mm/s, 4 mm and 4, respectively. Fig. 4 shows the relationship between thickness of S1805 photoresist and flow rate. The amount of photoresist deposited on the wafer directly depends on volume flow rate of the mixture.

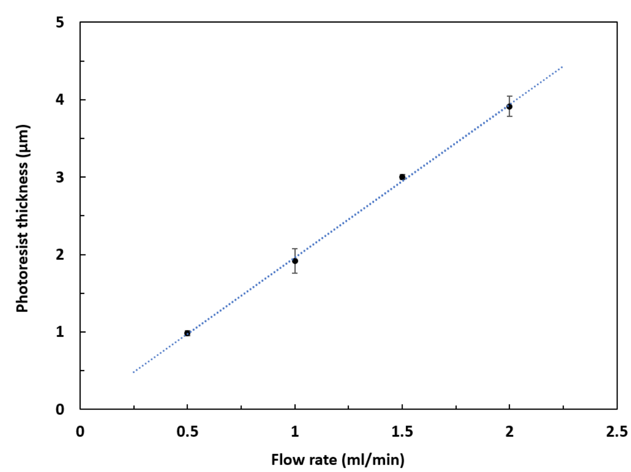

FIG. 4. S1805 photoresist coating thickness μm versus nozzle flow rate (ml/min). The data has a linear fit with $R^2 = .9989$

TABLE I. Difference in thickness between sides of wafer facing inside the rotating platform and outside of the platform

Flow rate (ml/min)	Nozzle speed (mm/s)	Pitch (mm)	Cycles (Passes/4)	Average coat thickness (μm)
0.5	90	4	1	0.98
1	90	4	1	1.92
1.5	90	4	1	3.00
2	90	4	1	3.91
2	60	4	1	6.17
2	120	4	1	3.02
2	150	4	1	2.37
2	180	4	1	1.96
2	90	5	1	3.06
2	90	6	1	2.54
2	90	7	1	2.33
2	90	4	2	8.00
2	90	4	3	12.88
2	90	4	4	16.04

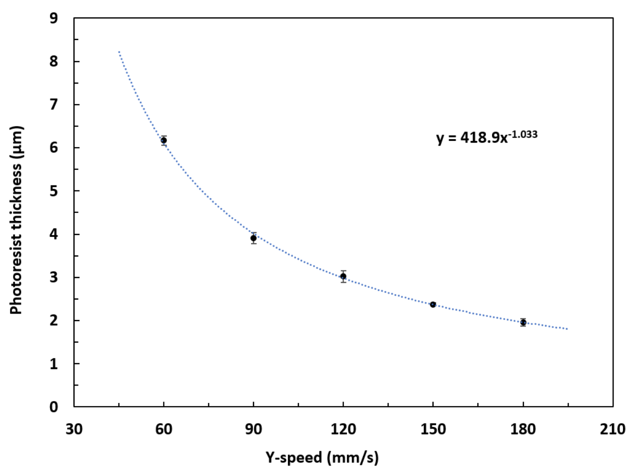

FIG. 5. S1805 photoresist coating thickness μm versus nozzle speed in y-direction

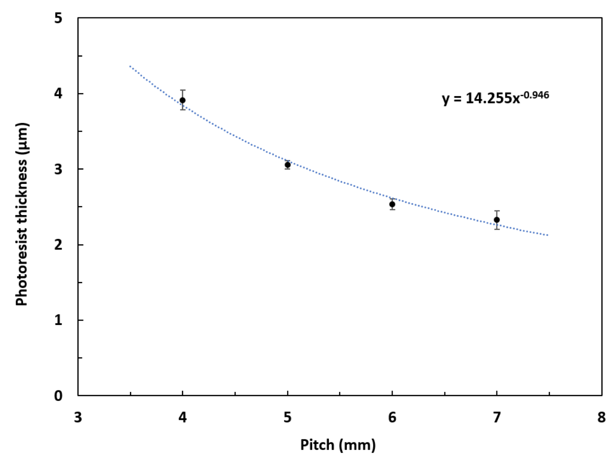

FIG. 6. S1805 photoresist coating thickness μm versus nozzle pitch

B. Nozzle speed (y-axis)

Fig. 5 shows the thickness - nozzle speed curve. Whereas the nozzle speed in y-direction varied from 60 mm/s to 180 mm/s, the flow rate, pitch and number of passes were kept constant at 2 ml/min, 4mm and 4, respectively.The results show the thickness is inversely proportional to the speed of nozzle. This is because the speed of nozzle is inversely related with the time of sprays on the wafer.

C. Pitch

The pitch was varied from 4 mm to 7 mm, where the flow rate, nozzle speed and number of passes kept at 2 ml/min, 90 mm/sec and 4, respectively. The relationship between thickness and pitch is shown in Fig. 6. The thickness was inversely proportional to the pitch. As previously described in Fig. 1 (b), pitch is the distance between the two consecutive y-direction strokes of the nozzle. Thus, a larger pitch would correspond to lesser number of strokes over the wafer area. This in turn results in a thinner coat.

D. Number of passes

A single cycle consists of four passes over the wafer. The wafer on the chuck turns by 90 degrees when every pass is completed for uniform coating in all directions. Fig. 7 shows the resist thickness after one, two, three and four cycles which correspond to 4, 8, 12 and 16 passes. The flow rate, nozzle speed and pitch were maintained at 2 ml/min, 90 mm/sec and 4mm. The thickness followed a linear trend with the number of passes as expected.

E. Photoresist coating thickness

The thickness of photoresist (t) was derived with the selected parameters - flow rate of photoresist (Q ml/min), nozzle speed (v mm/s), pitch (p mm) and number of passes (n) can be calculated by the equation -

$$\mathrm{t}\ (\mu m) = 180\,\frac{\mathrm{n\,Q}}{\mathrm{v\,p}} \tag{1}$$

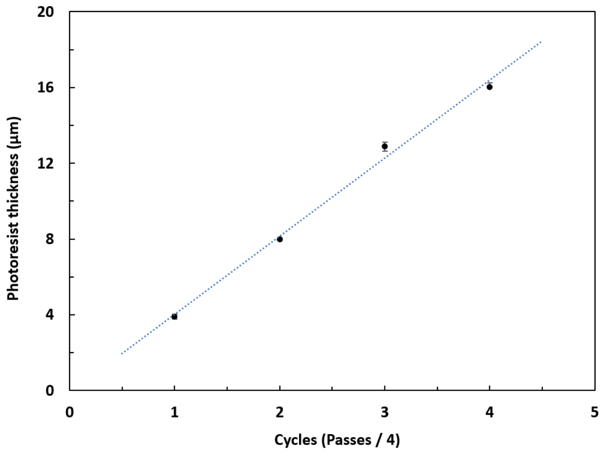

FIG. 7. S1805 photoresist coating thickness μm versus number of passes. The data has a linear fit with $R^2 = .9937$

It must be noted that the value of the constant in Eqn. 1 is valid for chuck temperature of 60°C, nitrogen pressure of 20 ± 2.5 l/min and working distance of 12 mm. This value may vary with a change in these parameters.

IV. Summary

The S1805 photoresist was coated using Suss MicroTec AS8 spray coater. The thickness of S1805 photoresist increased linearly with the nozzle flow rate and the number of passes, whereas inversely proportional to the nozzle speed and pitch. A summary of the results is listed in Table I. These results will provide guidelines for selecting the optimal recipe to obtain desired resist thickness.

V. Acknowledgements

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