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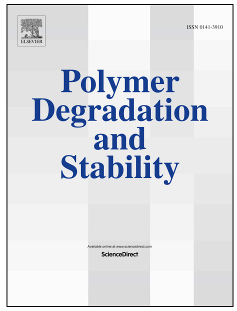

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A Non-Destructive Method for Crack Quantification in Photovoltaic Backsheets Under Accelerated and Real-World Exposures

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Abstract

The long-term durability of photovoltaic modules is paramount for the continued growth of the industry. Polymer backsheets are of particular concern since they provide electrical insulation and an environmental barrier. In this study, 23 freestanding, multilayer backsheets with nine unique material combinations underwent four different weathering exposures under accelerated and real-world conditions. Besides changes in color and gloss, the induced degradation included parallel or mudflat cracks on 11 backsheets, sometimes in combination with delamination or blistering. Similar degradation has been observed in previous studies and is concerning since cracks compromise the mechanical integrity and electrical safety of backsheets. Quantitative parameters are desirable to reliably classify categories of cracks and supply unbiased features for statistical analysis in predictive lifetime models. We developed an analysis technique that utilizes surface profilometry data to quantify the depth, width, area, spacing, and number of cracks. Parameters are automatically extracted from the raw data by an algorithm running on a high performance distributed computing cluster. Our algorithm excelled at characterizing parallel cracks with minimal de-adhesion, and only an estimated 4% of crack detections were false positives. The addition of humidity and temperature variation formed up to three times as many cracks on a photodose basis compared to dry, constant temperature exposures. Cracks in real-world and accelerated exposures propagated to similar depths with equivalent photodoses; however, the number of cracks formed in accelerated exposures was far greater on a photodose basis. Of samples that cracked, the best performing backsheet configuration was polyvinyl fluoride/poly(ethylene-terepthalate)/polyethylene (PVF/PET/PE) while the least durable was PET/PET/ethylene-vinyl acetate. None of the six PVF/PET/PVF backsheets cracked in any of the exposures.

Keywords: Photovoltaic, Backsheet, Cracking, Data Science, Predictive Lifetime Models, Degradation Science

1. Introduction

With rapidly dropping prices, the photovoltaics (PV) industry is becoming an increasingly important contributor to the global energy market [1, 2]. PV energy costs have been approaching price parity with fossil fuels resulting in an increased emphasis on large-scale, industrial PV power plants [3, 4]. To continue this positive trend and promote wide-scale adoption of PV, it is imperative to understand the forms of degradation that can jeopardize a module's long-term profitability [5, 6, 7, 2].

Our approach to this lifetime and degradation science [8] challenge utilizes data science and statistics to extract unbiased correlations between environmental stressors and degradation responses. Identifying these statistically significant relationships requires large data sets [7]. Knowledge of physical models then enables further exploration of the indicated correlations to identify active and quiescent degradation pathways. Cross-correlation between accelerated and real-world models also helps develop accelerated lifetime qualification standards and tests [9] which accurately reflect real-world PV degradation [10, 11, 12, 13]. As additional data becomes available, models can be iteratively updated and improved, ultimately leading to predictive lifetime models that are validated against a wide range

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