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D5-THU-AM3-2 - Subcritical crack growth in freestanding silicon nitride and silicon dioxide thin films

D5. Micro- and Nano-mechanics – Characterization and Modelling

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Introduction/Purpose

Thin film materials are the main building blocks in many fields of application like flexible electronics, microelectromechanical / nanoelectromechanical systems (MEMS/NEMS) and functional coatings. However, the determination of the intrinsic fracture toughness of these materials, which is the key property controlling the failure resistance remains a challenge.

Methods

In this work, a new on-chip testing method for freestanding films is developed. The technique consists of two long actuators beams pulling on a notched specimen by exploiting the residual stress inside the actuators. The residual stress upon release by chemical etching leads to the actuator contraction, hence pulling on the central notched specimen. A crack is initiated at the notch tip, propagates and finally stops when the energy release rate has decreased down to its critical value. This crack arrest measurement avoids the problem of introducing a sufficiently sharp precrack. Further subcritical crack growth can be investigated by this fracture on-chip testing technique through repeating crack length measurement over time, without monopolizing any test equipment.

Results

The understanding of the mechanisms causing the subcritical crack growth is crucial to define the reliability of devices made with thin films that are showing time-dependent failure. Low-pressure chemical vapor deposition (LPCVD) silicon nitride (SiN) and silicon dioxide (SiO_2) films deposited by electron beam-evaporation technique were studied with a variety of thicknesses. The specimens were tested in laboratory air and dry nitrogen environments under various temperature conditions.

Conclusions

Based on both experimental data and finite element simulation results (FE), the stress intensity factor (K) and the crack velocity (v); K-v curve in different environments is determined, following classical exponential law.