Hail impact testing on crystalline Si modules with flexible packaging %

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INTRODUCTION %

Semi-flexible packaging of silicon solar cells has potential applications in BIPV and consumer electronics. One of the more difficult reliability requirements for modules without a glass superstrate is hail impact robustness. Here, we investigate the effect of hail impact testing on standard silicon solar cells in non-traditional packaging. We test a variety of constructions without glass superstrates and show the effect of adding additional protective polymer layers. In addition, the effect of the backstop of the test apparatus is explored in anticipation of realistic BIPV installations.

MODULE CONSTRUCTION

For each configuration, a single cell module using a conventional front contact cell was used as the test configuration with a combination of superstrates, encapsulant layers and substrates as shown in Table 1.

The four factors to be explored for hail impact resistance were:

1. Superstrate hardness/rigidity (ETFE versus glass)
2. Substrate hardness/rigidity (Polymer backsheet versus glass)
3. Encapsulant thickness for improved cushioning (0.5mm or 2.0mm (4x) EVA)
4. Influence of mounting surface (rigid backing versus neoprene)

Part #	Superstrate	Front encapsulant thickness (mm)	Rear encapsulat thickness (mm)	Substrate	Hail Test backstop
01	Glass	0.5	0.5	TPT	NA
02	ETFE	0.5	0.5	Glass	
03		2	0.5		
04		0.5	2		
05		2	2		
06	ETFE	0.5	0.5	TAPE	Hard
14					Soft
07		2	0.5		Hard
15					Soft
08		0.5	2		Hard
16					Soft
09		2	2		Hard
17					Soft
10	ETFE	0.5	0.5	TPT	Hard
11		2	0.5		
12		0.5	2		
13		2	2		

Table 1: Sample configuration matrix

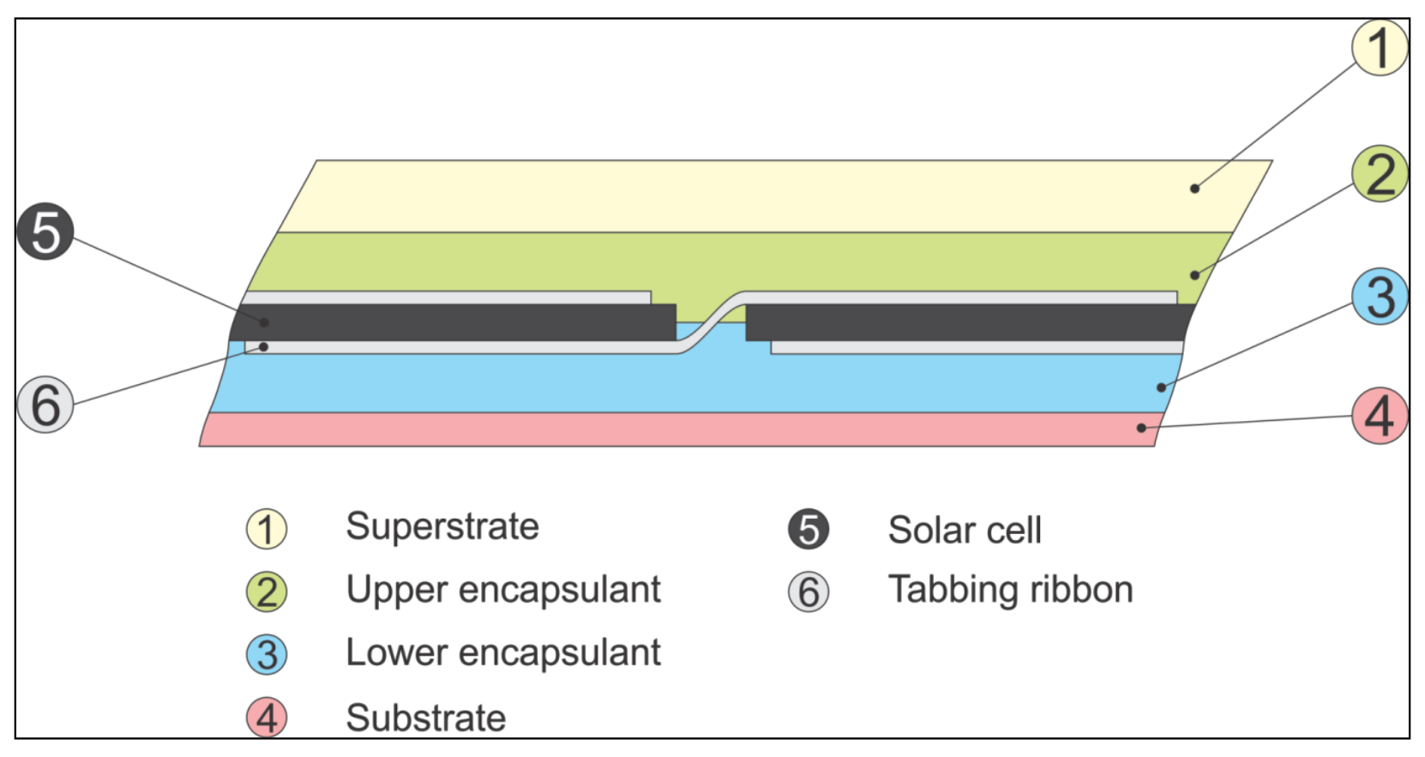

Figure 1: Layers in sample construction !

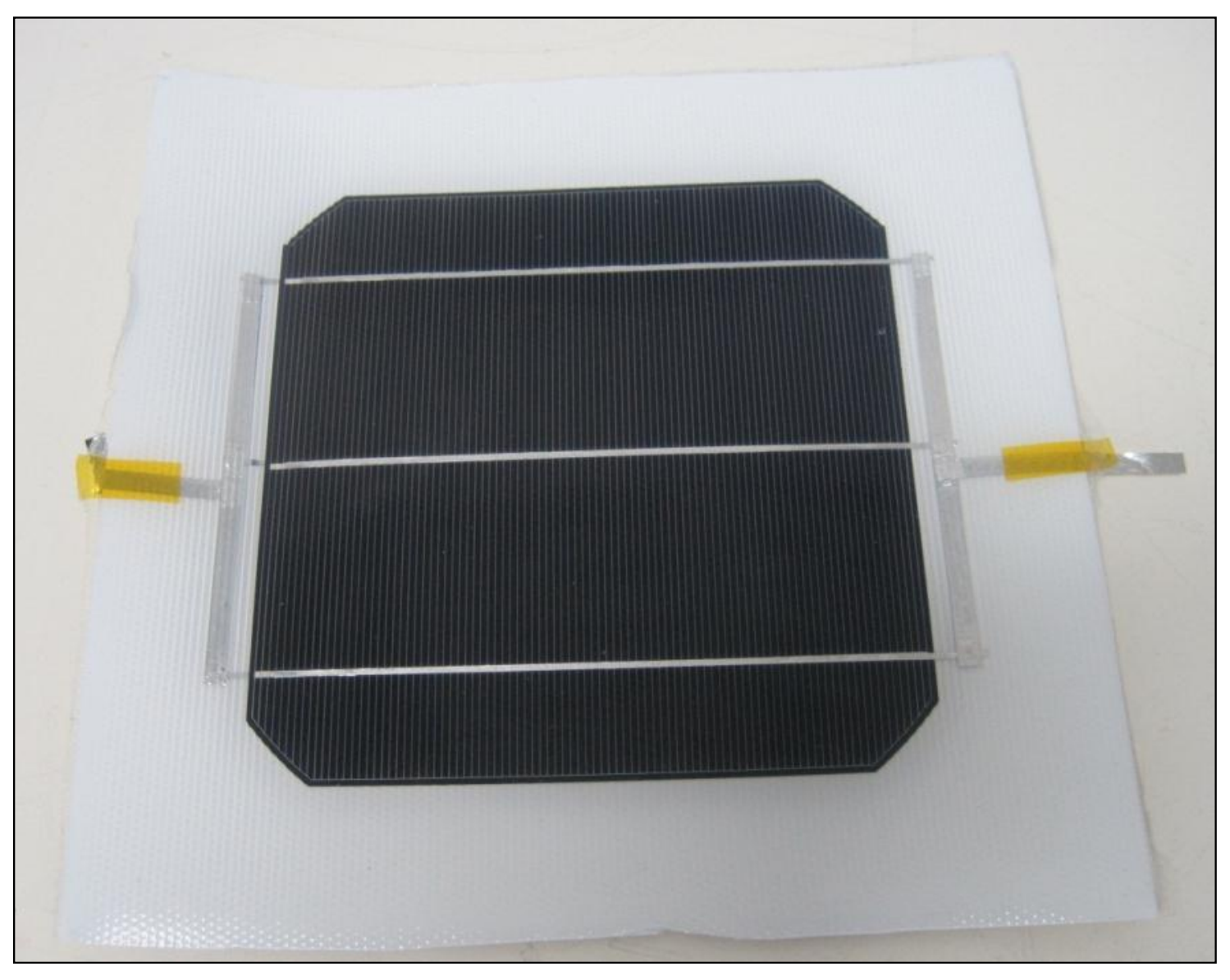

Figure 2: Sample 15 prior to testing !

TEST SETUP

Each sample was characterized by IV testing and EL imaging prior to hail testing. Hail impact testing was conducted using a hail launching apparatus compliant with IEC 61215/61646 Clause 10.17. The launcher was used to propel 25mm diameter hail stones at a velocity of 23 m/s. Each sample tested was struck with a single hail stone at the center of the cell. Samples were mounted against either 5mm fiberglass board representing a rigid structural backing (Figure 5) or 3mm neoprene layer over a 5mm fiberglass board representing a soft or compliant structural backing (Figure 6).

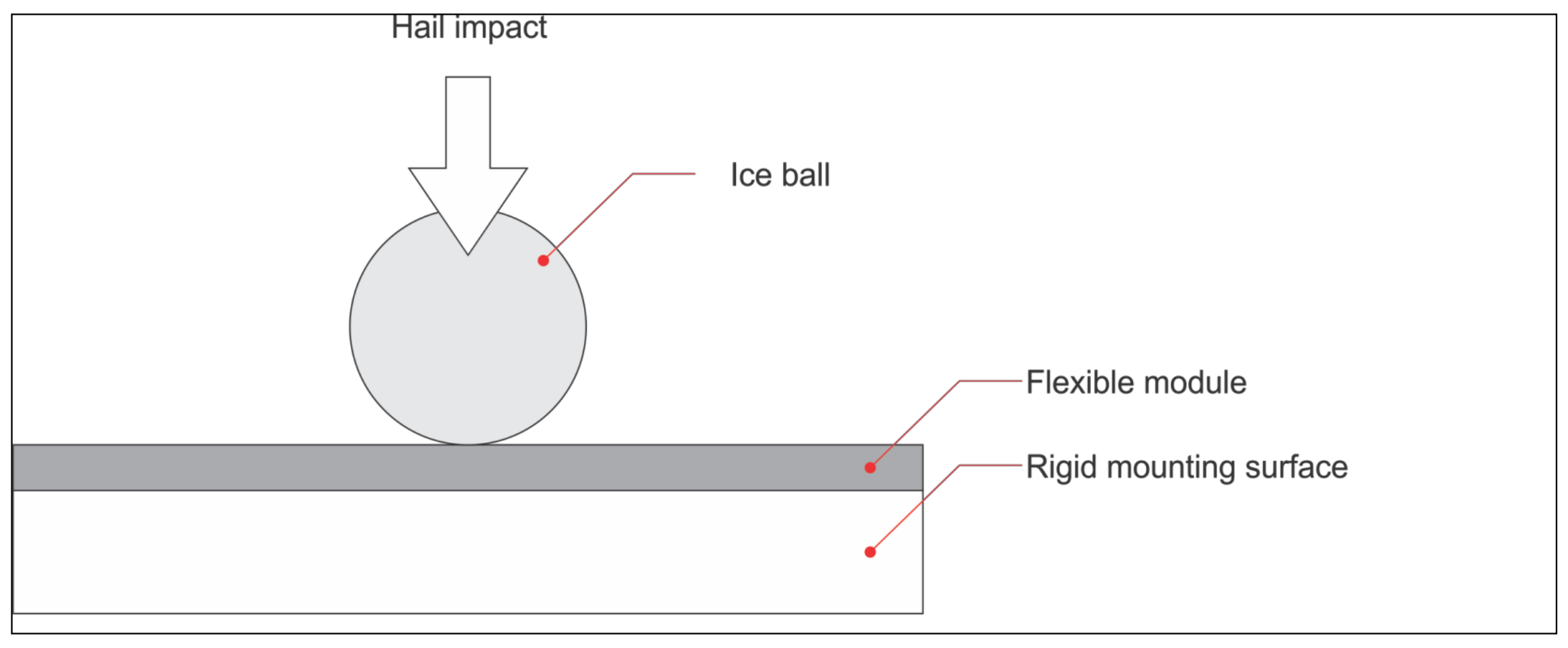

Figure 3: Impact deformation of sample struck against rigid mounting surface !

Figure 5: Rigid backing test setup !

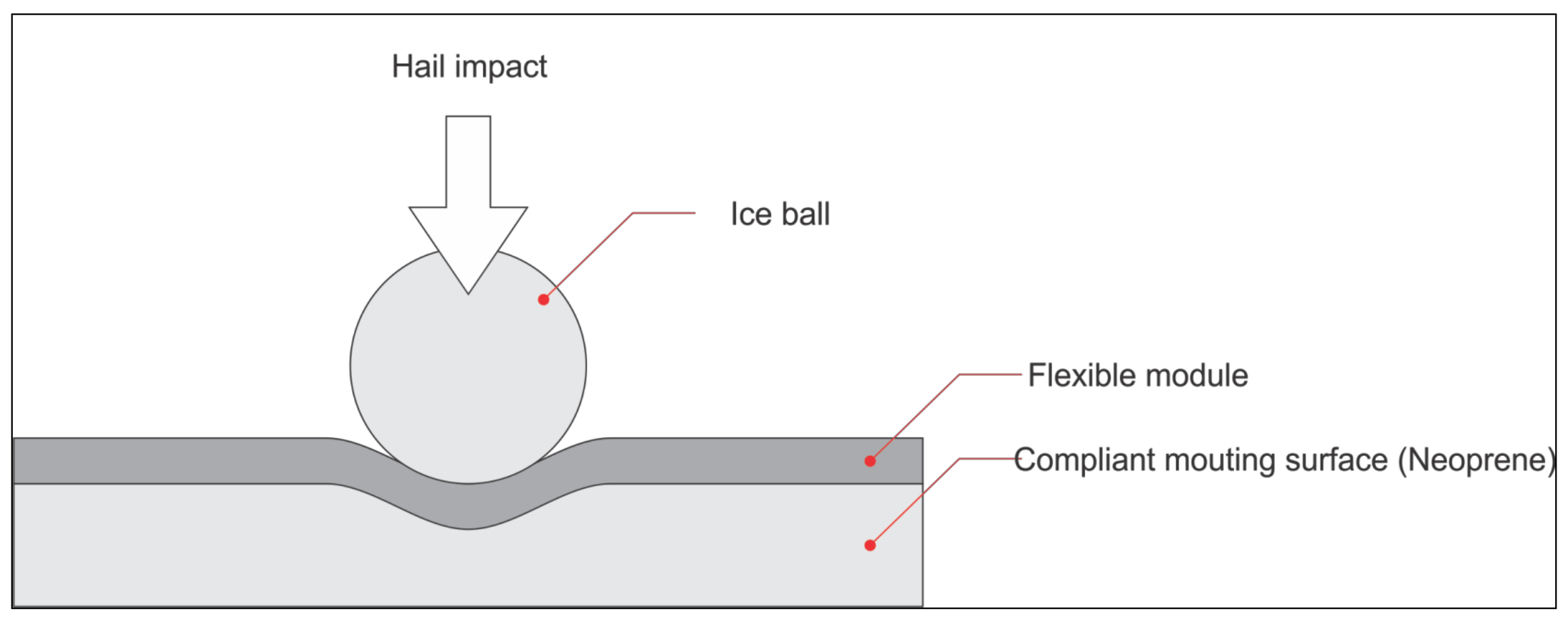

Figure 4: Impact deformation of samples struck against soft backing surface !

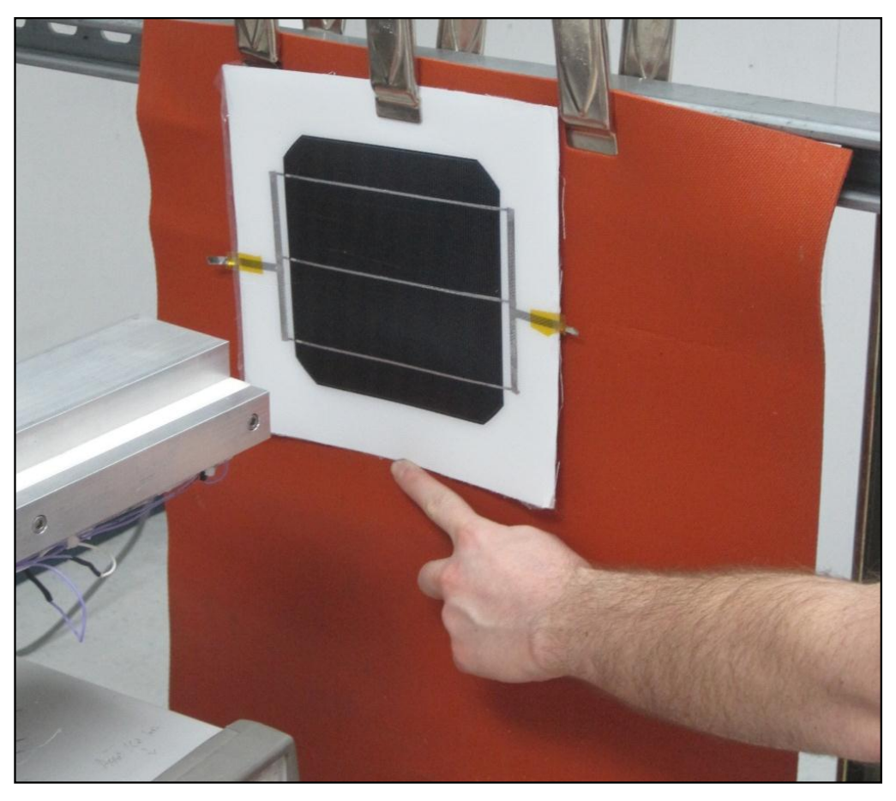

Figure 6: Soft backing test setup !

RESULTS

Changes in sample efficiency grouped by variable are plotted in Figure 7. EL images of the samples post-hail impact are shown in Figure 9. Samples with glass substrates showed the best resistance to damage caused by hail impact. Flexible samples constructed with 1.0mm total encapsulant thickness saw a 41% average decrease in power output; cells with 2.5mm or 4.0mm of total encapsulant saw a 21% average decrease in power output. Of the samples with 2.5mm of total encapsulant the samples with 2.0mm front layers and 0.5mm back layers had an average power decrease of 24%, where the samples with 0.5mm front layers and 2.0mm back layers had an average power decrease of 17%.

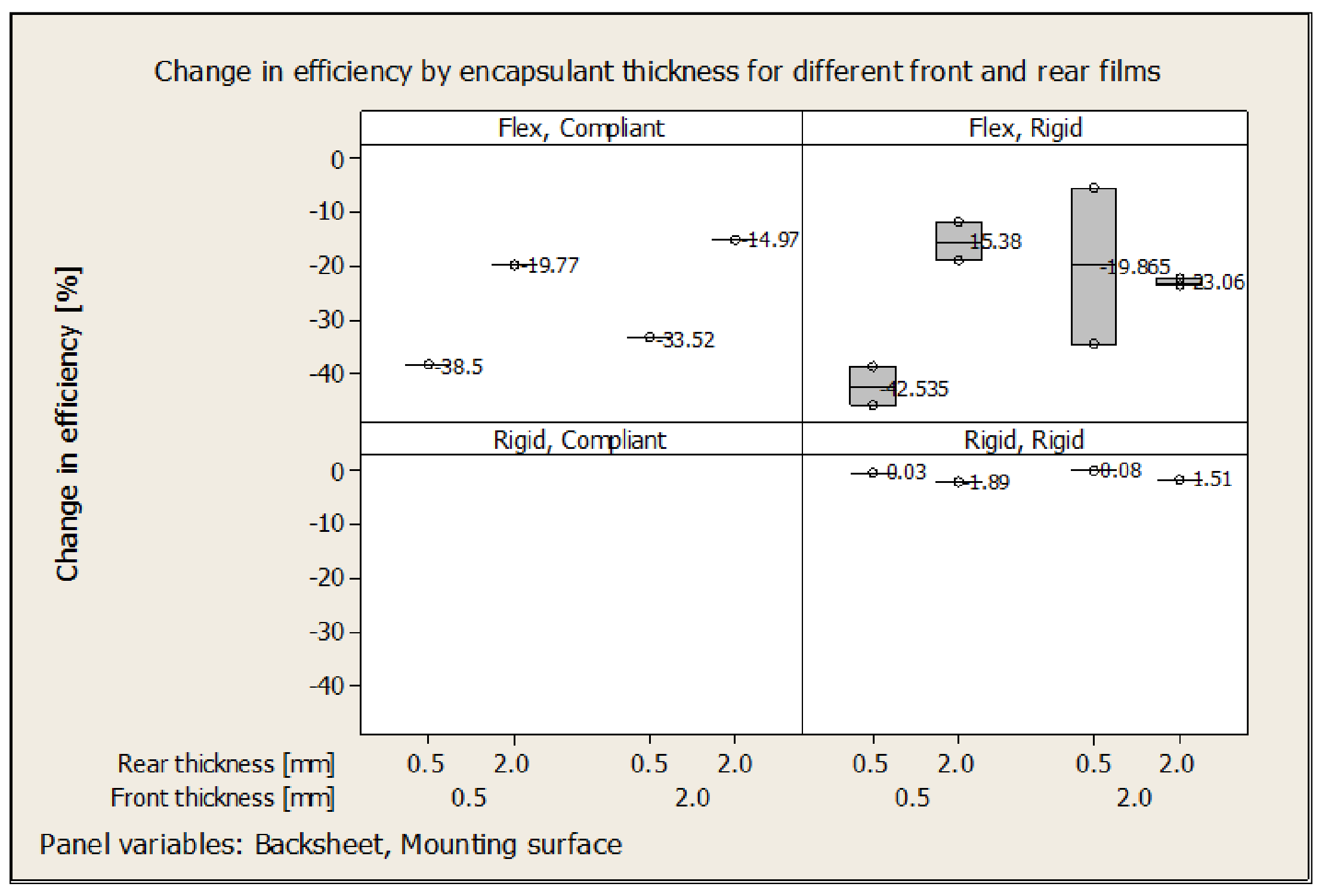

Figure 7: Pre and post hail efficiency data, grouped by total package thickness and impact backing !

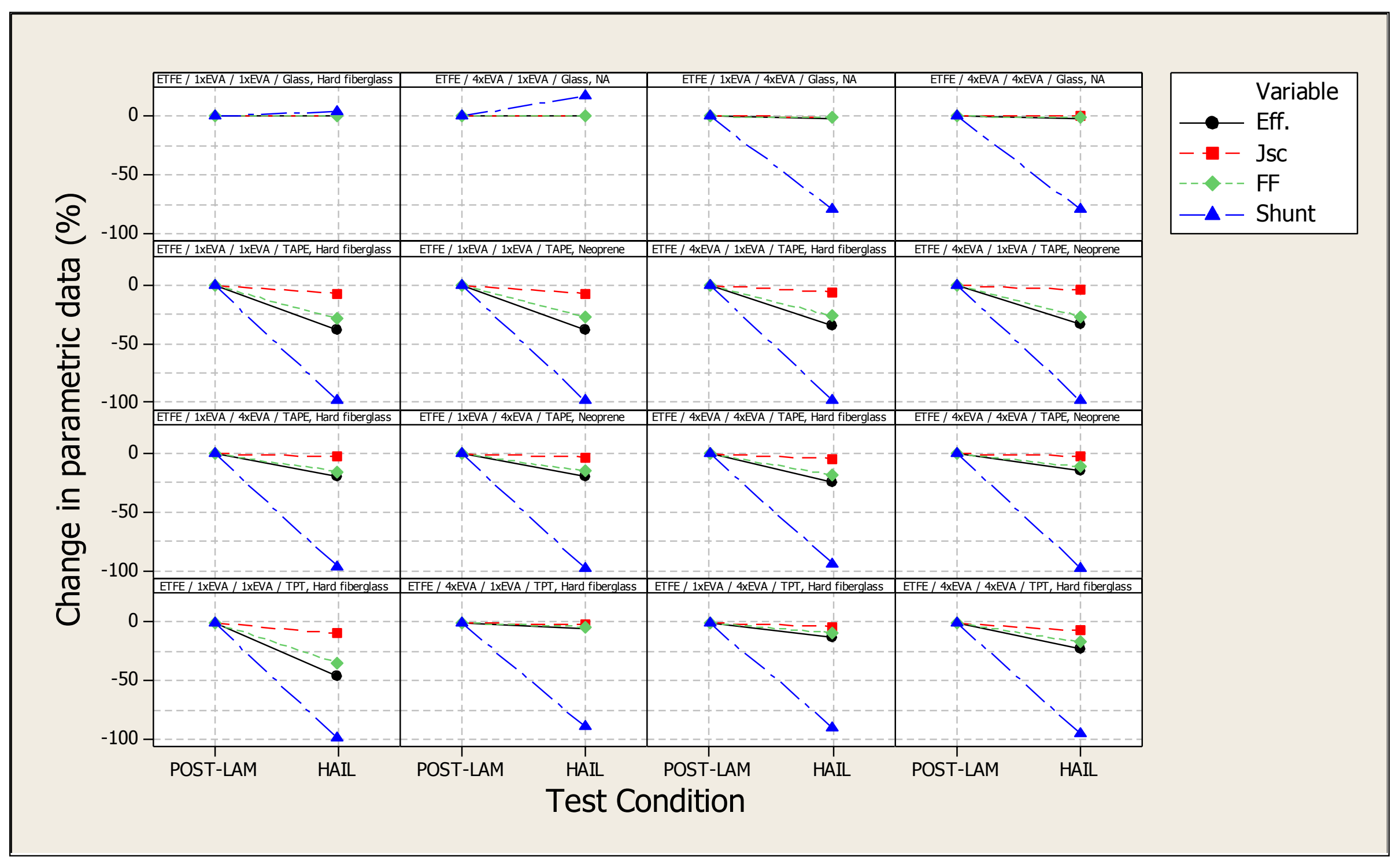

Figure 8: Pre and post hail performance data

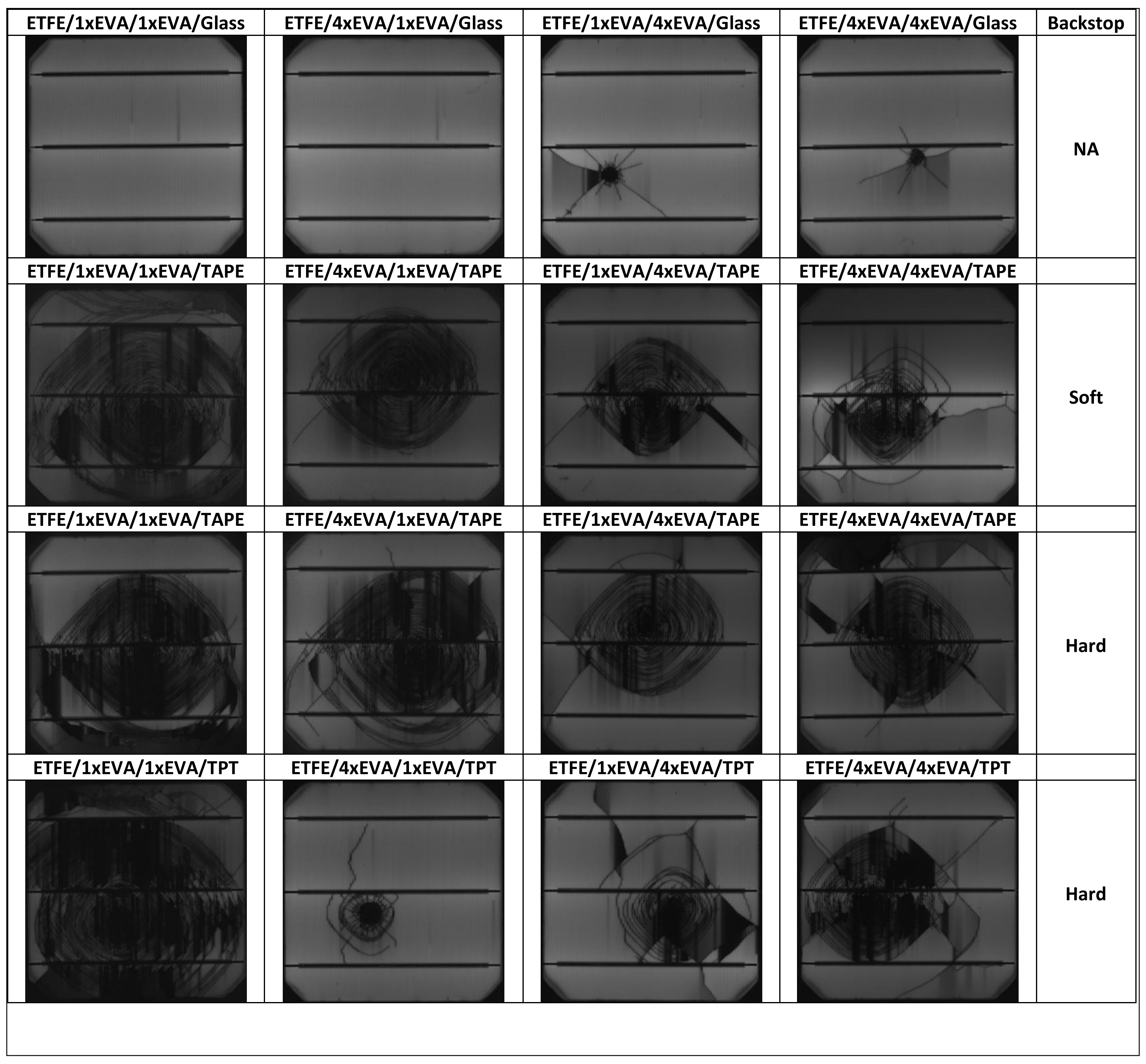

Figure 9: Post hail impact EL images

CONCLUSIONS

For semi-flexible modules, hail impact resistance may be improved by using a rigid substrate with minimal encapsulant behind the cell to minimize cell flexure. For flexible modules, increasing the encapsulant thicknesses particularly behind the cell can mitigate some of the damage caused by impact.

Based upon this study hail and mechanical impact resistance will prove to be a reliability challenge for c-Si modules with flexible packaging.