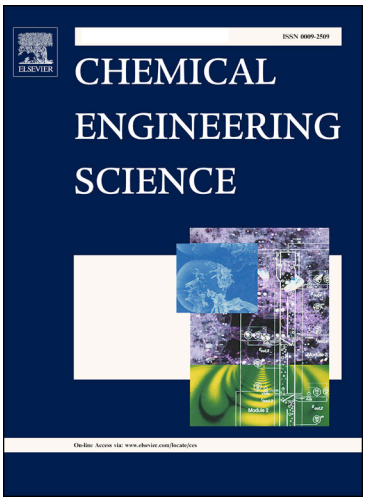

Deposition of polymer films by spin casting: A quantitative analysis

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Deposition of polymer films by spin casting: A quantitative analysis

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Abstract

Spin casting of mixtures of nonvolatile polymeric solutes dissolved in volatile solvents is studied experimentally and theoretically. The final solute coverage, time-resolved film thinning, time-resolved solvent evaporation, and evolution of the solute concentration within the thinning film is investigated for various combinations of different polymers (PMMA, PS, PS-b-PMMA) and different solvents (toluene, ethyl-acetate) for a wide range of polymer concentrations and spin cast conditions. The comprehensive data unveil a clear picture of the spin cast process. The findings are translated into a concise theoretical description. Easily available bulk properties of the solvent/solute mixture plus a single "calibration" experiment are sufficient for a quantitative description of the spin cast process including a prediction of the final solute coverage. This and the well-specified boundary conditions render the approach useful for practical applications.

Keywords: Spin-Coating, Spin-Casting, Polymer films

Introduction.—

Spin casting (spin coating) is a widely used technique to deposit films of uniform thickness on planar solid substrates[1–3]. In this process a liquid melt or solution is deposited on a rotating substrate. During a transient period the combination of radial and hydrodynamic (viscous) forces will flatten the deposited liquid bulk into a planar film. With on-going rotation this planar film will continuously become thinner[4, 5]. If the liquid film consists of a nonvolatile solute and a volatile solvent, film thinning also occurs due to solvent evaporation in addition to the hydrodynamic thinning. In the beginning, with thicker films, film thinning will be dominated by hydrodynamics. With thin films evaporation will dominate the film thinning process. Hence, to a first approximation spin casting of volatile liquids can be considered as a sequence of hydrodynamic planar film formation and thinning followed by evaporative thinning/drying of this film [6]. If the liquid consists of a mixture of a nonvolatile solute and a volatile solvent, the solvent evaporation causes a continuous enrichment of the nonvolatile solution components. In the end, the solute will be deposited as a dry film.

Even assuming idealized hydrodynamic and evaporative behavior, film thinning and the accompanying solute enrichment is a rather complicated process, because the increasing solute concentration has an influence on the hydrodynamic and on the evaporative properties of the film. Viscosity and evaporation behavior change continuously during film thinning. In addition, because the evaporation occurs from the film surface, the vertical solute concentration profile within the thinning film changes with time, possibly leading to a high solute enrichment close to the surface ("skin formation" [7], "crust" effect [8]). The combined process of hydrodynamic and evaporative film thinning

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