Modeling of Residual Stresses in Thin Metal Films

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Residual mechanical stresses introduced during deposition of thin films and coatings have a significant impact on the reliability of electronic devices and structural components. The mechanical stress in thin metal films consists of a thermal component and an intrinsic component due to the evolution of the metal microstructure during film growth. Controlling of the intrinsic stress component has become one of the most important challenges in modern technology.

In this work we introduce an intrinsic stress model which combines three stress generation mechanisms where each is related to one of the three characteristic phases of thin film growth and corresponding microstructure evolution. In the initial phase we assume the Volmer-Weber growth which includes a build-up of strong compressive stress components due to the Laplace pressure of isolated material islands [1]. It is followed by a tensile mechanism which operates during the island coalescence phase and thereafter [1]. The third phase introduces again a compressive component but this time due to adatom insertion into the top of the grain boundaries (Figure 1). The basic feature of our approach is an introduction of a strain gradient function which depends on grain the size distribution. This distribution can be obtained by using several different algorithms which simulate the morphology evolution according to the Van der Drift mechanism [2].

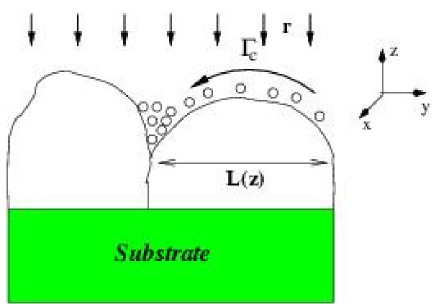

Figure 1: Third phase. Adatoms are inserted between the grain boundaries.

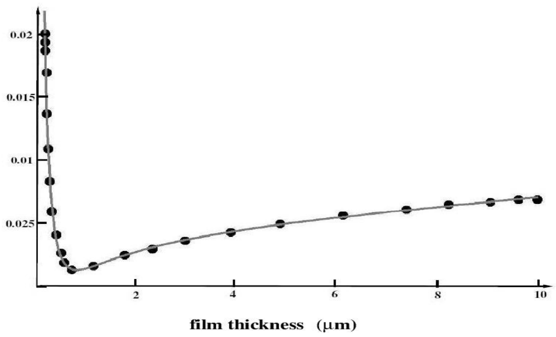

Figure 2: Comparison between experimentally determined microstrains (dots) with simulation (full line).

We have applied our model to a Poly-SiGe PECVD thin film deposition [3]. For an experimental thin film deflection a microstrain curve has been extracted in our previous work [4]. The comparison between this experimental microstrain and the microstrain obtained by the introduced three-phase model is given in Figure 2. Since the model explicitly includes both process and material parameters, it can readily be used to improve the mechanical behaviour of thin films. For example, a compensation effect [3] of top layers can be enhanced by increasing the compressive component of the third phase by means of a reduction of the deposition rate.

Acknowledgment: This work has been supported by the European Community PROMENADE project.

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