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Modelling damage and cracking in polycrystalline solar cells using the cohesive zone model and the phase field approach

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ABSTRACT
The reliable characterization of failure mechanisms in polycrystalline materials is of vital importance for their incorporation in advanced engineering applications. This is for instance the case of polycrystalline Silicon semiconductors used in photovoltaic (PV) solar cells embedded in PV laminates. Mechanical degradation in form of cracks and diffuse damage in Silicon leads to a reduction of electrical performance of PV modules, affecting their durability, see recent experimental results in [1-3].
In these polycrystalline materials, two principal failure modes have been experimentally observed in case of bending [2,3]: (i) intergranular cohesive fracture involving crack propagation at the grain boundaries;(ii) transgranular damage and fracture involving cracks travelling through the grains. Recently, an attempt to simulate the interplay between intergranular and transgranular cracking in polycrystalline Silicon for PV applications has been proposed in [4] by considering cohesive interface elements embedded in the finite element mesh and with different properties depending on their position (grain boundary vs. grain interior). This strategy, although computationally robust and of easy implementation, has the drawback of suffering from mesh-size dependency. Corrective techniques to minimize these effects have therefore to be employed [4], which limit the applicability of the approach to large scale problems. .

With the advent of the phase field approach to fracture, unprecedented opportunities are now feasible to study diffuse damage, brittle fracture nucleation, and frature propagation [5]. In the present work we explore the combination of the phase field approach to fracture [5] and of interface cohesive crack elements [6] to simulate crack patterns in polycrystalline Silicon solar cells. The former is used to simulate cracks and diffuse damage inside the polycrystalline grains, without the need of re-meshing techniques, whereas the latter is used to depict the phenomenon of fracture along pre-existing interfaces, i.e., along the grain boundaries. Comparisons with experiments are provided.

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