Convective transport and stability in films of binary mixtures

Santiago Madruga[1),*], Fathi Bribesh[2)] Uwe Thiele[3)]

1) Universidad Politécnica de Madrid, ETSI Aeronáuticos, Plaza Cardenal Cisneros 3, 28040 Madrid, Spain
2), 3) School of Mathematics, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK

∗ e-mail: santiago.madruga@upm.es

Abstract

Thin polymer films are increasingly used in advanced technological applications. The use of these films as coatings is often limited by their lack of stability due to their wettability properties on the selected substrates. The instabilities may be employed to create complex morphologies for polymeric functional layers and their development is relatively well understood for single component liquids. However, in many relevant applications the film consists of a binary mixture such as a polymer blend. For such systems the dynamics of the decomposition within the film and of the dewetting of the film itself may couple. This allows for new pathways of structuring like decomposition induced dewetting [1].

We present a model for the evolution of films of isothermal binary liquid mixtures with a free evolving surface [2]. The model is based on model-H [3] supplemented by appropriate boundary conditions at the free surface and the solid substrate. The equations account for the coupled transport of the concentration of a component (convective Cahn-Hilliard equation) and the momentum (Korteweg-Navier-Stokes equation). The inclusion of convective motion makes surface deflections possible, i.e., the model allows to study couplings between the decomposition of the mixture and the evolving surface corrugations.

After determining homogeneous and vertically stratified base states of free surface films of polymer mixtures we analyse their linear stability with respect to lateral perturbations [4]. For purely diffusive transport, an increase in film thickness either exponentially decreases the lateral instability or entirely stabilizes the film. The inclusion of convective transport leads to a further destabilization as compared to the purely diffusive case. In some cases the inclusion of convective transport and the related widening of the range of available film configurations (films are then able to change its surface profile) change the stability behavior qualitatively.

We show two dominant driving mechanisms for the convective motion in binary mixtures with diffuse interface: Marangoni driving for energetic biased surfaces, and Korteweg driving for neutral surfaces.

In addition, we discuss the role of composition for off-critical mixtures on surface deflections, and the dependence of the instability on parameters such as the Reynolds number, the surface tension number and the ratio of velocities of convective and diffusive transport.

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