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PII: S0022-5096(18)30586-6
DOI: https://doi.org/10.1016/j.jmps.2018.09.031
Reference: MPS 3462

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 4 July 2018
Revised date: 20 September 2018
Accepted date: 24 September 2018

Crack plane deflection and shear wave effects in the dynamic fracture of silicon single crystal

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Abstract

Fracture paths in crystalline solid can be significantly altered upon encountering stress perturbations. Here, we investigate the dynamic cleavage deflection in (001) silicon single crystal wafers under three-line bending load. It is found that the crack propagates preferentially along the (110) cleavage plane. However, when the crack front interacts with shear waves induced by the line-contact, it tends to deflect onto the (111) cleavage plane and forms secondary Wallner lines. Yet, the crack deflection is not permanent and a recovery process to the (110) plane is observed, suggesting that the (110) cleavage plane remains energetically prevailing during the high-speed crack propagation. We show that the ratio between the dynamic fracture energy of the (111) plane and that of the (110) plane at the deflection position is invariably larger than the one when the local crack velocity is lower than 40% of the Rayleigh wave speed. This confirms that the crack deflection is triggered by shear waves. Therefore the theory of crystallographic direction dependence of dynamic fracture toughness evolutions proposed in earlier literature needs to be further assessed before generalization.

Keywords: Brittle fracture, Single crystalline silicon, Crack deflection, Shear waves

1. Introduction

Crystalline silicon has received a large number of investigations in the last few years owing to its wide applications in photovoltaic (PV) systems and microelectromechanical systems (MEMS) (Petersen, 1982; Köntges et al., 2011; Borri et al., 2018). In

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