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Effect of Temperature on the Response of PV Modules to Mechanical Stress

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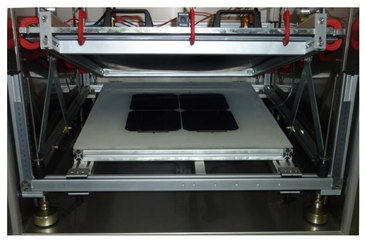
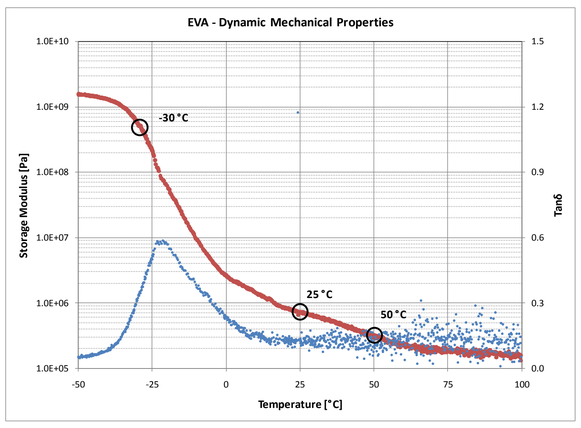
MOTIVATION

The crystalline silicon photovoltaic (PV) module is a laminate assembly composed of materials with widely varying mechanical and thermal properties. The properties of these materials are important factors influencing the performance and reliability of modules following exposure to external mechanical stress. In particular, a key role of encapsulation is to protect the solar cells from external stresses, yet some encapsulant mechanical properties can vary with temperature. Since current mechanical loading tests for certification of PV modules are performed at room temperature, these tests may not adequately simulate or accelerate in-field mechanical stresses and failures. This work examines the impact on module performance and cell integrity of dynamic and static load testing at both high and low temperature using a custom-built mechanical testing rig capable of operating inside a climate chamber. The loading conditions were based on relevant qualification test standards and test modules were characterized for performance and damage using a solar simulator and electroluminescence imaging .

EXPERIMENTAL

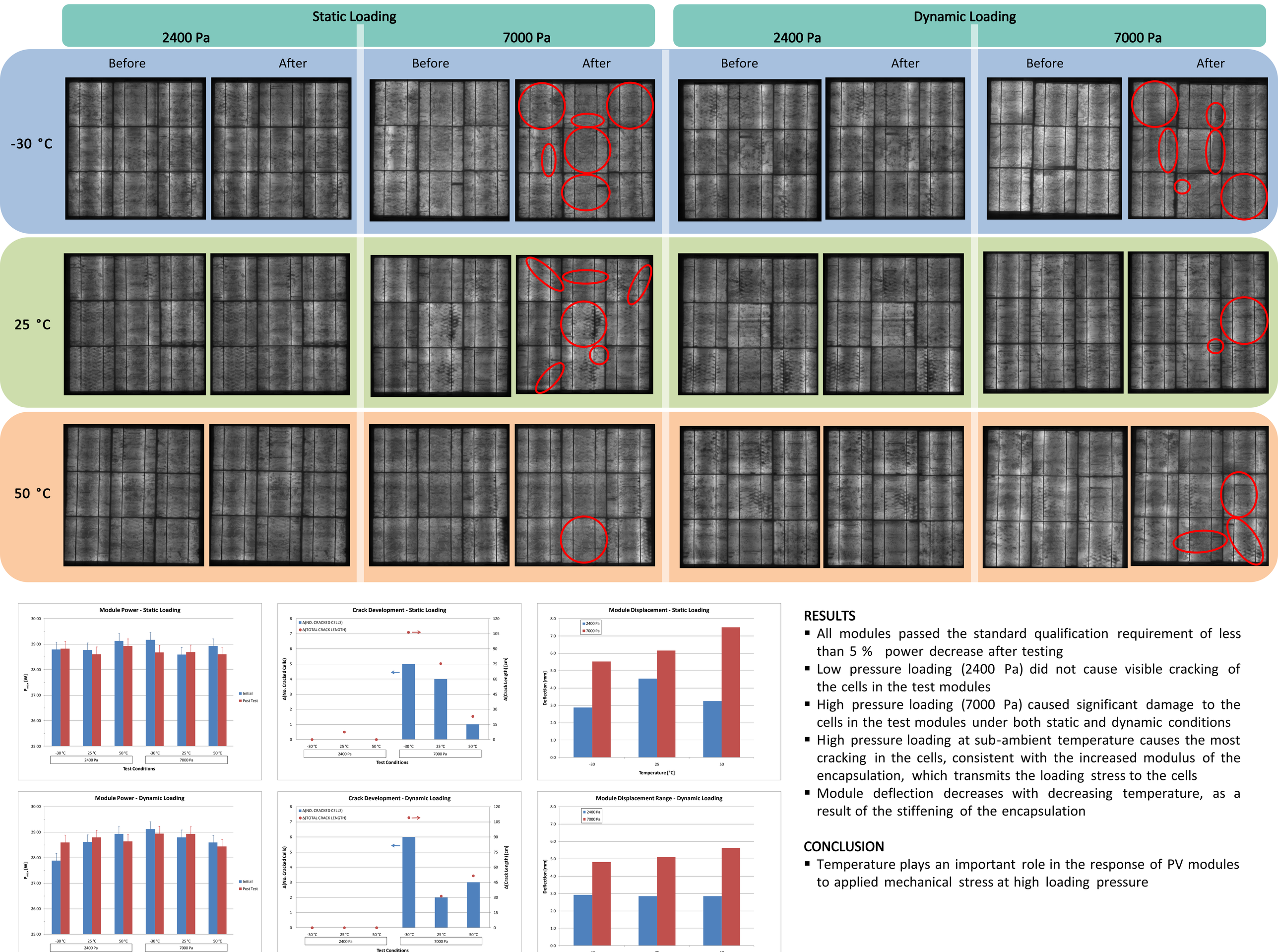


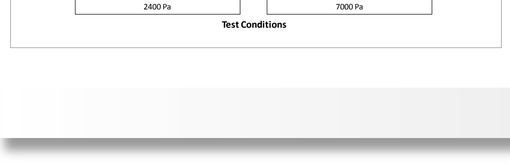
- Mechanical test stand designed and built to fit inside a climate chamber
- Elastomeric bladder applies uniform load from 2,400 Pa to 10,000 Pa
- Test modules with maximum dimension of 550 mm x 550 mm
- Flexibility in mounting configuration
- Deflection measurements using LVDT
- Static and dynamic loads (up to1 Hz)

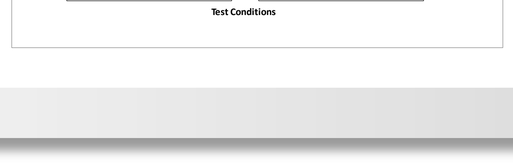


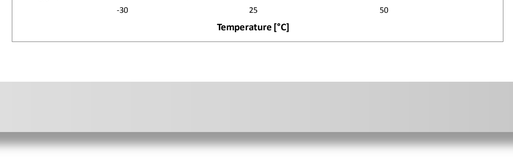
Experimental Test Parameters		
Modules	**Temperatures**	**Applied Loads**
Encapsulation:	-30 °C	Static:
EVA	25 °C	3 x 1 hr @ 2400 Pa
Backsheet:	50 °C	3 x 1 hr @ 7000 Pa
TPE		Dynamic (0.5 Hz):
Strings:		10 000 cycles @ 2400 Pa
3 x 3 -cell mc-Si		10 000 cycles @ 7000 Pa

- Module behavior was characterized before and after loading using electroluminescence and solar simulator
- EVA modulus changes by several orders of magnitude in the operating temperature range due to glass transition at around -20 °C









RESULTS

- All modules passed the standard qualification requirement of less than 5 % power decrease after testing
- Low pressure loading (2400 Pa) did not cause visible cracking of the cells in the test modules
- High pressure loading (7000 Pa) caused significant damage to the cells in the test modules under both static and dynamic conditions
- High pressure loading at sub-ambient temperature causes the most cracking in the cells, consistent with the increased modulus of the encapsulation, which transmits the loading stress to the cells
- Module deflection decreases with decreasing temperature, as a result of the stiffening of the encapsulation

CONCLUSION

- Temperature plays an important role in the response of PV modules to applied mechanical stress at high loading pressure