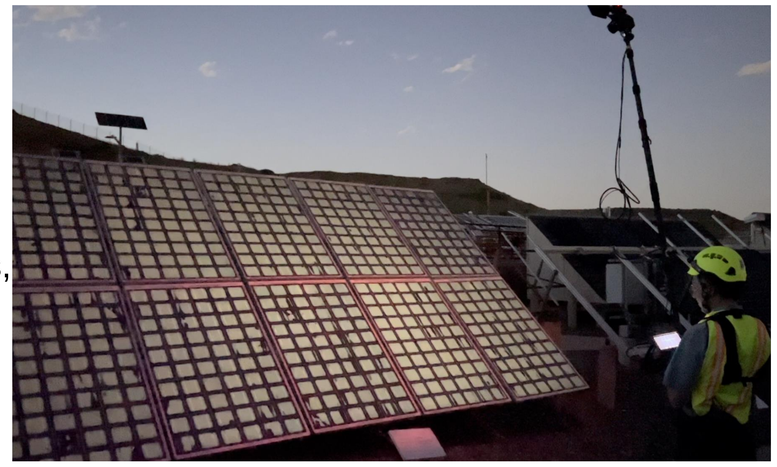
UV Fluorescence Imaging for Solar Panel Product Development and Durability Testing

Andrew M. Gabor[1], David C. Miller[2], Rachael L. Arnold[2], Michael Owen-Bellini[2], Todd Karin[3]
[1]BrightSpot Automation, Boulder, CO, USA [2]NREL, Golden, CO, USA [2] PVEL, Napa, CA, USA

1. Background

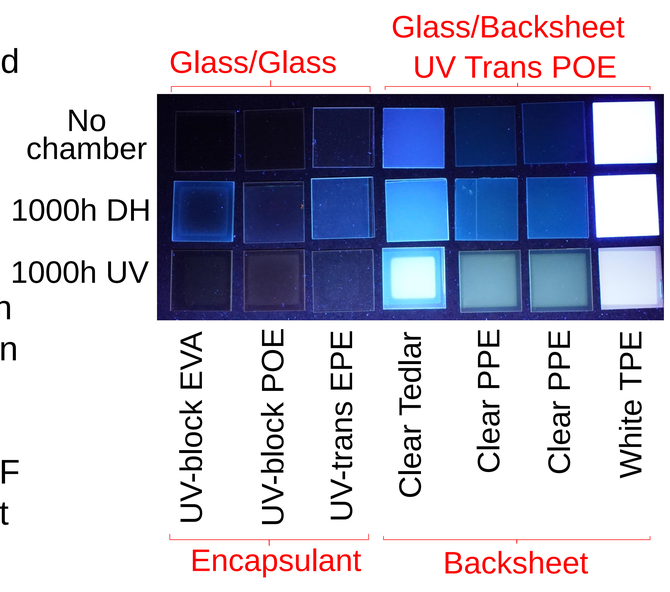
- UV Fluorescence (UVF) is a known technique for **outdoor imaging** of aged solar panels to see problems such as 1) Cracked Cells, 2) Hot Spots, 3) Sealing problems, 4) Gridline corrosion, and 5) Bill of Materials Variations
- What about **indoor applications?**



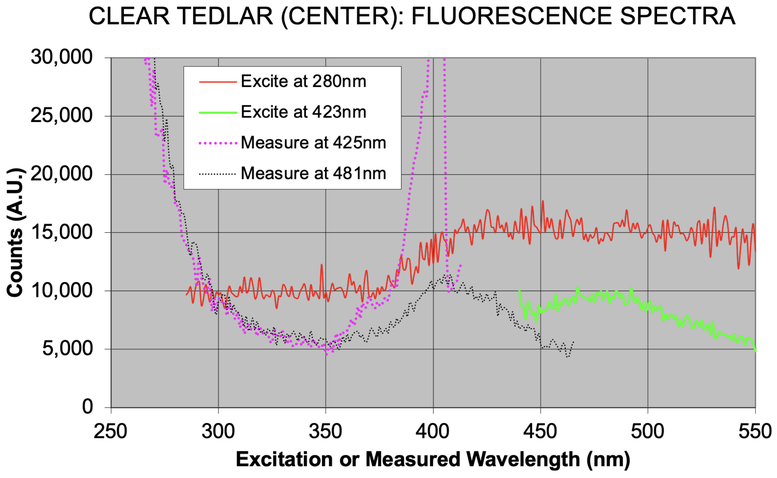
- UVF signal strength tends to improve the longer the field exposure time due to exposure to heat and the sun's UV rays
- Oxygen activity tends to quench the UVF signal
- Environmental Chambers can also provide heat or UV exposure to evolve the fluorescence of the encapsulant layers and allow oxygen/moisture ingress so that defects can be seen
- We explore here the **pre-shipment opportunities for using UVF in product development, durability testing, and quality control**

2. Experiment – UV & Damp Heat Coupons

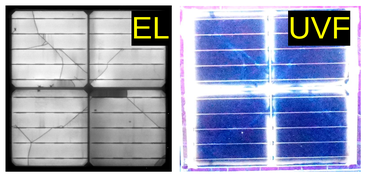
- 3" Coupons were made with a range of different encapsulants and backsheets and placed in a Damp Heat or UV Chamber
- A BrightSpot UVF Flash Camera system was used to image coupons
- The UV Fluorescence evolved with both types of chamber exposure, in some cases with noticeable edge effects
- Demonstrates the potential for UVF to be used in product development and to see sealing problems
- Possible follow-on studies: Break glass? Cut backsheet? Other?



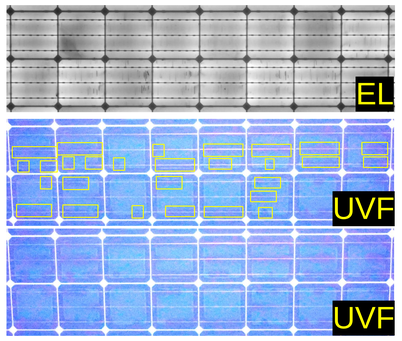
- Fluorescence spectroscopy can be used to help us design customized light sources with an optimal excitation spectrum to maximize the signal for a particular application
- Can also inform the filters needed on the camera



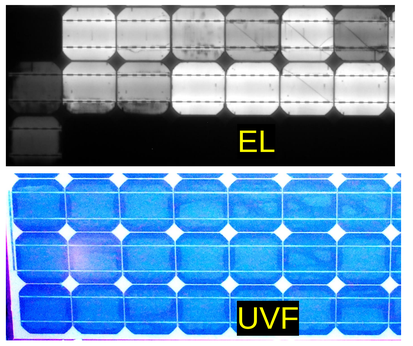
3. Chamber Aged Modules & Mini-Modules



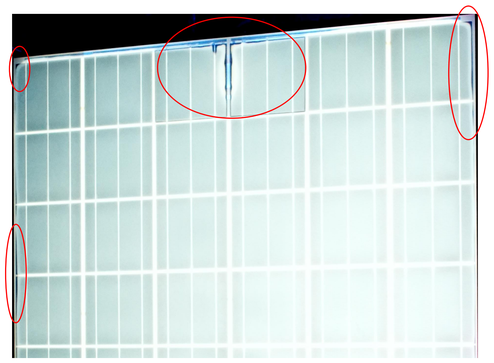
- Combined Accelerated Stress Testing (CAST) can lead to UVF patterns that reveal the cell crack location (source: Peter Hacke)



- LETID chamber testing can lead to UVF patterns that reveal the locations of **"hidden" cracks under wires that cannot be seen in EL images**



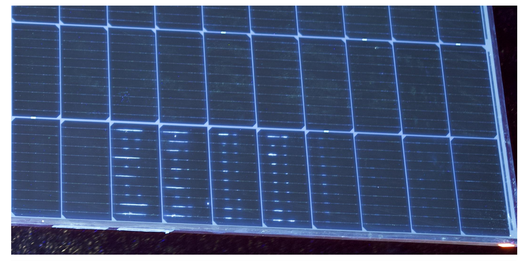
- PID chamber testing can lead to "dark cells" in the EL image where other defects are obscured, while in the UVF image, all cracked cells are easily seen

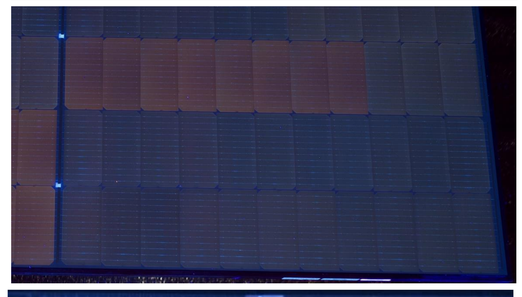


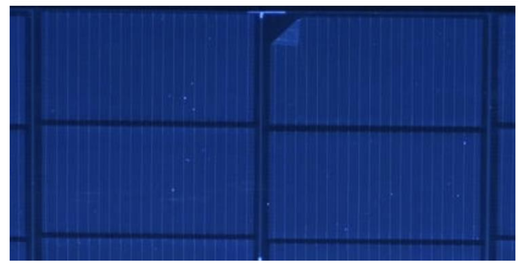
- Damp heat chamber testing can lead to UVF patterns where **sealing problems** at the junction box penetration and the perimeter edges can be easily seen. Technologies that are particularly sensitive to sealing failure such as **Perovskites may find this technique valuable for product development**. The use of strongly fluorescing encapsulants specifically for product development may be helpful in solving such problems.

4. Pre-shipment Quality Control

- A wide variety of product variations can be seen in UVF images of finished modules prior to shipping including encapsulant and backsheet type, and other variations shown here
- UVF images can be easily taken at same time as IV or EL images
- **Review of factory UVF images could be required by sophisticated module buyers to ensure they are receiving consistent product with a single Bill of Material for a particular project to reduce performance risks**
- AI software could automate the review of these images by the module buyers or their auditing partners







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