

Fracture toughness and environmentally assisted subcritical cracking of thin freestanding Al_2O_3 and SiO_2 films

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Abstract

Aluminum oxide (Alumina, Al_2O_3) and silicon dioxide (silica, SiO_2) freestanding thin films are extensively used in a large number of electronic applications as protective layers, dielectric materials and sacrificial release layers during a device micromachining stage. Al_2O_3 films were deposited by electron beam-evaporation technique while SiO_2 were thermally grown. The fracture toughness and environmentally assisted subcritical crack growth have been investigated using a new on chip fracture mechanics test. This technique consists of two long actuators beams pulling on a notched specimen thanks to the release of the residual stress inside the actuators after etching the material beneath. A crack is initiated from the notch tip, propagates and finally stops when the energy release rate has decreased down to its critical value [1]. Both freestanding films are susceptible to stress corrosion especially, in the presence of moisture. The mechanisms responsible for this slow cracking behavior are investigated as well as the subcritical crack growth rate in laboratory air and dry environments under various temperature conditions. The combined experimental and finite element studies provide an insight on the variation of the crack propagation rate (v) as a function of the stress intensity factor (K) in different environments. This variation follows a power law exhibiting a higher cracking rate under high K loading configurations. The fracture toughness value is around $1 \text{ MPa}\sqrt{\text{m}}$ for both films. This toughness value is compared to the value obtained by push-to-pull technique (PTP) inside transmission electron microscopy (TEM) using Al_2O_3 and SiO_2 specimens that contain a real sharp pre-crack generated during the crack-on-a-chip test.

Keywords

Fracture toughness, subcritical cracking, freestanding thin films, alumina, silica, crack-on-a-chip and push-to-pull.

References

[1] Jaddi, Sahar et al. "Crack on a chip test method for thin freestanding films." J. Mech. Phys. Solids 123, 267 (2019).