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Multi-scale Analysis of Nano-size Thin Film and Thin Film/Substrate Systems

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ABSTRACT

Nowadays, the applications of thin film structure have been getting larger, especially, in MEMS or NEMS. Besides, the dimension of thin film becomes small down to the nano-scale due to the requirement of more miniaturized devices in the market. It is known that the properties of thin film with nano-scale thickness are different from those of bulk one because of the surface effects [1,2,3]. The surface effects are usually negligible in macro scale because the surface-to-bulk ratio is very small but the surface effect must be considered in nano-scale due to the high surface-to-bulk ratio. So the continuum based multi-scale model which is able to describe the surface effects occurring in nano-scale thin film was developed in our previous study. Fig.1 shows that the Young's modulus of the thin film decrease as the thickness of film is getting smaller due to the surface effect and a good agreement was found between the result of finite element method(FEM) and that of molecular dynamics(MD) simulations.

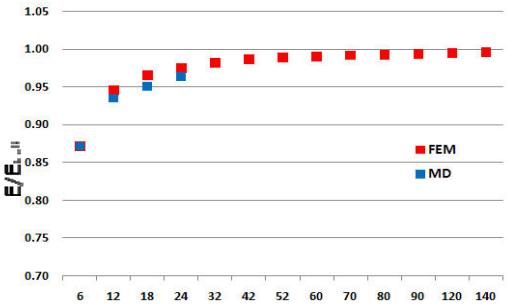

Fig. 1 Non-dimensional moulus of copper single crystal about (100)face

Even though thin film structures have been one of the independent components of microelectromechanical systems(MEMS), currently, various kind of thin film structures are integrated on various types of plate substrate such as integrated electronic circuits, integrated optical devices and MEMS deposited on wafers and so on. Especially, applications in flexible electronics require that thin films grown on elastic substrates be deformable. Usually a freestanding thin film subject to external force(tension) will rupture at a small strain due to a necking instability but a substrate will retard this instability to an extent that depends on the relative stiffness and thickness of thin film and substrate[4,5]. The elastic response of thin film/substrate systems can be different according to the stiffness or material properties of thin film and substrate [6]. However,

such thin film and substrate system is still not well understood. The molecular dynamics(MD) simulations may give more precise results on thin film/substrate system but it is almost impossible to apply MD simulations to the structure ranging from sub-micro to micro scale due to computational limitations.

Therefore, in this study, continuum model of thin film and substrate system is developed to overcome the limitation of computing time by extending previously suggested continuum model for the thin film structure. In order to analyze and predict the elastic response of thin film and substrate system, finite element formulation is also implemented based on the suggested continuum model for assembled thin film and substrate system.

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