Residual stress and mechanical property measurements in amorphous Si photovoltaic thin films

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ABSTRACT

The mechanical reliability and efficiency of thin film photovoltaics attached to structural members depends on the initial state of residual stresses in the films. In this study, predictions for the mechanical and functional failure of photovoltaic films cocured with carbon fiber composite laminates were made possible by quantifying the mean and gradient residual stresses and the failure properties of the individual layers in thin film inorganic photovoltaics consisting of an amorphous silicon (Si) p–n junction diode, a zinc oxide (ZnO) Transparent Conductive Oxide layer (each 1 micron thick), a Kapton layer, and a thick aluminum substrate. The mean residual stress (1466 ± 118) MPa in the Si monolayer and the Si/ZnO bilayer (1661 ± 93) MPa were calculated from the geometrical details of straight and telephone cord type buckling delaminations induced to the p–n junction layer. Curvature measurements provided the residual stress gradient of the Si monolayer as 274 ± 20 MPa/microns and the stress gradient profile in the Si/ZnO bilayer. The tensile strength of freestanding amorphous Si monolayer and Si/ZnO bilayer strips was measured as 425 ± 75 MPa and 109 ± 23 MPa, respectively. These microscale tension experiments also showed that there is weak adhesion between the Si and the mechanically weak ZnO layers. The aforementioned experimental results were employed to predict the onset of fragmentation of the ZnO layer and the initiation of functional degradation of the PV films that were cocured with 00 carbon fiber composite laminates, as 0.3% and 0.9% applied strain, respectively, which was in very good agreement with experimental measurements at the composite level.