Adhesion and Debond Kinetics of Encapsulants PV Backsheets

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Objectives

•Develop a quantitative technique to measure adhesion and debond kinetics in EVA Encapsulants and TPE backsheets.

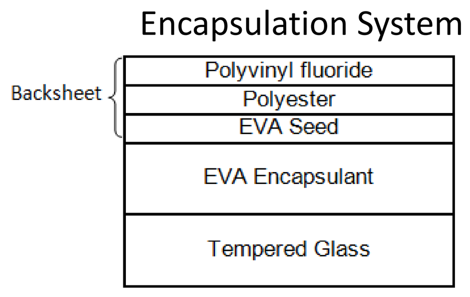
•Characterize the effect of ageing treatment duration, as well as the effects of environmental temperature and relative humidity on backsheet and encapsulant debond energy.

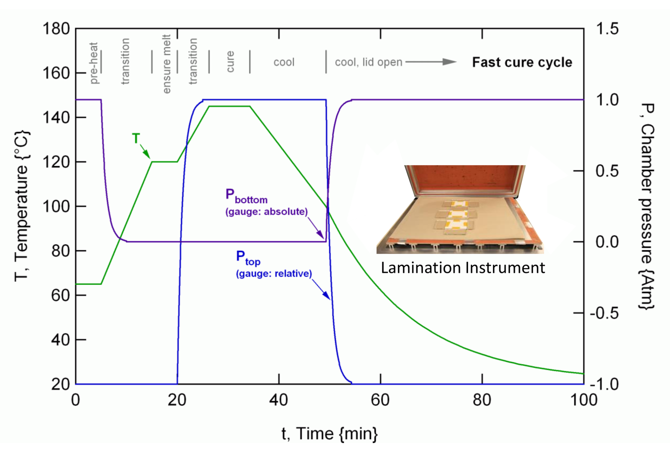
•Investigate the effect of mechanical stress, moisture and temperature on debond growth rate.

•Develop a predictive model of the effect of mechanical stress, moisture and temperature on debond growth rate.

Encapsulation Specimen Preparation

A Polyvinyl fluoride-polyester backsheet with EVA seed was laminated to a layer of EVA encapsulation and a glass substrate.





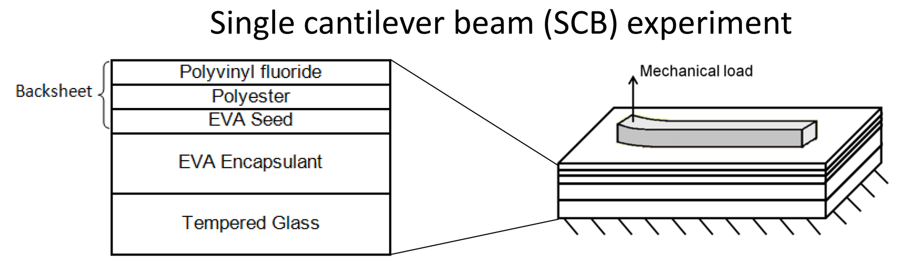
Lamination was performed at 145°C for 8 minutes at 1 atmosphere pressure.

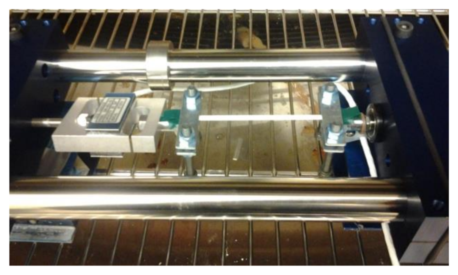
The glass was cleaned prior to lamination, including: buffing with pumice powder; washing and rinsing.

The specimen components were fixed during lamination to improve their thickness uniformity.

Debond Energy and Debond Growth Experiment

A single cantilever beam (SCB) testing metrology, based on the well-known double cantilever beam method, was developed.



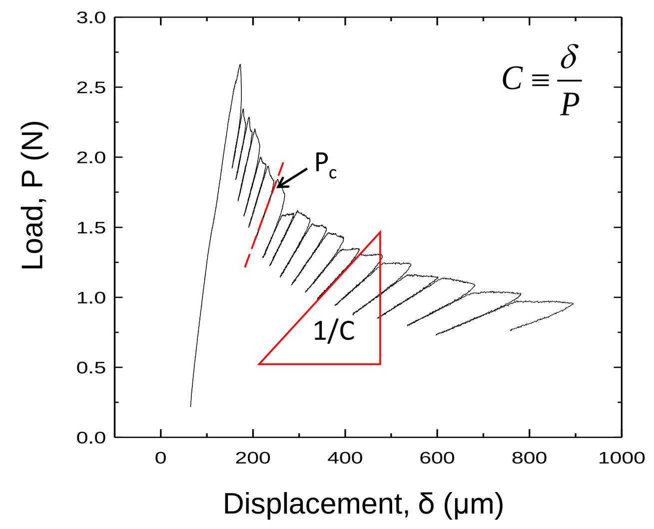


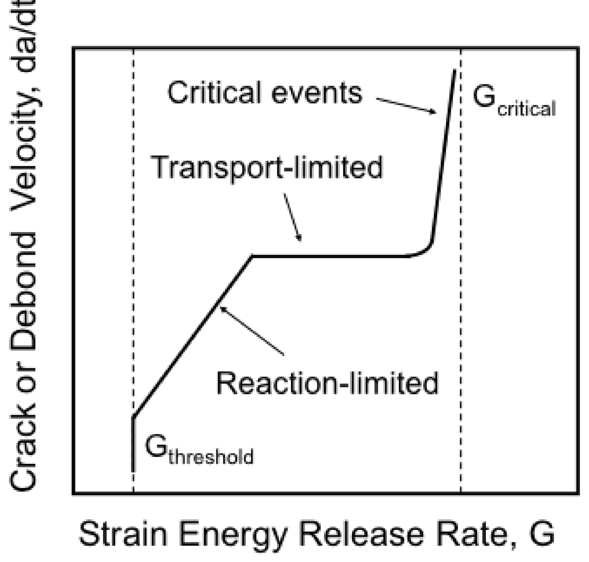
•A PMMA (or Ti) beam was bonded to the backsheet and a loading tab was bonded to one end of the beam. An incision was made through the backsheet and underlying encapsulant

•The glass substrate was rigidly fixed to a testing table and the loading tab was connected to a linear actuator in series with a load cell.

• Load and displacement were measured during the experiment. The debond energy, G_c was calculated using crack length (a), critical load (P_c), thickness of the beam h, width B and plane strain elastic modulus E'.

$$C = \frac{4a^3}{E' B h^3} \qquad G_c = \frac{P_c^2}{2B} \frac{\partial C}{\partial a}\bigg|_{a_c}$$



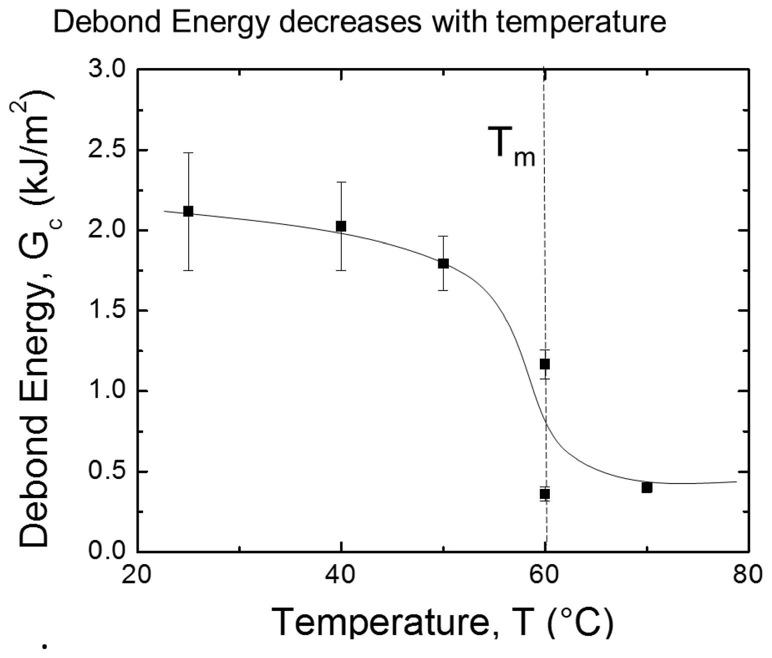


• To measure debond growth, the SCB specimens were loaded below G_c. The displacement was fixed and the load relaxation inherent to debond growth was recorded.

• Analysis of the load relaxation and increasing compliance determined the debond growth rates.

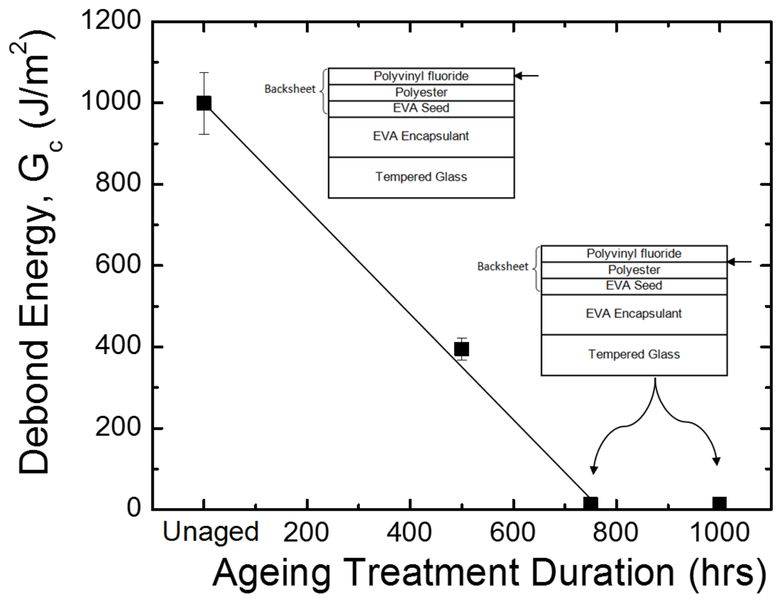
• The experiments were performed at selected values of temperature and relative humidity.

Debond Energy of EVA Encapsulants and TPE Backsheets



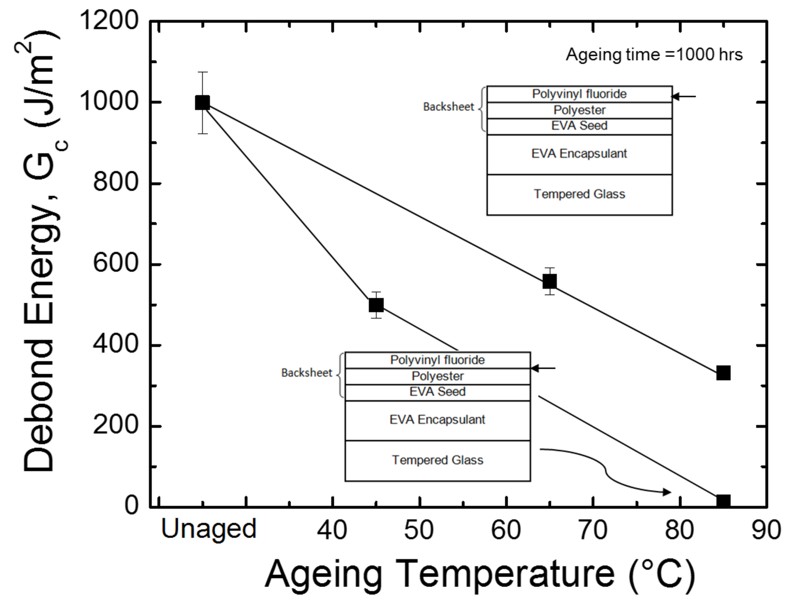
• The debond energy of the EVA–glass structure decreased with testing temperature.

• The debond energy decreased precipitously at T~60°C, which corresponds to one of the transition temperatures of the polymer.



• The debond energy of the backsheets decreased linearly with ageing duration for 800hrs to very low values (~28 J/m²).

• Failure occurred at the PVF-PET interface

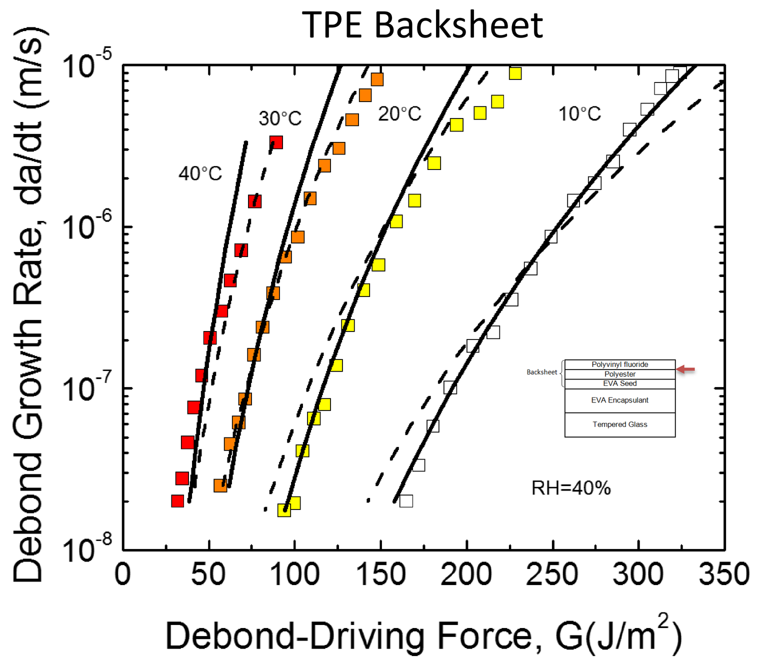


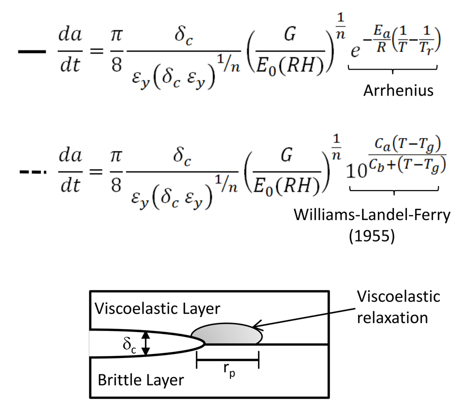
• Higher ageing temperature and relative humidity corresponded to lower debond energies .

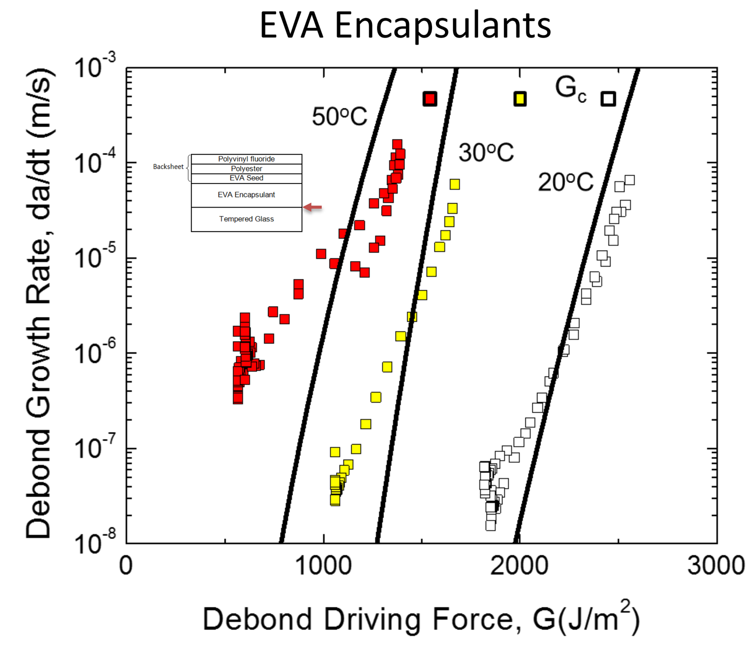
• High values of debond energy corresponded to partially cohesive failure in the PVF.

Debonding Kinetics of EVA Encapsulants and TPE Backsheets in Controlled Environments

Temperature Effect on Debond Growth Rate



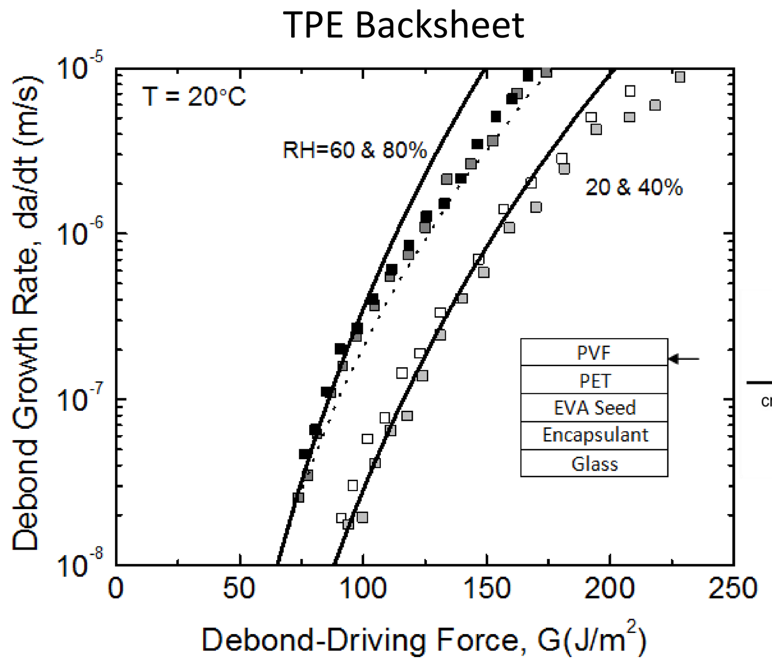


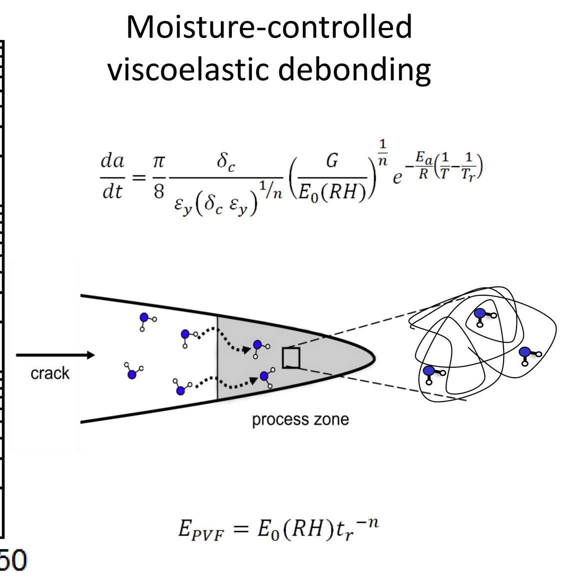


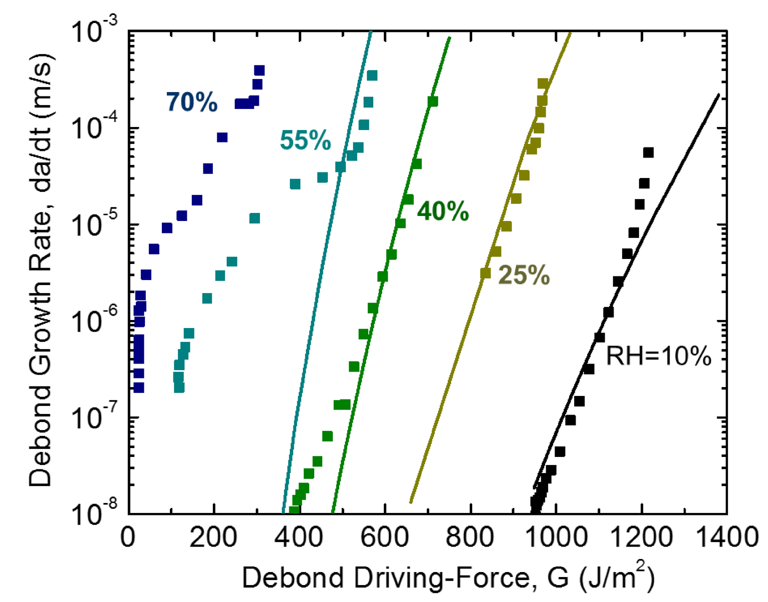
The debond growth curves were shifted to lower values of G at higher temperatures.

Lines are model model predictions using the Arrhenius and the Williams-Landel-Ferry equation.

Moisture Effect on Debond Growth Rate







The debond curves were shifted to lower values of G with increasing RH.

Lines are model predictions using the humidity dependence of the PVF modulus (backsheet), and the plasticizing effect of water (EVA encapsulants.)

Conclusions

• The debond energy of a PV encapsulant and backsheet were measured after several ageing treatments. The debond energy decreased with ageing treatment duration, relative humidity and temperature.

• The effect of mechanical stress, temperature and relative humidity on encapsulant and backsheet debond growth was reported. The debond growth rate increased up to 500-fold with small changes of temperature (10°C) and relative humidity (20%) .

• The effect of temperature on debond growth was modeled with the Arrhenius and the Williams-Landel-Ferry equation. The effect of moisture on the debond growth rate was modeled with the humidity dependence of the PVF modulus and the plasticizing effect of water on EVA.

Acknowledgments

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