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Microcantilever Anelastic Recovery: Probing Viscoelastic Behavior in Al/Ni Multilayer Thin Films

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Abstract

Multilayered materials are widely employed in micro- and nano- electromechanical systems (MEMS/NEMS) due to their high strength and multifunctional properties arising from engineered interfacial structures. However, the time-dependent deformation behavior and its dependence on interfaces and characteristic length scales remain incompletely understood. In this study, we investigated the time-dependent deformation behavior of Al/Ni multilayers with individual layer thicknesses ranging from 10 to 125 nm to obtain new insights into the anelastic recovery of such interface-dominated materials. Si3N4 microcantilevers coated with Al/Ni multilayers were subjected to bending with varying deflections. After full removal of the applied load, instantaneous elastic recovery was observed. The residual deflection then gradually recovered with a logarithmic dependence on time. Comparative bending tests performed on bare Si3N4 microcantilevers showed purely elastic behavior without any measurable anelastic recovery, thereby excluding substrate effects. Furthermore, recovery behavior was observed to be independent of any prior plastic deformation. The observed recovery was modeled using viscoelasticity theory. The associated viscoelastic properties were quantified using a standard linear solid model. Notably, the characteristic relaxation time in recovery increases slightly as the individual layer thickness decreases from 125 to 25 nm, but

decreases significantly for the 10 nm individual layer thicknes. In parallel, bending tests conducted at different strain rates revealed stiffness variations,which were used to independently determine the viscoelastic properties of the Al/Ni multilayers. A consistent dependence of viscoelastic behavior on individual layer thickness was observed using both approaches. This size-dependent anelastic recovery may be related to the unique microstructure of the metallic multilayer, particularly Al/Ni interfaces and grain boundaries, which likely introduce varying frictional resistance that governs residual stress relaxation through mechanisms such as grain boundary diffusion and interfacial sliding. This work highlights the critical role of viscoelasticity in microcantilever deformation with multilayer structure and provides new insights for the design of nanomechanical devices.

Keywords:

Viscoelasticity Anelasticity Thin films Multilayer Time-dependent response