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STRESS RELAXATION IN THIN ALUMINIUM FILMS

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The mechanisms of relaxation of internal stress σ in thin films are considered using deformation–mechanism maps (DMMs). The maps were constructed with due regard to the features of thin films associated with their structure and phase instability and the size effect. The dependence of the stress on temperature during thermal cycling of thin aluminium films in vacuum was analysed. At temperatures higher than $0.2T_m$ (where T_m is the melting point of aluminium) and at sufficiently high tensile stresses (below the flow stress) the stress relaxation in aluminium films develops mainly by dislocation climb mechanisms, and strain rates are more than 10^{-8} s^{-1}. The dislocation climb controlled by pipe self-diffusion, *i.e.* low temperature dislocation climb ($\dot{\sigma} \propto \sigma^{n+2}$ where n is a constant), causes relaxation of stress in the grain boundary regions of the film. High temperature dislocation climb ($\dot{\sigma} \propto \sigma^n$) due to lattice self-diffusion controls stress relaxation inside the grains of the film. The influence of dislocations on stress relaxation permits the hysteresis of the stress *versus* temperature curves to be explained on the basis of the Bauschinger effect. By using the DMMs, notions of low temperature and high temperature yield limits are introduced which correspond to relaxation of stresses in the grain boundary regions and inside the grains of the film respectively.

1. INTRODUCTION

Thin metal films are widely used in microelectronics for production of integrated circuits and semiconductor devices. Unlike bulk materials, thin films condensed onto substrates are in an extremely non-equilibrium state characterized by a high level of stress. This non-equilibrium is caused by a number of factors associated with both the preparation technique and the physicochemical properties of the substrates and film materials. The tendency of a thin film towards equilibrium brings about relaxation of the internal stress in the film. Stress relaxation in thin films can take place during their thermal treatment, *e.g.* when passivating and insulating layers are deposited. The relaxation often causes the formation of filamentary crystals (whiskers), voids and cracks, and in certain cases the film breaks

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