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MORPHOLOGICAL INSTABILITY OF A FILM SURFACE UNDER HIGH TEMPERATURE

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ABSTRACT

It is well known that initially flat surface of a stressed solid is unstable under various conditions. As a consequence of this morphological instability, the surface shape can form different configurations, including islands, smooth undulation and cusped surfaces. The rate of surface roughening is controlled by associated kinetics of mass transport, such as volume and surface diffusion.

Heteroepitaxial thin-film structures are inherently stressed due to lattice mismatch between the film and the substrate. Similar to other stressed solids, the film can undergo surface instability. However, unlike a semi-finite homogeneous solid, the presence of a substrate affects the stability in several ways. For example, a simple analysis of the evolution of stressed sinusoidal surfaces of small amplitude via volume and surface diffusion shows that critical wavelength depends on the elastic stiffness of the substrate as well as on the film thickness [1].

In this presentation, we extend the model reported in our recent paper [1] to analyze the effects of a surface shape on the stability and kinetics of surface roughening assuming no dislocation formation. We consider a semi-infinite substrate covered by a layer under plane strain conditions. A remote stress applied to the film is parallel to the film\substrate interface. This stress can arise as a result of differential expansion or contraction of the film with substrate due to thermal-expansion mismatch, phase transformations or defects during deposition. According to Asaro and Tiller [2], it is assumed that the chemical potential gradient driving the mass transport along the surface comes from a stress variation along the surface and a surface curvature. Although surface diffusion is an important kinetic process, other kinetic processes such as volume diffusion could affect the evolution of stressed surfaces at high temperatures. We suppose that the chemical potential gradient driving diffusion of atoms through the bulk would arise due to capillarity and stress variations in the bulk produced by surface waviness [3]. Further, the surface and volume diffusion are assumed to take place in the region close to the surface and so, the volume flux can be used to compute the velocity of the surface as it was done by Panat and Hsia [4]. Thus, we derive a kinetic equation describing an evolution of the surface profile. In order to integrate this equation, we solve the corresponding boundary-value problem for finding elastic strain energy at the film surface. For this purpose, an arbitrary surface profile described by a periodic function

is represented by a Fourier series. Based on the perturbation technique, a corresponding variation of a stress field is obtained by solving an equivalent elastic problem for composite film-substrate with a flat surface. The exact solution of such boundary-value problem with arbitrary distributed periodic traction has been recently obtained in the form of functional series in [5].

Thus, we considered the formation of periodic structures on surface of stressed film at high temperature by investigating the deformation kinetics governed by volume and surface diffusion. A derived governing equation gives the amplitude of a surface roughening as a function of time.

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