Hot Plate Process Theory:

Hotplate bake processing has increased in popularity since the early 1980s. Previously the most common technique for film drying and curing as the convection oven. Hotplates offer several advantages in the form of increased throughput, increased uniformity and reproducibility and decreased particle contamination. In a typical bake process the substrate is placed into contact with a heated surface of known temperature. The substrate quickly rises to a peak temperature slightly lower than the hotplate surface temperature. Drying and curing steps generally take about few minutes. This is in contrast to traditional oven processes taking 30 minutes or more.

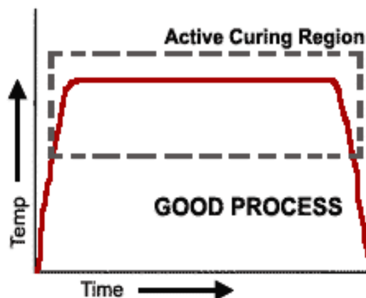
Hotplate Bake Variables and Methods

A typical bake process consists of preheating the surface to a known temperature, loading the substrate onto the surface for a specific length of time and removing it promptly at the end of the cycle. The selection of the temperature and time values used as well as the bake method employed all affect the overall performance of the process.

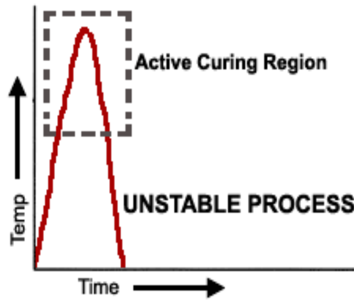
Bake Temperature

The bake temperature used is dependent on several factors. The material and substrate being baked as well as the results desired are key factors to be considered in developing a bake process. In general hotplate baking will be performed at temperatures slightly higher than those used in oven bake processes. The film being baked will reach a temperature somewhere between the temperature of the hotplate and the ambient air above the film. As an example, with a hotplate surface temperature of 115°C, a layer of photoresist on a silicon wafer will reach a final temperature of about 105°C after a few seconds. Thicker substrates and/or substrates with lower coefficients of thermal conductivity will require even higher temperatures to compensate for this phenomenon. Another reason for using higher temperatures is to increase process throughput. In oven processes, there is a problem commonly known as the "skin effect". This is a result of the outer exposed layer of the film drying and forming a skin before all of the solvents in lower layers have evaporated. Most oven processes are adjusted to use lower temperatures and bake times measured in minutes and hours to prevent this. During a hotplate bake process, the film is baked from the bottom up thus preventing the formation of a skin over the surface. Because of this it is possible to increase temperatures and adjust bake times to be measured in seconds without danger of blistering or cracking in the film.

Bake Time



The selection of the bake time parameter plays an important role in the reproducibility of the bake process. Substrate thermal properties and the choice of bake method greatly affect the amount of time necessary for the substrate and therefore film temperature to stabilize during the bake. Thicker substrates and the use of proximity bake methods will increase the time necessary for the film to reach its final temperature. It is important that most of the baking action in the film takes place after this temperature is reached. A silicon wafer will reach a stable temperature within a few seconds and so it is traditional to adjust a photoresist bake processes to be completed in 60-90 seconds with an appropriate bake temperature.

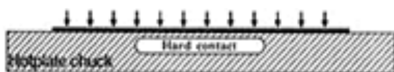


For thicker substrates such as photomasks and ceramic modules the increased time necessary to heat the larger mass of the substrate results in bakes times approaching five minutes. It should be noted that these substrates can be processed with higher temperature and much shorter bake times but reproducibility may suffer. If the bake time is too short then a significant amount of the actual bake process will take place during the loading and unloading steps as well as while the substrate is cooling after removal from the hotplate. This is an unstable condition since it is very difficult to exactly reproduce conditions during these steps. In general, the temperature-time relationship in a bake process can be taken as a "dose" of the (temperature) x (time) product. Increasing the bake temperature results in a need for decreasing bake time. The limits for both of these parameters can be considered to be reached when the process is no longer reproducible or when the physical temperature limitations of the resin or substrate have been reached.

Bake Method-*Three bake styles exist Hot Plates: proximity bake, soft contact bake and hard contact bake. These may be used in combination to further refine your baking process. The following section will discuss these methods and the advantages of each*

- **PROXIMITY BAKE**

In this method, substrates float on a pillow of nitrogen that is blown through orifices in the chuck surface. A combination of heated gas and radiant heat from the chuck heats the substrate. This slower heating of the substrate reduces blistering and cracking of films incorporating fast-drying solvents.
Commonly used as a pre-bake stage and /or in combination with the hard-contact bake, the proximity bake makes two temperature bake schedules obsolete.



- **HARD-CONTACT BAKE**

Hard-contact bake represents the most accurate baking method for hotplates. Vacuum ports in the chuck hold the substrate securely in place. This method insures bake uniformity and minimizes bowing and warping of the substrate. A quicker warm-up and more efficient heating produces faster throughput in shorter bake times. Selecting the "VAC" (vacuum bake) method initiates the hard-contact bake cycle-the preferred bake method.

- **SOFT-CONTACT BAKE**

gravity alone holds the substrate against the surface of the chuck. While this represents the least accurate bake style, this method finds some use as an intermediate style, between the hard-contact and the proximity bakes, as a multiple step warm-up.

Hotplate Process Troubleshooting

As with the spin coating process there are no absolute rules for hotplate baking, only general guidelines. Following is a list of issues to consider for specific hotplate process problems.

Film overbaked	
Bake temperature too high	Select lower temperature
Bake time too long	Decrease bake time
Film under-baked	
Bake temperature too low	Select higher temperature
Bake time too short	Increase bake time
Film blistering or cracking	
Unstable balance in temp. / time parameters	Decrease temp. / increase time
Warm-up time too fast	Use proximity bake to preheat substrate
Non-uniform bake	
Unstable balance in temp. / time parameters	Decrease temp. / increase time
Operating with exhaust lid raised	Lower the exhaust lid
Unstable ambient conditions	Protect against major fluctuations
Bake time too short	Increase bake time
Hotplate surface contaminated	Clean surface of hot plate