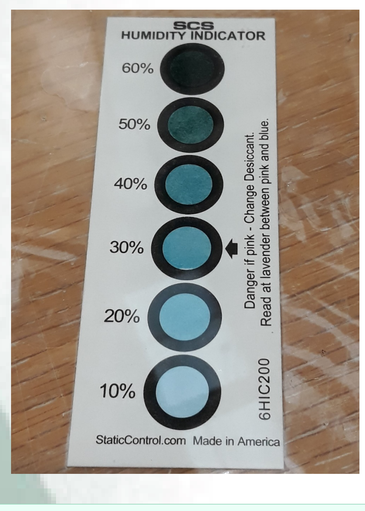
Direct Measurement of Moisture Ingress in PV Laminates

Nikoleta Kyranaki*[1], David C. Whalley[3], David A. Hutt[3], Ralph Gottschalg[2], Thomas R. Betts[1]
[1]Centre for Renewable Energy Systems Technology (CREST), [3]Wolfson School, Loughborough University, United Kingdom
[2]Fraunhofer Center for Silicon Photovoltaics CSP, Halle, Germany
*N.Kyranaki@lboro.ac.uk, +44 (0)1509 227161

Introduction

- PV modules installed in the field are exposed to various environmental conditions that can lead to different types of performance degradation and, ultimately, failures.
- Moisture ingress is a particular issue and therefore its measurement and prediction is very important.
- This work demonstrates a novel method to measure moisture ingress into PV laminates, through the use of humidity indicator cards encapsulated within the structure.
- The successful implementation of this work will enable the future quantification of the moisture that accumulates at the front side of PV cells, thereby providing a better understanding of degradation models related to corrosion.

Humidity Indicator Cards

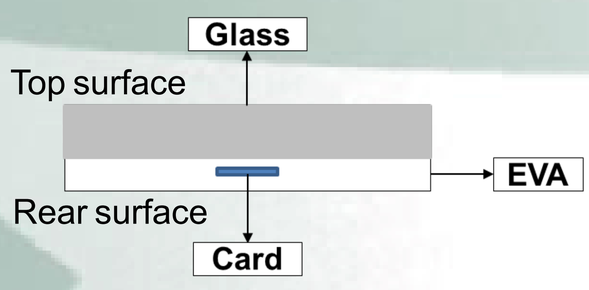


- The humidity indicator cards include dots constructed from blotting paper impregnated with cobaltous chloride, which is sensitive to moisture.
- Each dot has a different concentration of cobaltous chloride and is designed to indicate a different level of humidity [1].
- Measurement of more moisture levels can be achieved, as the colour of the dots changes gradually over a range of humidity levels.
- The dots designed to indicate 40, 50 and 60% humidity were studied to be able to monitor the wide range of values required.

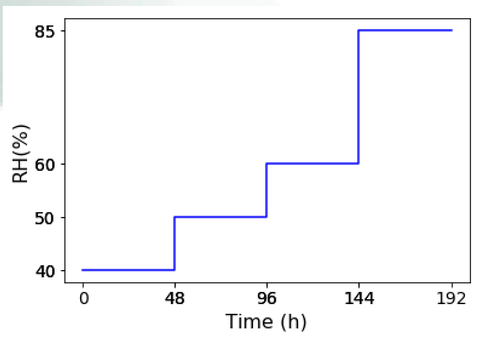
Calibration Procedure

- To match the colour changes to specific levels of humidity, a detailed calibration was performed.
- Laminates with the structure shown below were stabilised (for 48 hrs) in an environmental chamber (85°C) at increasing levels of relative humidity (RH).
- The colour change of the humidity indicator cards corresponding to the relative humidity inside the chamber was then plotted on RGB colour space diagrams.

Structure of samples

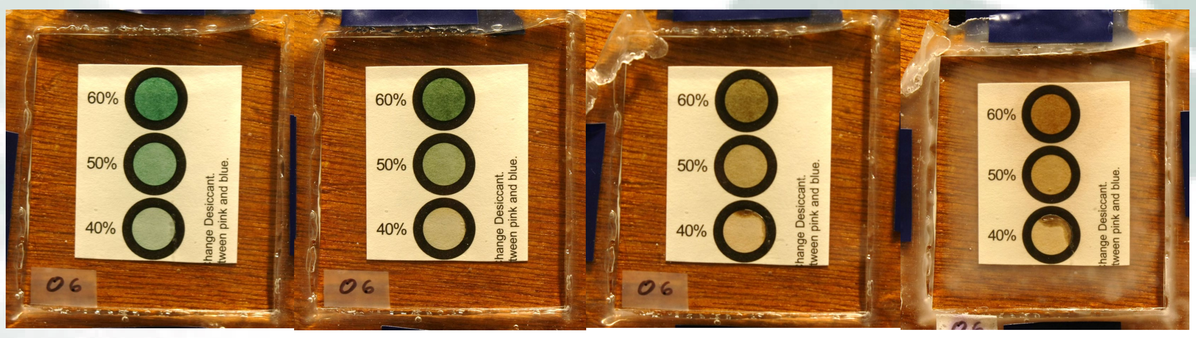


Chamber conditions (T= 85°C)



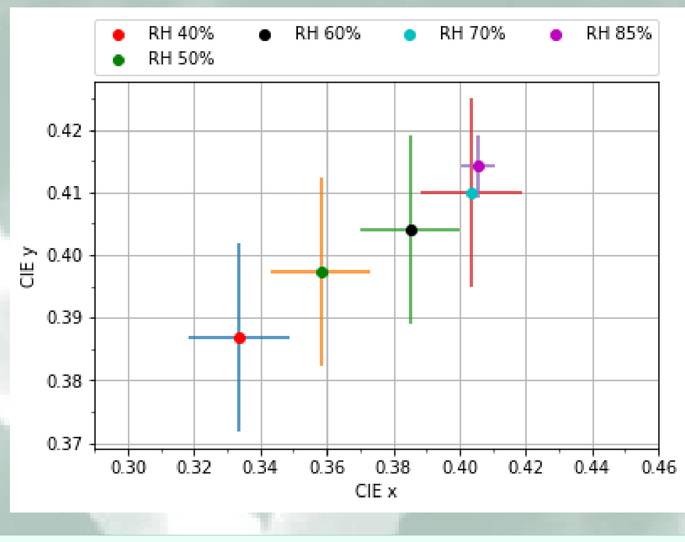
Calibration Results

- The samples were photographed using a standard configuration and the variance of the colour of the encapsulated humidity indicator cards for each RH level of the calibration (40%, 50%, 60% and 85%) is presented below.
- The 40% indicator dot changed colour before the 50% and 60% dots. This is thought to be due to the cobaltous chloride concentration in each dot.
- The dots continued to change colour even if they exceeded the upper humidity limit that they were designed to indicate.



- The graphs below show the average x and y 2D colour coordinates after the transformation of the average RGB 3D coordinates, for the dot that can measure up to 50% humidity, at different RH exposure levels. This provides a calibration against which other samples can be compared.
- The preferred dot to be used for moisture measurements is the one that can measure up to 50% of humidity, as it combines smaller errors (±5%, comparable to the error of a digital sensor ±3.5%) and sufficient range (x axis between 0.333 and 0.406) .

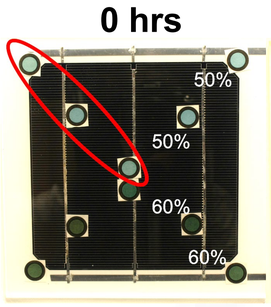
Dot 50%



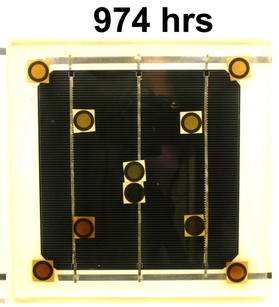
Application in Single Cell PV Modules

- Indicator dots for 50% and 60% humidity were embedded at the front side of a PV cell and then encapsulated into a PV module.
- The sample was aged under 85% RH / 85°C for up to 1763 hrs.
- The images below show the change in colour of the dots with exposure time and the colour analysis of the dots indicated.
- It was noticeable that after 503 hrs of exposure, the moisture level at the corner of the PV cell was around 70%, while the inner dot indicated 60% humidity with the central dot at only 40%. After 974 hrs, both the dot at the corner and the inner dot were saturated and the central dot showed 70% humidity. Finally, after 1763 hrs, the whole front side of the cell was saturated.

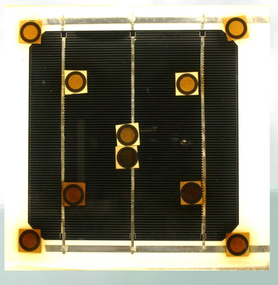
0 hrs

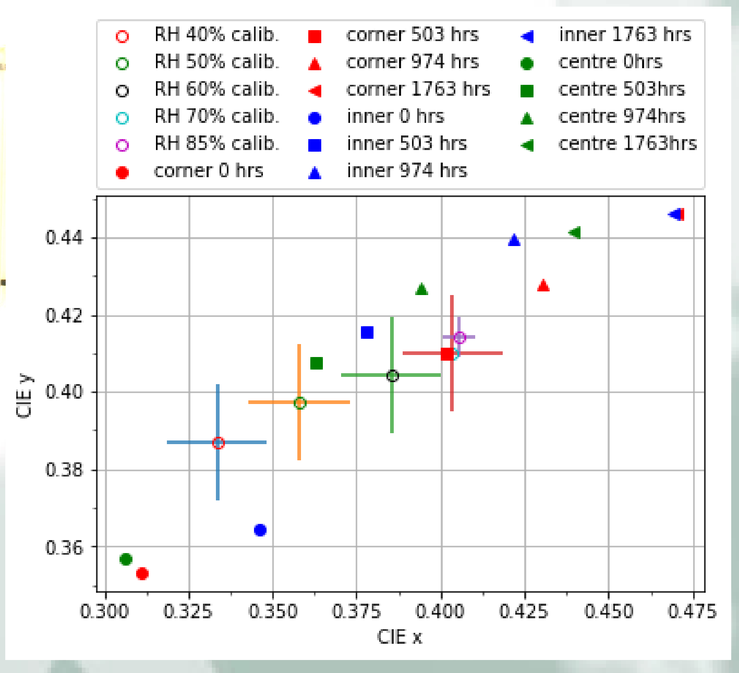


974 hrs



1763 hrs





Conclusions

- The purpose of this ongoing study is the development of a novel measurement method to determine the moisture that accumulates at the front side of PV cells within a laminate structure.
- The potential for humidity indicator cards to be used as a method to quantify the moisture level in laminates was demonstrated and also applied to a PV module.
- A method to calibrate the colour change of the indicator cards and convert the results to a 2D format was developed.
- The variation of the colour parameters with the RH exposure was found to follow an approximately logarithmic behaviour, but further research is needed, such as measurement of more moisture points and fitting, to confirm this.
- Further work is underway to understand the interaction of the humidity indicator cards with the EVA under long term damp heat exposure, to investigate the further colour change of the dots encapsulated in the PV module after saturation.

Reference

[1] 3M™ Humidity Indicator Cards (HICs) datasheet, [Online]. Available: https://docs-emea.rs-online.com/webdocs/1446/0900766b81446f54.pdf [Accessed: 15-Aug-2019]

Loughborough University

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