LINEAR STABILITY ANALYSIS AND DYNAMICS OF A DRYING VISCOELASTIC POLYMER SOLUTION

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ABSTRACT

We examine the dynamics of an evaporating viscoelastic liquid film, which consists of a volatile solvent and a non-volatile polymer solute. Although drying polymeric solutions are encountered frequently in technological applications [1,2] and a number of studies have focused on the effect of solutocapillary and thermal Marangoni effects, the effect of the rheological characteristics of the polymeric film have been largely ignored. Polymeric solutions, though, are known to exhibit viscoelastic behavior with properties (i.e. viscosity, relaxation time) that may depend on the local concentration of the solvent. In the present work we derive a detailed theoretical model which takes into full consideration its complex rheological character and examine the dynamics of drying polymer films by performing (a) a linear stability analysis under the assumption of slow quasi-steady evaporation and (b) transient numerical simulations to investigate the non-linear regime. The finite element method has been employed for solving the governing equations.

Our results indicate that the varying rheological properties affect the evaporation process. The increasing elasticity of the polymeric solution due to the evaporation (increase of local solute concentration leads on increase of relaxation time) destabilizes the systemand reduce the size of the cellular structures. On the other hand, increasing viscosity during the drying process provides a stabilizing effect. Our investigation reveals the presence of three modes of instability, one monotonic for disturbances with short wavelengths leading to the formation of cellular structures due to Marangoni convection and two oscillatory modes, one longwave which expresses the coordinated action of the capillary pressure and Marangoni stresses and another shortwave that appears for case of high dependence of the relaxation time on the local concentration of the solute.

KEYWORDS: Solutocapillary Marangoni, Viscoelasticity, Oldroyd B model, Evaporating Film

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