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Defining Threshold Values of Encapsulant and Backsheet Adhesion for PV Module Reliability

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Introduction

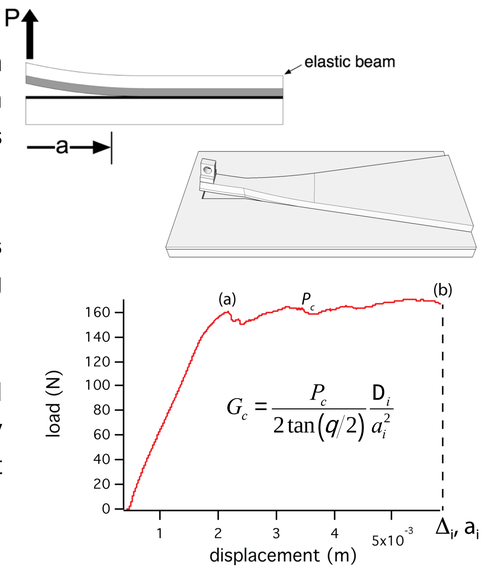
The method of quantifying the critical strain energy release rate, or debond energy, (material property of adhesion) of encapsulant and backsheet interfaces has only recently been applied within the PV industry. Consequently, values of adhesion adequate to avoid delamination in the field have not been established. These **threshold values of adhesion** (an adhesion value above which a module should remain intact throughout its lifetime) are required to improve accelerated lifetime tests and for the development of new, low-cost materials.

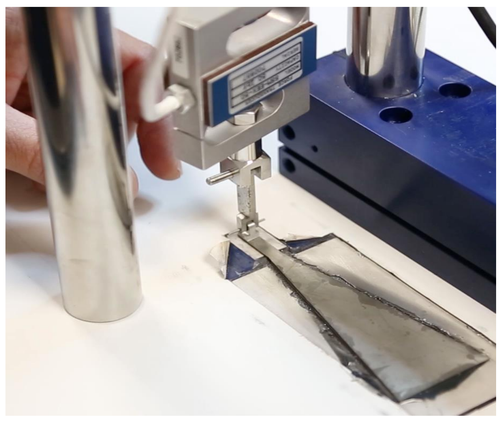
Materials and Methods

Flat plate, one-sun, crystalline silicon photovoltaic modules were collected from numerous locations with deployment histories between **two and 27 years**.

Front encapsulant and backsheet interfaces were examined and areas of pre-existing delamination noted.

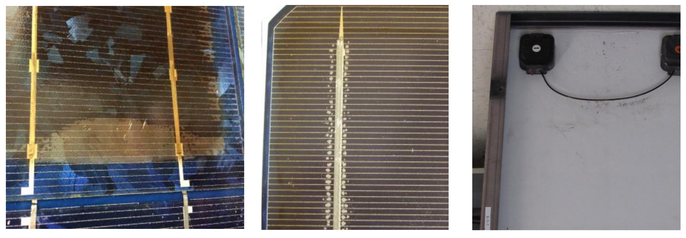
The **width-tapered cantilever beam method** was used to measure the critical strain energy release rate (adhesion) of the front encapsulant and backsheet structures.





Width-tapered cantilever beam method being applied to quantify adhesion of the front encapsulant via the back-side of a full sized PV module.

Results and Observations



Examples of encapsulant and backsheet delamination encountered in module survey

Front Encapsulant

All thirteen instances of front encapsulant pre-existing delamination were observed in modules with adhesion levels **below ~160 J/m²**.

Four modules measured with similarly low adhesion values did not exhibit delamination (**<120 J/m²**). Of these, one was never deployed outdoors and the remaining three contained relatively thin cells.

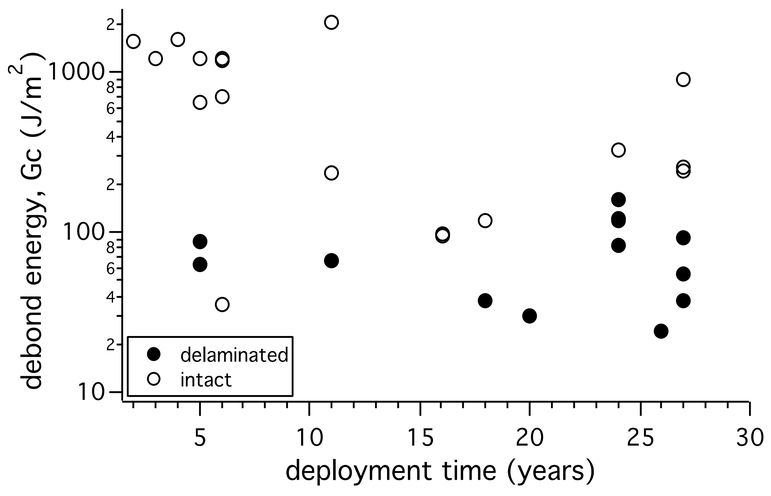
Thinner, more compliant cells could lower the driving force for delamination and therefore lower the adhesion threshold for more modern modules to below **35 J/m²**.

Backsheet Adhesion

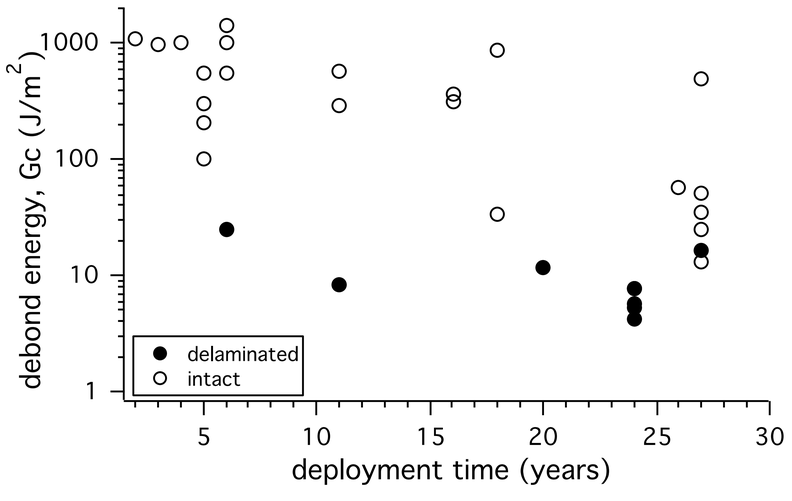
All modules measured to have backsheet adhesion **less than 12 J/m²** (seven) exhibited signs of **pre-existing delamination**.

All of these were also more modern backsheet laminate structures that delaminated at the outer PET/ PVF interface.

In nine modules characterized, only a lower limit of backsheet adhesion may be reported. In each of these cases the adhesion of the backsheet structure was so high (>300 J/m²) that delamination occurred at a lower interface.



Front encapsulant adhesion of the surveyed modules



Backsheet adhesion of the surveyed modules

Conclusions

This study has introduced our initial effort to quantify a threshold value of both encapsulant and backsheet adhesion.

These threshold values should be considered the very minimum required to ensure delamination does not occur at the interfaces of these PV module laminate materials while in service.

For encapsulants **>160 J/m²**

For backsheets **>10 J/m²**

Our expectation is that these threshold values of adhesion will continue to evolve, and be refined, as the PV community adopts the width-tapered beam method and the population of characterized modules continues to grow.

SunShot National Laboratory Multiyear Partnership
SuN LaMP
Scientific Approach to Reducing PV Module Material Costs While Increasing Durability

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