Spray Coating of Photoresists

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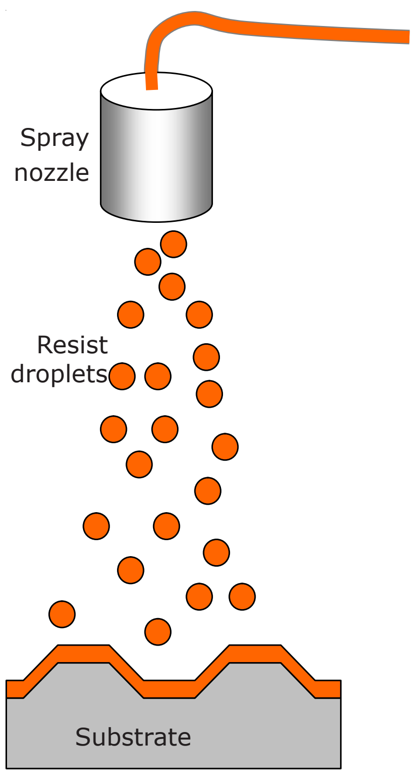
Spray Coating: Basics and Motivation

Spray coating denotes the formation of a resist film via millions of µm-sized resist droplets moving towards the substrate. This coating technique allows a - at least in principle - lower resist consumption as compared to spin coating. The main advantage, however, is the possibility to coat arbitrary shaped and textured substrates where spin coating cannot attain satisfying results by means of film thickness homogeneity and edge coverage.

Atomized Spray Formation

Each technology for droplet generation requires a certain low resist viscosity of usually a few cSt. Varying the resist viscosity impacts on the droplet generation rate as well as the droplet diameter distribution.

When diluting resists with a solvent, one has to consider possible incompatibilities of certain solvents with the resist, as well as the fact that highly diluted photo resists generally reveal an accelerated ageing of the resist in the diluted state with particle formation as a consequence.



Solvent Evaporation during Flight

A certain solvent evaporation out of the droplets during flight (between spray nozzle and substrate) is required for a sufficient resist edge coverage onto textured substrates: The hereby increased resist viscosity prevents the resist from macroscopically flowing on the substrate.

If, however, too much solvent evaporates during flight, this prevents the droplets from sticking to the substrate or at least causes a rough surface.

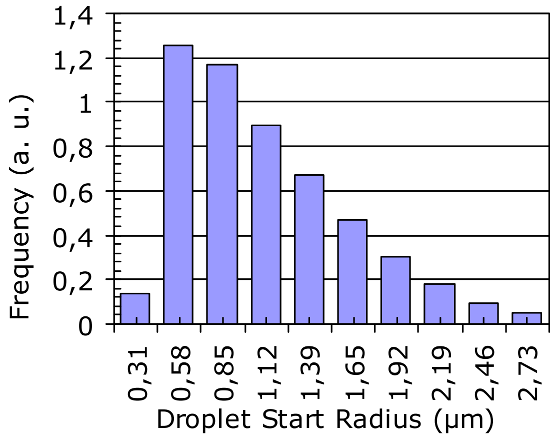
The parameters temperature, droplet velocity (relative to the ambient air), and air solvent saturation, as well as the solvent composition and concentration determine the evaporation rate for each droplet as a function of the droplet surface. This surface concentration again depends on the temperature- and solvent concentration dependant diffusion constant of the solvent from the droplet bulk to its surface.

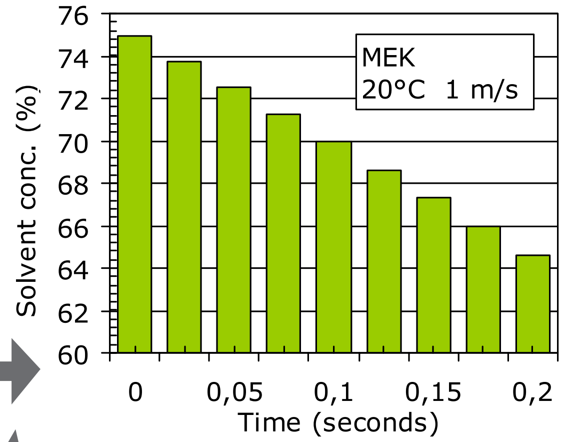
Wetting and Edge Coverage

A homogeneous resist film requires a certain flowing of the resist film on the substrate for at least few µm, thus defining an upper limit for the resist viscosity or, respectively, a certain minimum for the remaining solvent concentration. A viscosity, which is too low (or, respectively, a remaining solvent concentration that is too high) causes macroscopic resist flowing thereby reducing the edge coverage of the resist film in the case of textured substrates.

The parameters wetting, edge coverage, and homogeneity, which strongly impact the spray coating performance, depend on the initial coverage of the droplets from the atomized spray, the resist adhesion to the substrate, the resist surface tension, and its viscosity.

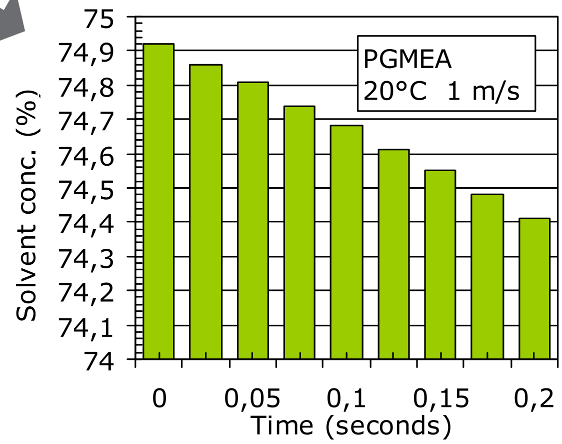
Therefore, besides the chemical and physical resist properties, the atomized spray formation

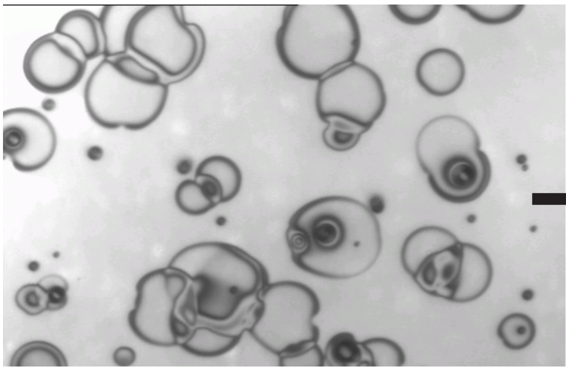




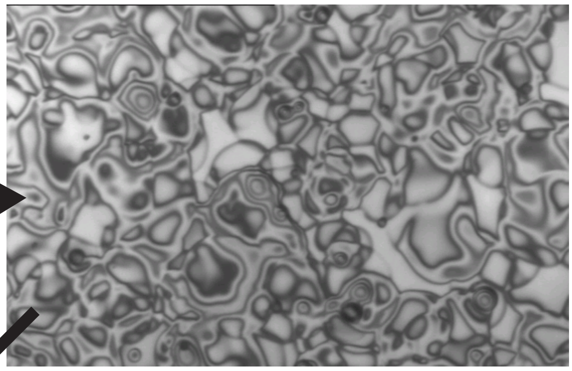
The bar graphs to the right plot the results from numerical simulation of a spray fog consisting of droplets with a certain (histogram above) radius distribution.

If MEK is used as diluent (upper right), evaporation causes a significant loss in the droplet solvent concentration in much less than a second, while PGMEA (lower right) evaporates much slower. Since the solvent concentration of the droplets hitting the substrate reflects the solvent concentration of the resist film formed, choosing the proper solvent(s) strongly impacts the resist edge coverage. Please not the different scale in the y-axis!



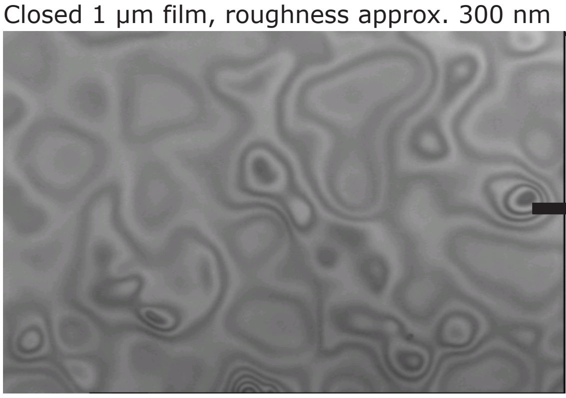


Few overlapping droplets

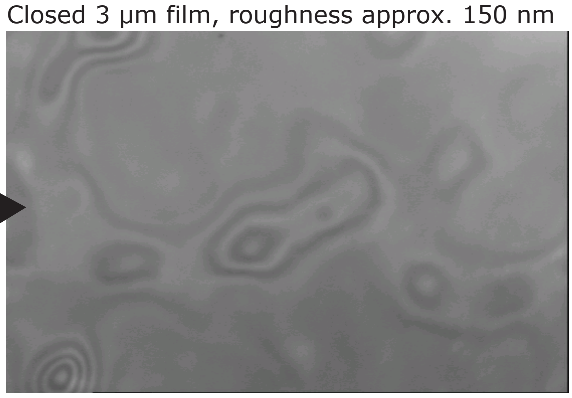


Resist film not completely closed

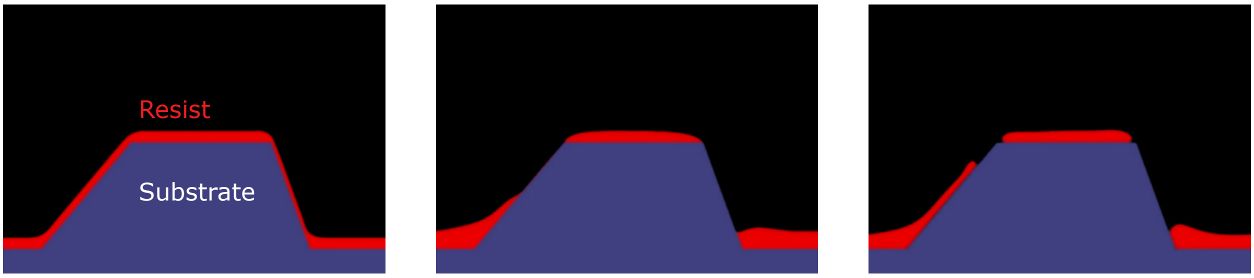
Closed 1 µm film, roughness approx. 300 nm



Closed 3 µm film, roughness approx. 150 nm



The figures above show snapshots during the formation of a resist film via spray coating.



Modeled cross sections of resist flowing on a textured substrate. The bottom left image reflects optimum edge coverage, while the other two images show what happens when the resist adhesion is too low (right) or, respectively, a resist viscosity too low for too long time (center).

mechanism (distribution of the droplet sizes), the flight of the droplets to the substrate (evaporation), and the solvent evaporation out of the growing/grown resist film (time dependant surface tension and viscosity) determine the spray coating result with respect to homogeneous, smooth, and closed films.

Spray Coating Resists and Process Optimization

For spray coating, we recommend the spray coating resists TI Spray and AZ® 4999 with a solvent composition optimized for typical spray coating equipment.

Please contact us if you would like us to assist you in improving your (scheduled?) spray coating process!