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Ratcheting-induced Wrinkling of an Elastic Film on a Metal Layer Under Cyclic Temperatures

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A compressively strained elastic film on a compliant substrate can form wrinkles. Previous studies have focused on elastic, viscous, and viscoelastic substrates. The present study develops a theoretical model for wrinkling of an elastic film on an elastic-plastic metal layer caused by cyclic temperatures. The thermal expansion mismatch between the metal layer and the underlying substrate causes the metal to deform plastically. Each cycle the metal gains a small amount of plastic deformation, driven by the normal and shear tractions at the interface between the metal and the film. As the ratcheting deformation accumulates in the metal, the film forms wrinkles, analogous to wrinkling on a viscous layer. Analytical solutions are obtained for linear perturbation analysis and equilibrium states. Numerical simulations show the evolution of wrinkles. The implications of the results for structural evolution and failure mechanisms in integrated electronic devices and thermal barrier coating systems will be discussed.

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