Contact line instability in a thermocapillary-driven thin film and the effect of gravitational couterflow

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For a micro-scale liquid film interfacial forces may play important role in the dynamics due to high surface area-to-volume ratio. Thermocapillary stress due to an applied temperature gradient can force a thin liquid film to rise-up on a vertical solid substrate against gravity. Generally a capillary ridge forms at the three phase contact-line for such a flow that is susceptible to a rivulet or fingering instability at the advancing front. Larger ridges have been observed to be more unstable. The application of a sufficiently strong gravitational counterflow has been shown to drain fluid from the ridge and stabilize the film against rivulet formation as well as lead to interesting spreading dynamics. In this presentation, mathematical model of such a film dynamics is presented. Through proper scaling gravitational drainage parameter is introduced in the model which is a ratio of force due to gravity to the applied thermocapillary stress. The dynamics and stability of thermocapillary driven films are analyzed for the entire range of gravitational drainage parameter. At the three phase boundary slip is allowed. Conventional slip-model is employed to alleviate the stress singularity at the contact-line. The slip model introduces the static contact angle and slip coefficient as parameters in the model that can typically be specified independently. The contact angle of the spreading film is allowed to depend on the velocity of the contact line, and the effects of this dependence on the film profile, linear stability, and transient response of perturbations are examined. Increasing gravitational drainage from zero has a stabilizing influence on the traveling wave solutions but is accompanied by an increase in the amplitude of the capillary ridge, which is contrary to stability results for spreading films with only one driving force. This behavior is explained through an energy analysis of the disturbance operator. Above a threshold value of the drainage parameter the film becomes stable to rivulet formation, and the film shape evolves continuously in time. For even larger amounts of drainage, traveling wave solutions can again be found, but only for particular combinations of the slip coefficient and contact slope. While results for the different spread-

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ing regimes are generally consistent with predictions based on the more extensively used precursor film model of the contact line, there are deviations in the spreading predictions for a substantial range of gravitational drainage, which suggests potential differences in the spreading behavior of completely and partially wetting films.