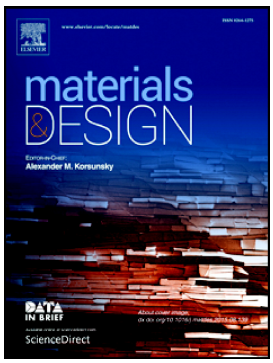

Fracture of Silicon: Influence of rate, positioning accuracy, FIB machining, and elevated temperatures on toughness measured by pillar indentation splitting

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Fracture of Silicon: Influence of rate, positioning accuracy, FIB machining, and elevated temperatures on toughness measured by pillar indentation splitting

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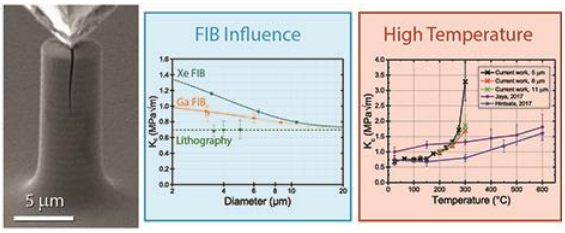
Graphical Abstract



Abstract

The pillar indentation splitting test is a novel technique for assessing the fracture behavior of materials using micro-scale pillar samples. One typical limitation of this technique is the necessity of fabricating samples using focused ion beam (FIB) machining, which both creates damage to the samples and limits the number of samples which can be manufactured in a set timeframe. An alternative fabrication technique, lithography, is used here to fabricate a large number of (100)-oriented, Silicon micro-pillar samples. This allowed parametric studies of pillar splitting to be performed to study the influence of testing rate and positioning accuracy. Further, it allows the comparison of samples produced using different methods (lithography, Gallium FIB, and Xenon FIB) as a function of size. FIB damage was found to significantly increase the apparent toughness at smaller pillar sizes, but the influence diminishes to negligibility at pillar diameters > 10 µm. Lastly, the fracture behavior of Silicon was investigated as a function of temperatures up to 300 °C. Apparent toughness values began increasing at 175 °C due to crack blunting due to partial dislocation-mediated plasticity. At temperatures > 250 °C, the plasticity was sufficient to prevent splitting – requiring elastic-plastic fracture mechanics methods for further analysis.

Keywords: Silicon; fracture mechanisms; temperature dependence; pillar indentation; focused ion beam damage

Highlights

- To avoid error, necessary positioning accuracy is ~20% of pillar diameter.
- Influence of FIB damage on toughness observed to diminish by 10µm diameters.
- Increase in toughness observed at 175°C due to partial dislocation plasticity.
- Above 250°C, plasticity prevents Silicon pillars from splitting.