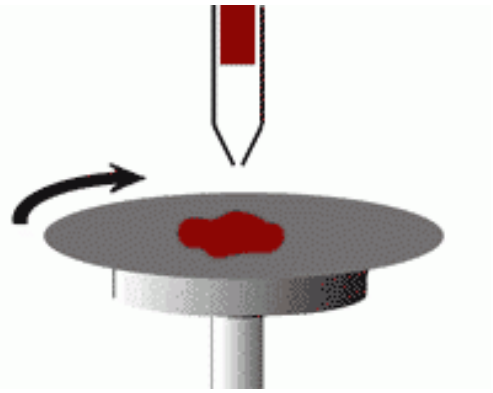
SPIN-COATING OVERVIEW

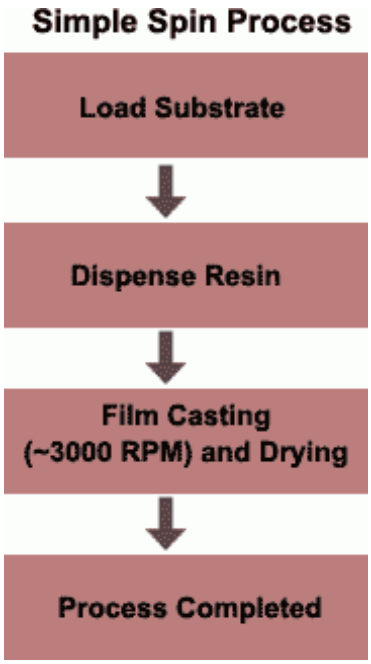
https://www.costeffectiveequipment.com/service-support/technical-resources/spin-coating-theory/

Spin coating has been used for several decades as a method for applying thin films. A typical process involves depositing a small puddle of a fluid material onto the center of a substrate and then spinning the substrate at high speed. Centripetal acceleration will cause the resin to spread across the substrate, leaving a thin film of material. Final film thickness will depend on the fluid material properties (viscosity, drying rate, percent solids, surface tension, etc.) and the spin process parameters (rotation speed, acceleration, and fume exhaust). 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 a dispense step in which the resin fluid is deposited onto the substrate surface, a high speed spin step to thin the fluid, and a drying step to eliminate excess solvents from the resulting film. Two common methods of dispense are Static dispense, and Dynamic dispense.



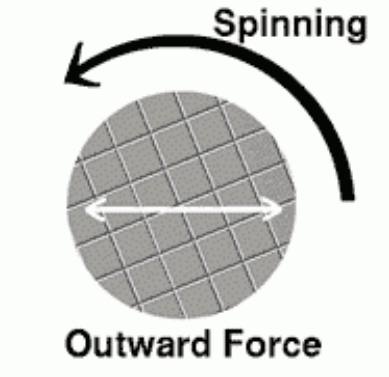
Static dispense is simply depositing a small puddle of fluid on or near the center of the substrate. This can range from 1 to 10 cc depending on the viscosity of the fluid and the size of the substrate to be coated. Higher viscosity and or larger substrates typically require a larger puddle to ensure 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 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 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 1500-6000 rpm, depending on the properties of the fluid 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.

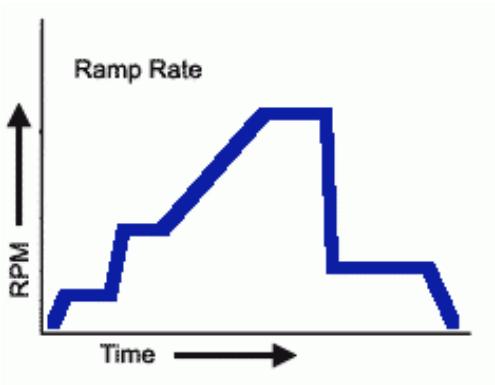
A separate drying step is sometimes added after the high speed spin step to further dry the film without substantially thinning it. This can be advantageous for thick films since long drying times may be necessary to increase the physical stability of the film before handling. Without the drying step problems can occur during handling, such as pouring off the side of the substrate when removing it from the spin bowl. A moderate spin speed will aid in drying the film without significantly changing the film thickness.

SPIN SPEED

Spin speed is one of the most important factors in spin coating. The speed (rpm) affects the degree of centrifugal force applied to the resin and the turbulence of the air immediately above it. Relatively minor speed variations at this stage can result in large thickness changes. Film thickness is largely a balance between the force applied to shear the fluid resin towards the edge of the substrate and the drying rate of the resin. As the resin dries, the viscosity increases until the radial force of the spin process can no longer move the resin over the surface. At this point, the film thickness will not decrease significantly with increased spin time.



ACCELERATION

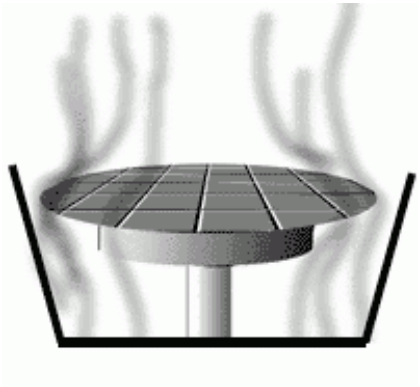


In addition to spin speed, acceleration can also affect the coated film properties. Since the resin begins to dry during the first part of the spin cycle, it is important to accurately control acceleration. In some processes, 50% of the solvents in the resin will be lost to evaporation in the first few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

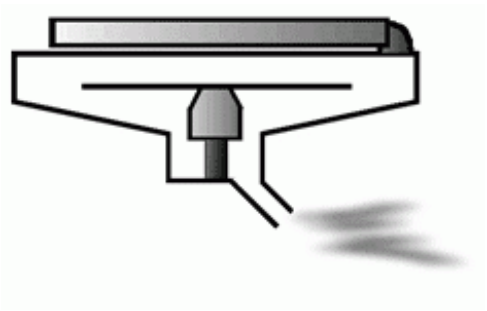
Acceleration also plays a large role in the coat properties of patterned substrates. In many cases the substrate will retain topographical features from previous processes; it is therefore important to uniformly coat the resin over and through these features. While the spin process in general provides a radial (outward) force to the resin, the acceleration aids in the dispersal of the resin around topography that might otherwise shadow portions of the substrate from the fluid.

FUME EXHAUST

The drying rate of the resin is defined by the properties of the fluid, as well as by the air surrounding the substrate during the spin process. 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.



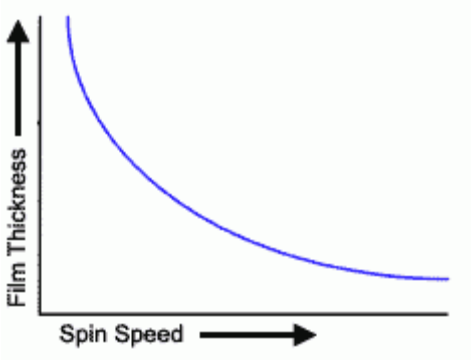
The distinct advantage to this system is slow drying of the fluid resin. The slower rate of drying offers the advantage of increased film thickness uniformity across the substrates. The fluid dries out as it moves toward the edge of the substrate during the spin process. This can lead to radial thickness 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.

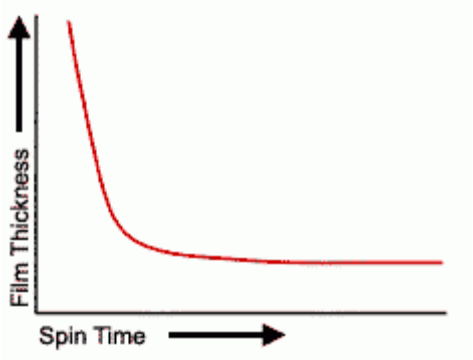


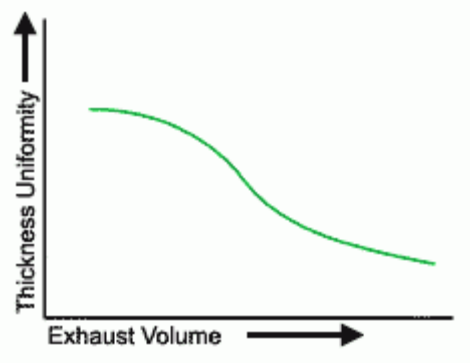
Drying rate and hence final film thickness is also affected by ambient humidity. Variations of only a few percent relative humidity can result in large changes in film thickness. By spinning in a closed bowl the vapors of the solvents in the resin itself are retained in the bowl environment and tend to overshadow the effects of minor humidity variations. At the end of the spin process, when the lid is lifted to remove the substrate, full exhaust is maintained to contain and remove solvent vapors.

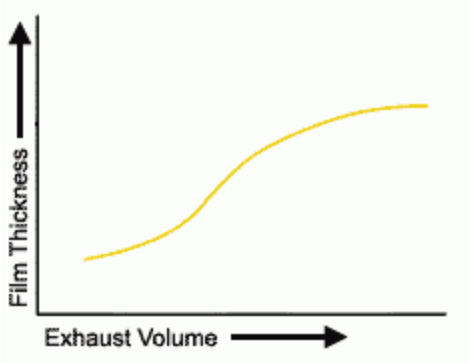
PROCESS TREND CHARTS

These charts represent general trends for the various process parameters. For most 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 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.

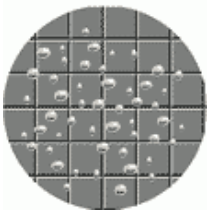
Film Too Thin

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

Film Too Thick

Spin speed too low	Select higher speed
Spin time too short	Increase time during high speed step
Inappropriate choice of resin material	Contact resin manufacturer

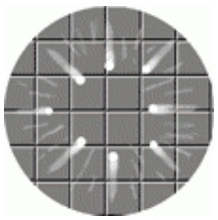
Spin Speed



Air bubbles in dispensed fluid (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

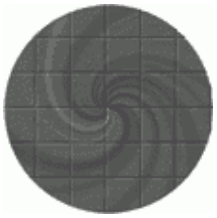
Swirl pattern

Spin bowl exhaust rate is too high

Fluid is striking substrate surface off center

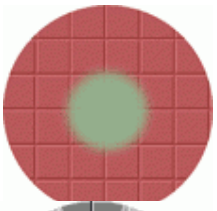
Spin speed and acceleration setting is too high

Spin time too short



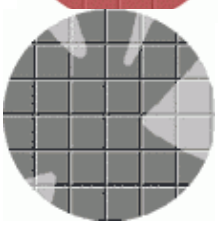
Center circle (chuck mark)

If the circle is the same size as the spin chuck, switch to a Delrin spin chuck



Uncoated areas

Insufficient dispense volume

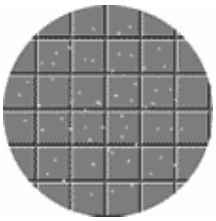


Pinholes

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 close
Substrate not centered properly	Center substrate before operation
Insufficient dispense volume	Increase dispense volume
Inappropriate application of resin material	Contact 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
Acceleration too high	Select lower acceleration
Insufficient dispense volume	Increase dispense volume
Inappropriate application of resin material	Contact resin manufacturer