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Fracture toughness at nanoscale: experimental challenges and physical meaning

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Abstract

Fracture mechanics is widely applied at nanoscale down to single atom thick 2D materials. The goal of fracture mechanics is two-fold: (i) to determine an “as intrinsic as possible” property that allow fair cross-comparison between material's fracture resistance, (ii) to assess failure risk in structures based on the material’s fracture toughness assuming thus that transferability is warranted. In order to generate clean data, fracture mechanics tests rely on sharp starter pre-crack, well-defined loading mode, accurate measurement of force, displacement and crack length. This leads to multiple challenges at nanoscale. This talk will address different questions along these lines based on recent developments of the MEMS-based on-chip cracking of freestanding films as applied to Al2O3, graphene [1], tungsten [2], and Al2O3/Al nanolaminates [3]. This includes (i) differences between an initiation toughness, a propagation toughness, a steady-state toughness, and arrest toughness; (ii) thickness effects; (iii) residual stress and mixed mode effects; (iv) ageing – irradiation effects. These questions touch both the problem

of the meaning of the extracted toughness and to the transferability problem. The pro- and cons of the on-chip method will be discussed, compared to other methods such as tensile testing of films on polymer substrate or nanoindentation induced cracking.

Keywords:
fracture mechanics on chip tests nanomechanics thin films cracking

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