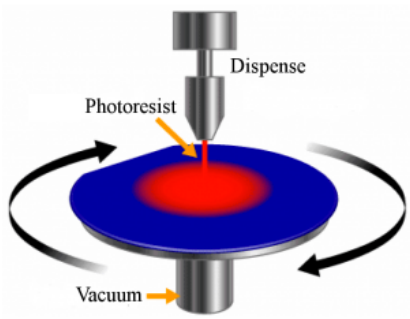
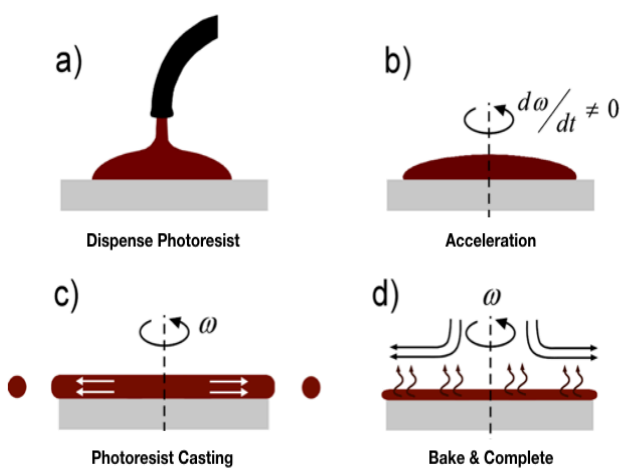
Spin Coating Overview:



Spin coating has been used for decades as a method for applying thin films. A typical process involves depositing a small amount of a photoresist (PR-resin) material onto the center of a substrate and then spinning the substrate at high speed (typically around 3000-5000 rpm). Centripetal force created by acceleration will cause most of the PR-resin to spread to, and eventually off, the edge of the substrate, leaving a thin film of material on the surface. Final film thickness and other properties will depend on the nature of the PR-resin (viscosity, drying rate, percent solids, surface tension, etc.) and the parameters chosen for the spin process. Factors such as final rotation speed, acceleration, and fume exhaust affect the properties of the coated films. One of the most important factors in spin coating is repeatability, as subtle variations in the parameters that define a spin-coating process can result in drastic variations in the coated film.

Spin-Coating Process Description

A typical spin process consists of 1-dispense step in which the PR-resin is deposited onto the substrate surface, 2-accelerationof high speed spin step to thin the PR-resin, 3- Spin and casting of PR-resin, 4- a drying step to eliminate excess solvents from the resulting film. Two common methods of dispense are Static dispense, and Dynamic dispense.

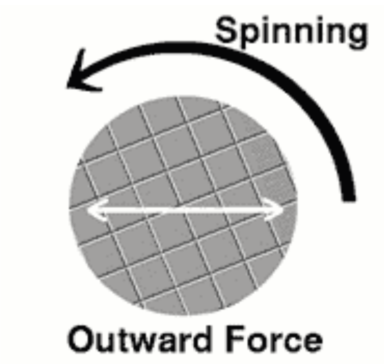


Static dispense is simply depositing a small puddle of PR-resin on or near the center of the substrate. This can range from 1 to 50 cc depending on the viscosity of the PR-resin and the size of the substrate to be coated. Higher viscosity and or larger substrates typically require a larger puddle to ensure full coverage of the substrate during the high-speed spin step. Dynamic dispense is the process of dispensing while the substrate is turning at low speed. A speed of about 50-500 rpm is commonly used during this step of the process. This serves to spread the fluid over the substrate and can result in less waste of PR-resin material since it is usually not necessary to deposit as much to wet the entire surface of the substrate. This is a particularly advantageous method when the fluid or substrate itself has poor wetting abilities and can eliminate voids that may otherwise form.

After the dispense step it is common to accelerate to a relatively high speed to thin the fluid to near its final desired thickness. Typical spin speeds for this step range from 1500-8000 rpm, again depending on the properties of the PR-resin as well as the substrate. This step can take from 10 seconds to several minutes. The combination of spin speed and time selected for this step will generally define the final film thickness.

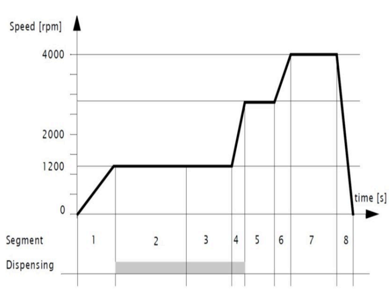
In general, higher spin speeds and longer spin times create thinner films. The spin coating process involves a large number of variables that tend to cancel and average out during the spin process and it is best to allow sufficient time for this to occur. A separate drying step is sometimes added after the high-speed spin step to further dry the film without substantially thinning it. This can be advantageous for thick films since long drying times may be necessary to increase the physical stability of the film before handling. Without the drying step problems can occur during handling, such as pouring off the side of the substrate when removing it from the spin bowl. In this case a moderate spin speed of about 25% of the high-speed spin will generally suffice to aid in drying the film without significantly changing the film thickness. Each program on an IOT Pal Corporation spin coater may contain up to 100 separate process steps. While most spin processes require only two to ten, this allows the maximum amount of flexibility for complex spin coating requirements.

Spin Speed



Spin speed is one of the most important factors in spin coating. The speed of the substrate (rpm) affects the degree of radial (centrifugal) force applied to the PR-resin as well as the velocity and characteristic turbulence of the air immediately above it. In particular, the high-speed spin step generally defines the final film thickness. Relatively minor variations of Â±50 rpm at this stage can cause a resulting thickness change of 10%. Film thickness is largely a balance between the force applied to shear the PR-resin towards the edge of the substrate and the drying rate which affects the viscosity of the PR-resin. As the PR-resin dries, the viscosity increases until the radial force of the spin process can no longer appreciably move the PR-resin over the surface. At this point, the film thickness will not decrease significantly with increased spin time. All Cee® spin coating systems are specified to be repeatable to within Â±5 rpm at all speeds. Typical performance is Â±1 rpm. Also, all programming and display of spin speed is given with a resolution of 1 rpm.

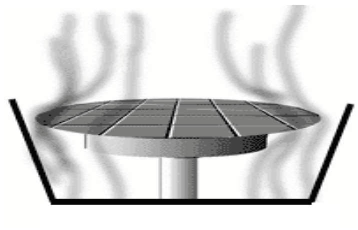
Acceleration



The acceleration of the substrate towards the final spin speed can also affect the coated film properties. Since the PR-resin begins to dry during the first part of the spin cycle, it is important to accurately control acceleration. In some processes, 50% of the solvents in the PR-resin will be lost to evaporation in the first few seconds of the process.

Acceleration also plays a large role in the coat properties of patterned substrates. In many cases the substrate will retain topographical features from previous processes; it is therefore important to uniformly coat the PR-resin over and through these features. While the spin process in general provides a radial (outward) force to the PR-resin, it is the acceleration that provides a twisting force to the PR-resin. This twisting aids in the dispersal of the PR-resin around topography that might otherwise shadow portions of the substrate from the fluid. Acceleration of IOT Pal Corporation spinners is programmable with a resolution of 1 rpm/second. In operation, the spin motor accelerates (or decelerates) in a linear ramp to the final spin speed.

Fume Exhaust



The drying rate of the PR-resin fluid during the spin process is defined by the nature of the PR-resin (volatility of the solvent systems used) as well as by the air surrounding the substrate during the spin process. Just as a damp cloth will dry faster on a breezy dry day than during damp weather, the PR-resin will dry depending on the ambient conditions around it. It is well known that such factors as air temperature and humidity play a large role in determining coated film properties. It is also very important that the airflow and associated turbulence above the substrate itself be minimized, or at least held constant, during the spin process.

IOT Pal Corporation spin coaters close lid design provides not only the safety, but also minimizes the exhaust during the spin process.

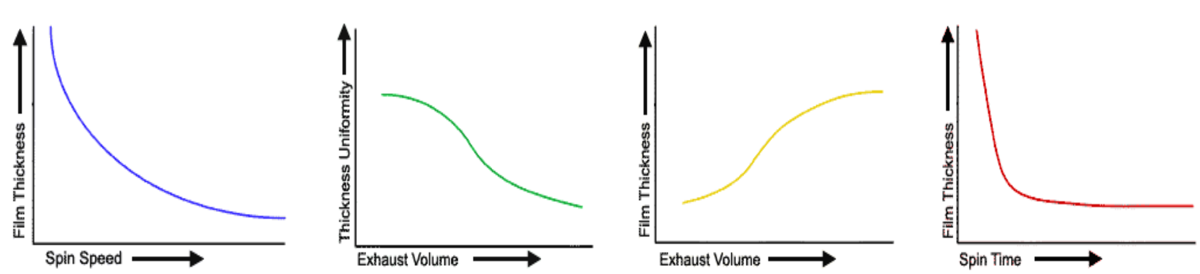
The slower rate of drying offers the advantage of increased film thickness uniformity across the substrates. The fluid dries out as it moves toward the edge of the substrate during the spin process. This can lead to radial thickness non-uniformities since the fluid viscosity changes with distance from the center of the substrate. By slowing the rate of drying, it is possible for the viscosity to remain more constant across the substrate.

Drying rate and hence final film thickness is also affected by ambient humidity. Variations of only a few percent relative humidity can result in large changes in film thickness. By spinning in a closed bowl the vapors of the solvents in the PR-resin itself are retained in the bowl environment and tend to overshadow the affects of minor humidity variations.

Another advantage to our closed lid design is the reduced susceptibility to variations in air flow around the spinning substrate. In a typical clean room, for instance, there is a constant downward flow of air at about 100 feet per minute (30m/min). Various factors affect the local properties of this air flow. Turbulence and eddy currents are common results of this high degree of air flow. Minor changes in the nature of the environment can create drastic alteration in the downward flow of air. By closing the bowl with a smooth lid surface, variations and turbulence caused by the presence of operators and other equipment are eliminated from the spin process.

Process Trend Charts

These charts represent general trends for the various process parameters. For most PR-resin materials the final film thickness will be inversely proportional to the spin speed and spin time. Final thickness will also be somewhat proportional to the exhaust volume although uniformity will suffer if the exhaust flow is too high since turbulence will cause non-uniform drying of the film during the spin process.



Spin-Coating Process Troubleshooting

As explained previously, there are several major factors affecting the coating process. Among these are spin speed, acceleration, spin time and exhaust. Process parameters vary greatly for different PR-resin materials and substrates so there are no fixed rules for spin coat processing, only general guidelines. Following is a list of issues to consider for specific process problems.

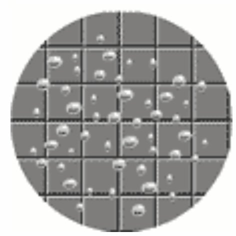
Film too thin

Spin speed too high	Select lower speed
Spin time too long	Decrease time during high speed step
Inappropriate choice of PR-resin material	Contact PR-resin manufacturer

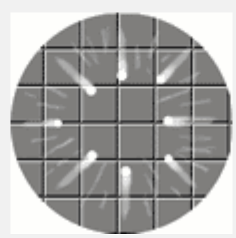
Film too thick

Spin speed too low	Select higher speed
Spin time too short	Increase time during high speed step
Exhaust volume too high	Adjust exhaust lid or house exhaust damper
Inappropriate choice of PR-resin material	Contact PR-resin manufacturer

Air bubbles on wafer surface
Air bubbles in dispensed fluid (PR-resin)
Dispense tip is cut unevenly or has burrs or defects

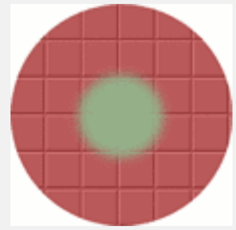


Comets, streaks, or flares
Fluid velocity (dispense rate) is too high
Spin bowl exhaust rate is too high
Resist sits on wafer too long prior to spin
Spin speed and acceleration setting is too high
Particles exist on substrate surface prior to dispense
Fluid is not being dispensed at the center of the substrate surface

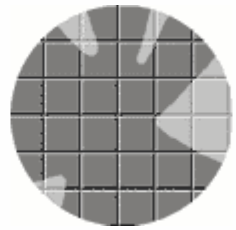


Swirl pattern
Spin bowl exhaust rate is too high
Fluid is striking substrate surface off center
Spin speed and acceleration setting is too high
Spin time too short

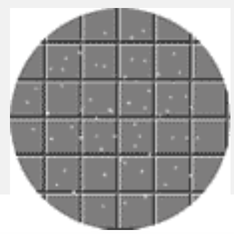
Center circle (chuck mark)
If the circle is the same size as the spin chuck,
switch to a Delrin spin chuck



Uncoated areas
Insufficient dispense volume



Pinholes
Air bubbles
Particles in fluid
Particles exist on substrate surface prior to dispense



Poor reproducibility

Variable exhaust or ambient conditions	Adjust exhaust lid to fully closed
Substrate not centered properly	Center substrate before operation
Insufficient dispense volume	Increase dispense volume
Inappropriate application of PR-resin material	Contact PR-resin manufacturer
Unstable balance in speed / time parameters	Increase speed / decrease time or vice versa

Poor film quality

Exhaust volume too high	Adjust exhaust lid or house exhaust damper
Acceleration too high	Select lower acceleration
Unstable balance in speed / time parameters	Increase speed / decrease time or vice versa
Insufficient dispense volume	Increase dispense volume
Inappropriate application of PR material	Contact PR-resin manufacturer