Throughput Increase by Adjustment of the BARC Drying Time with Coat Track Process

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ABSTRACT

Throughput of a coater module within the coater track is related to the solvent evaporation rate from the material that is being coated. Evaporation rate is controlled by the spin dynamics of the wafer and airflow dynamics over the wafer. Balancing these effects is the key to achieving very uniform coatings across a flat unpatterned wafer. As today's coat tracks are being pushed to higher throughputs to match the scanner, the coat module throughput must be increased as well.

For chemical manufacturers the evaporation rate of the material depends on the solvent used. One measure of relative evaporation rates is to compare flash points of a solvent. The lower the flash point, the quicker the solvent will evaporate. It is possible to formulate products with these volatile solvents although at a price. Shipping and manufacturing a more flammable product increase chances of fire, thereby increasing insurance premiums. Also, the end user of these chemicals will have to take extra precautions in the fab and in storage of these more flammable chemicals.

An alternative coat process is possible which would allow higher throughput in a distinct coat module without sacrificing safety. A tradeoff is required for this process, that being a more complicated coat process and a higher viscosity chemical. The coat process uses the fact that evaporation rate depends on the spin dynamics of the wafer by utilizing a series of spin speeds that first would set the thickness of the material followed by a high spin speed to remove the residual solvent. This new process can yield a throughput of over 150 wafers per hour (wph) given two coat modules. The thickness uniformity of less than 2 nm (3 sigma) is still excellent, while drying times are shorter than 10 seconds to achieve the 150 wph throughput targets.

Keywords: ArF, KrF, drying time, throughput, bottom anti-reflective coating, BARC, coating, photolithography.

1.0 INTRODUCTION

The cost of ownership for various wafer fab tools is critical to the profitability of today's wafer fabs. One avenue to decreasing the cost of ownership is to increase the throughput of the tool. In coat tracks this is accomplished several ways: by increasing the speed of the robot wafer handling system, by using more specific modules such as hotplates, or by increasing the throughput of specific modules.

An example of the last method is described here. Specifically, throughput of a coater module within the coater track is related to the solvent evaporation rate from the material that is being coated. Evaporation rate is controlled by the spin dynamics of the wafer and airflow dynamics over the wafer. Balancing these effects is the key to achieving very uniform coatings across a flat unpatterned wafer. As today's coat tracks are being pushed to higher throughputs to match the scanner, the coat module throughput must be increased as well.

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2.0 EXPERIMENTAL

A current production BARC, DUV52D, was chosen because of the different target thicknesses that were commercially available. The target thicknesses are 60, 80, and 140 nm at 1100 rpm. A diagram of a typical process tested herein is shown in Figure 1. The example process splits the cast spin into two parts, the spread spin and the cast spin. The design of experiments (DOE) was targeted for 300-mm wafer spin speeds and 200-mm wafer spin speeds.

The other factor that the DOE incorporated is the spread spin time. Responses that were reported back for analysis are thickness, uniformity, and drying time of the BARC. Drying time for this testing was defined the moment that the interference fringes that occur when a liquid is dispensed on a spinning wafer stopped.

Simulations were also run of the drying time required of a BARC to hit a target throughput. This target drying time was then compared to the results from the DOE to find the correct spin process to achieve a target thickness and drying time. The throughput calculations used are typical in the industry for various parts of the process and were timed on a TEL Mk8 track, The ranges are shown in Table 1.

3.0 RESULTS AND DISCUSSION

3.1 Throughput Calculations

The throughput calculations were used to target a particular drying time for the BARCs to achieve a certain throughput assuming two coat modules are being used and that the BARC coating modules were the limiting factor of the throughput for the entire coat/expose/develop process. The calculation is shown in Equation 1.

$$Throughput\,(WPH) = \frac{3600 * Number\ of\ Coat\ Modules}{Prewet\ Time + BARC\ Dispense\ Time + EBR/BSR\ Time + Robot\ Handling Time + BARC\ Dry\ Time} \qquad (1)$$

The results of the calculations with varying BARC drying times and using two or three coat modules are shown in Figure 2. Assuming a wafer throughput of today's scanners of 150 wph, it can be seen that the BARC drying time must be less than 20 seconds, preferably under 10 seconds, to allow for differences in other coating steps such as the prewet and EBR.

3.2 BARC Testing

First, spin speed curves for three different percent solids formulations were run to determine drying times, and the resulting data is shown in Figure 3a and b. A target of 70 nm was used to find the drying times for each solids formulation. Obviously, the drying rates of the solvents depends on the spin speed of the wafer. As the spin speed increases, the drying time decreases. For a 70-nm target with DUV52D, the time can be as short as 5 seconds, well below the 10– to 15-second target. For 200-mm wafer processing, throughput requirements are then not a problem because if an increase in throughput is needed, then the only changes needed to achieve that throughput is using a higher percent solids formulation and increasing the spin speed.

Assuming 300-mm wafer processing and its spin speed limitations, a problem does occur. With typical spin speeds of 1000 to 2500 rpm, the drying time can be anywhere from 8 to 20 seconds. Another problem also begins to show up at these speeds. Examining Figure 3b shows that drying times begin to split for the different percent solid formulations. Here, the higher the percent solids formulation (thicker film at a given spin speed), the slower the material dries on the wafer. This indicates that the polymer has an affinity to the solvent. From this it can be assumed that different solvents will dry differently from each other given the same polymer chemistry, or different polymer chemistries may dictate the drying rate of the solvent.

Further testing involved splitting the spin process after dispense into two parts: a spread step followed by the cast step. This process is commonly done today to achieve better coating uniformity. Here it will be used to achieve a better drying time. Figure 4a and b shows the drying time results of the DOE for a given spread time. These two graphs show that 10-second drying times are possible with proper optimization of the spin speeds. The data show that as the spread time decreases, the cast time or the cast speed must increase to increase the drying rate of the BARC to compensate for the higher amount of solvent left in the film as cast step begins.

The drawback to this process is that the expected thickness will be lower than the standard spin speed curve as shown in Figure 5a and b. However, the viscosity of the formulation can be easily changed by changing the amount of solvent that is placed in the formulation. This adjustment will counteract the thinning of the BARC during the process and yield the proper thickness needed for a specific application.

To check the thickness calculated from the DOE model, confirmation runs were carried out on two different viscosities of DUV52D. The process was set up so that the drying time could be found as well. The process was set using a spread speed and time of 2150 rpm for 2 seconds followed by a cast speed of 2750 rpm until dry. The drying time is the total time that the material took to dry. The cast time could then be found by subtracting the spread time from the drying time. The results are summarized in Table 2. From the results it can be seen that the DOE predicted the drying time and the thickness very well. The user can then use the DOE model to find the best drying time for the throughput requirements and to predict the viscosity needed to achieve the particular thickness needed. The thickness uniformity is considered excellent with 3 sigma standard deviation numbers of less than 2 nm. At the same time the target throughput of 150 wph can be achieved with an 8-second drying time.

4.0 CONCLUSIONS

As throughput requirements continue to increase, drying times of spin coated materials become an issue. To combat this, coater track manufacturers add coater modules into the coater tracks, which increase complexity and cost. Other solutions do exist such as solvent changes, which may not work for existing legacy products. The least problematic solution that gives the chip manufacturer the most flexibility is to change the spin process itself. By incorporating a modified spread and cast step into the process, drying times can be reduced so that higher throughputs can be achieved with fewer coat modules. The thickness uniformity of less than 2 nm (3 sigma) is still excellent, while drying time are shorter than 10 seconds, which will allow the throughput targets of 150 wph to be met. The main disadvantage is that the BARC is thinner than that for a normal single step spin. Adjusting the percent solids or viscosity of the BARC solves this problem. This new two-step spin process would allow legacy products to retain the same formulation, thus minimizing expensive requalification procedures. If a new BARC is being tested in an R&D project or in early pilot processes, the percent solids or viscosity can be adjusted by sending a new bottle of material, thus minimizing retesting of many process parameters such as photolithography windows, etch rates, etc.

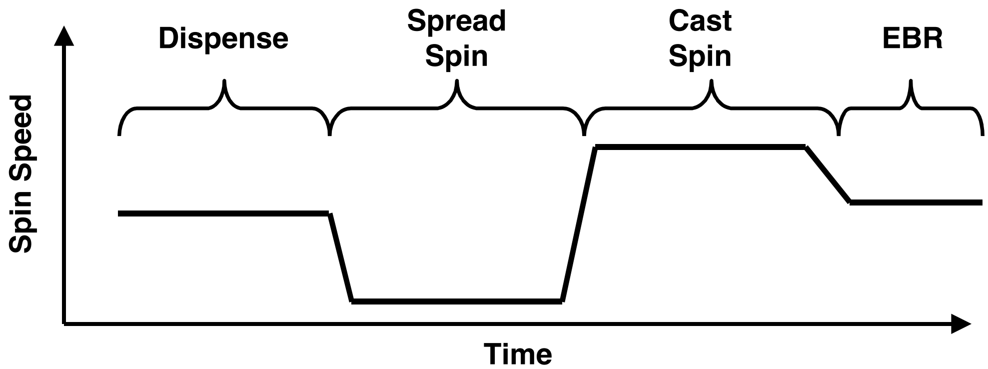


Figure 1. Schematic of the new spin process.

Process Step	Time
Prewet (Dispense and Spin)	3 – 5 sec
BARC Dispense	2 - 4 sec
EBR/BSR (Dispense and Spin Off)	13- 20 sec
Robot Handling (In and Out of Module)	6 – 10 sec

Table 1. Times used in the calculation of coater throughput.

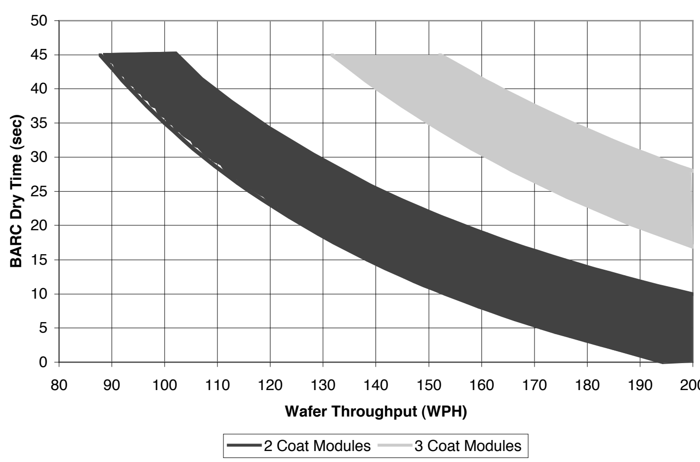
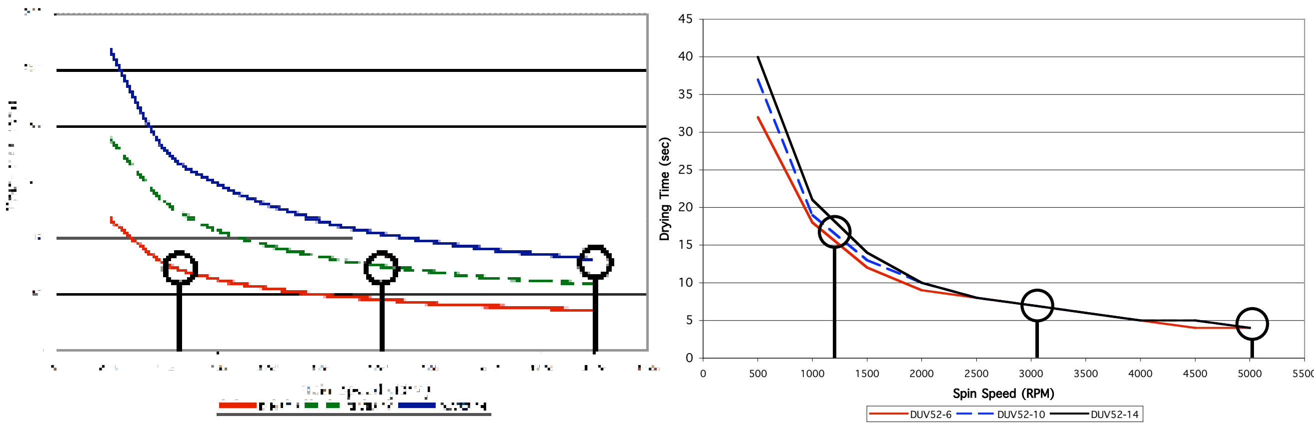
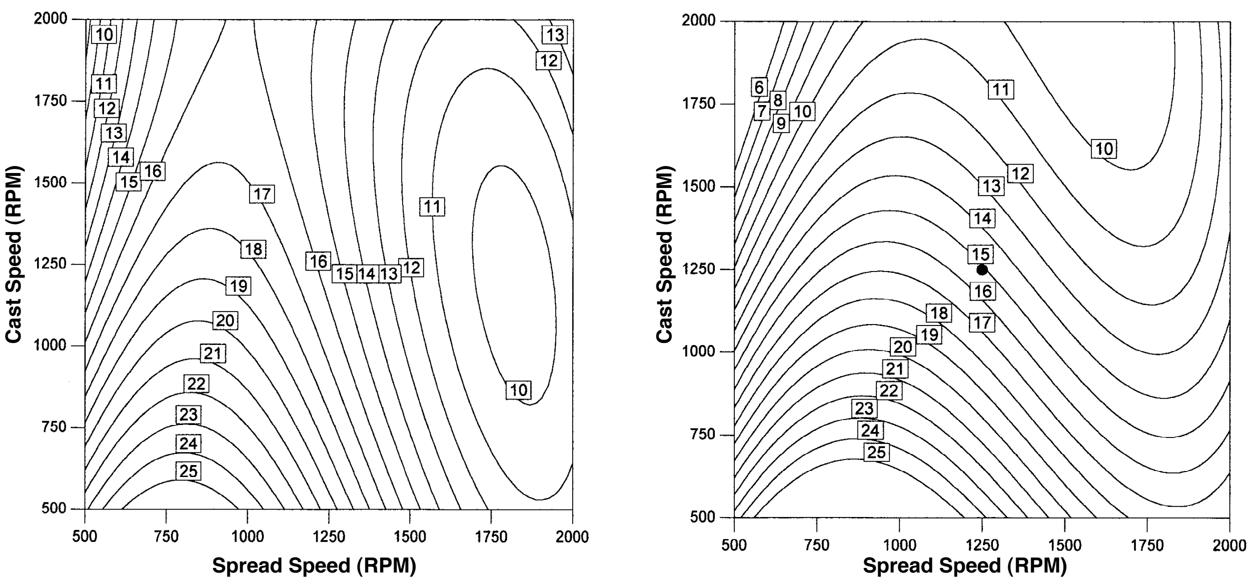


Figure 2. Throughput calculation results.



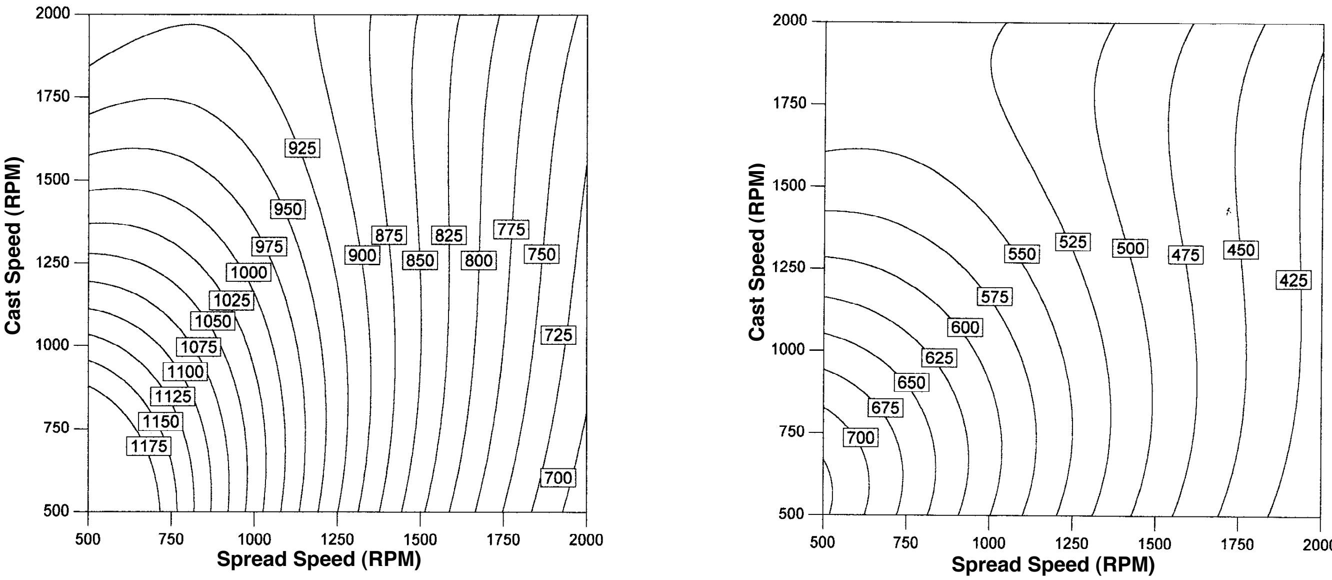
(a) (b)

Figure 3. Spin speed curves (a) and drying times (b) for different percent solids formulation of DUV52D. Circles indicate drying times for 70-nm target found in spin speed curves.



(a) (b)

Figure 4. DOE modeled graphs of (a) 8-second spread time and (b) 3-second spread time.



(a) (b)

Figure 5. DOE Modeled graphs of thickness for (a) DUV52D-10 and (b) DUV52D-6.

BARC	Process 2150rpm / 2 sec 2750rpm / **sec		
	Thickness (Å)	**Uniformity (Å 3sigma)**	**Dry Time (sec)**
DUV52D-6	399	16	8
DUV52D-10	650	4	8
Predicted			
DUV52D-6	378±17		7.1±1.3
DUV52D-10	604±100		6.7±1.4

Table 2. Summary of results for DUV52D-6 and DUV52D-10 compared to the DOE predicted results.