

Materials Test Coupon Fabrication and Stress Testing

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Overview

Under the PV module reliability effort, NREL has developed a number of capabilities to construct and evaluate module packaging materials. These can be in the form of mini-modules or of sample coupons.

Once samples are constructed we have a number of environmental and weathering chambers that apply thermal, humidity, voltage, or ultraviolet light stresses to materials to evaluate their long term durability. All these stresses can be applied at the same time, separately, or any combination thereof and at varied set points in different environmental chambers.

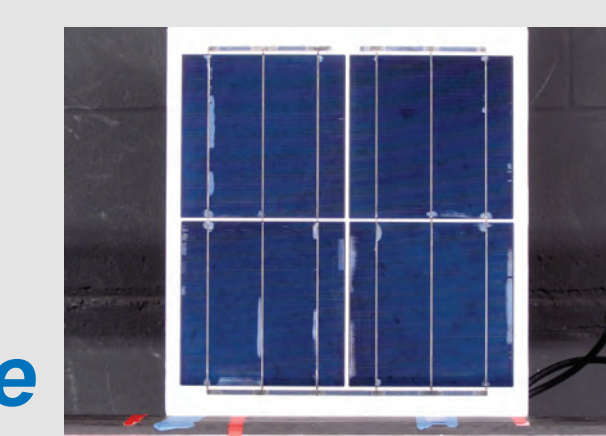
We have a large number of measurement techniques to evaluate the durability of materials. This includes evaluation of mechanical, optical, thermal, and permeation properties of materials. With careful evaluation of properties, performance can be extrapolated to outdoor environments.

Laboratory Laminator

We have a laminator capable of making mini-modules or module components for test with up to 16, 156 mm cells. Frequently we make single cell test specimens because they are easier to manage and enable testing of larger numbers of samples to improve the statistics of an experiment. Alternatively we make coupons without PV cells to evaluate packaging materials alone. This laboratory laminator provides the ability to construct a number of convenient sample sizes for evaluating many aspects of module construction.



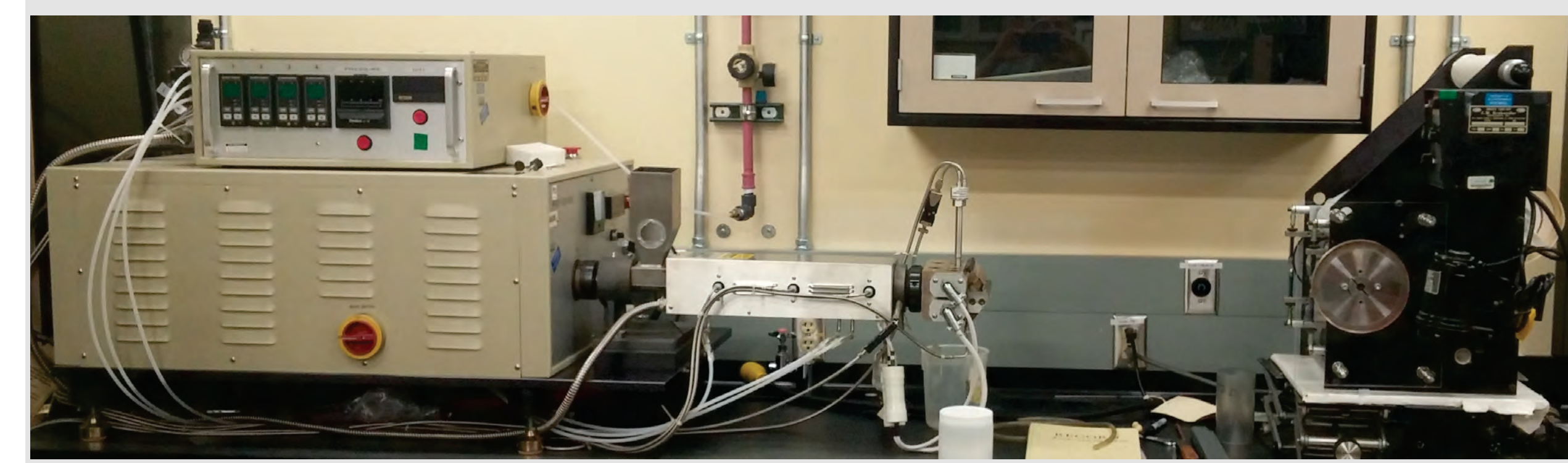
Laminator



4-Cell Minimodule

Polymer Extruder

Our extruder creates encapsulant films with customized stabilization packages to elucidate the degradation processes in polymeric materials. Or it can create encapsulants with unique mechanical, moisture ingress, optical, or adhesion properties. This extruder can also reproduce vintage encapsulant formulations which are no longer available. This gives us great flexibility in our evaluation of polymeric module components.

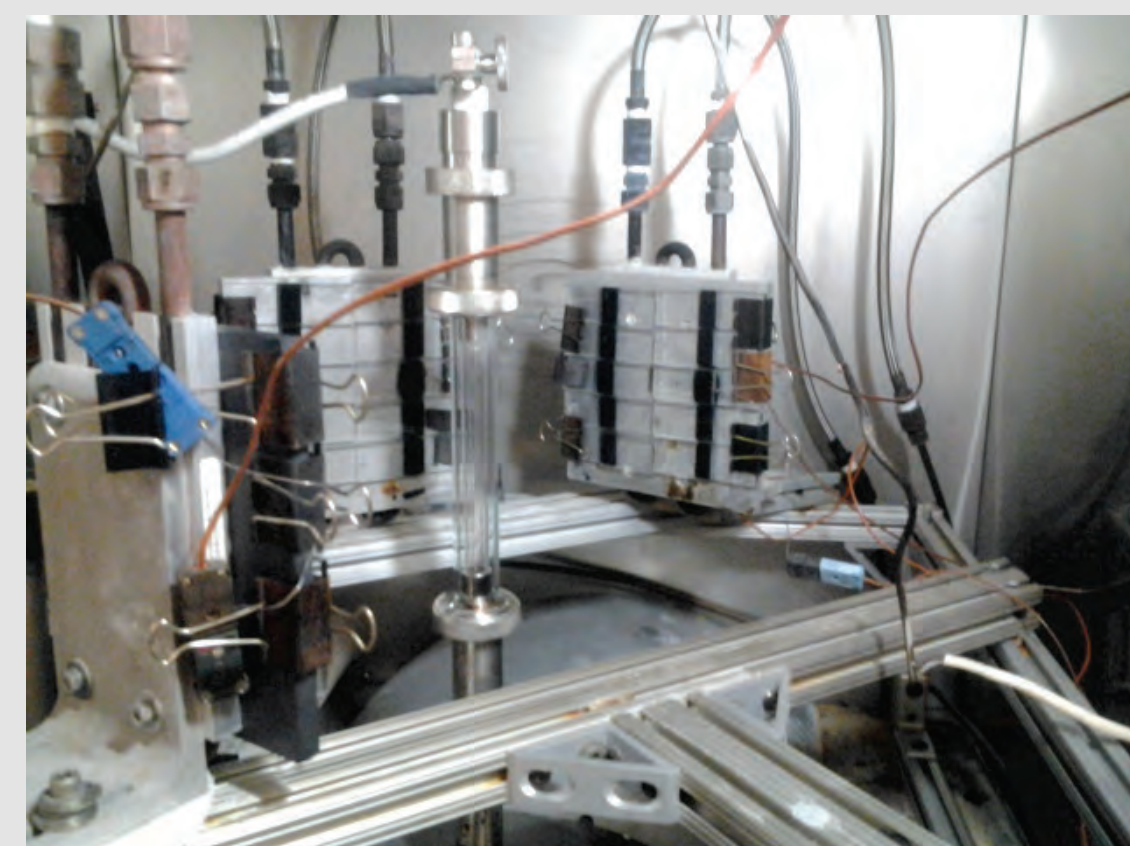


Accelerated Stress Testing

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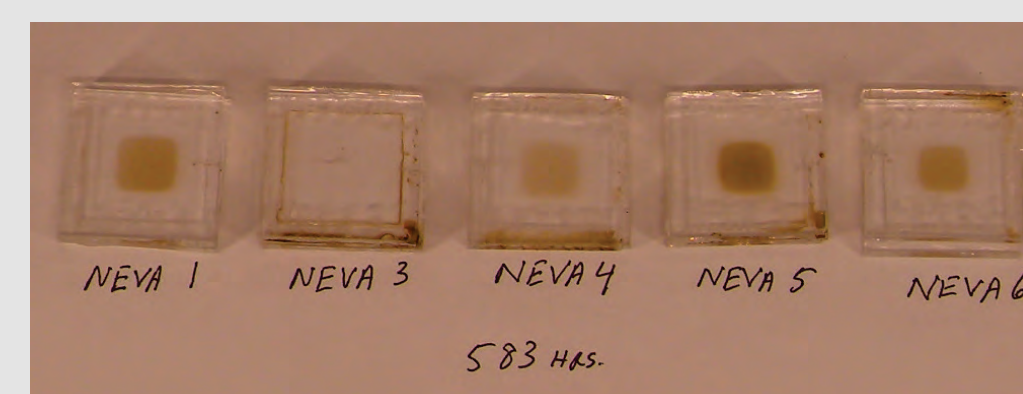
One of many Weather-Ometers capable of exposing samples to controlled irradiance, temperature and Humidity.



Custom High irradiance exposure equipment (up to 10 suns) with 4 individually controlled temperature plates.

Materials Evaluation

Comprehensive testing under multiple conditions is needed to be able to evaluate the dependence of degradation on different stressors to enable extrapolation of performance down to the field conditions.



Different EVA formulations exposed to the same conditions used to compare their performance.

Chambers for exposing materials to controlled temperature and humidity or to thermocycling.

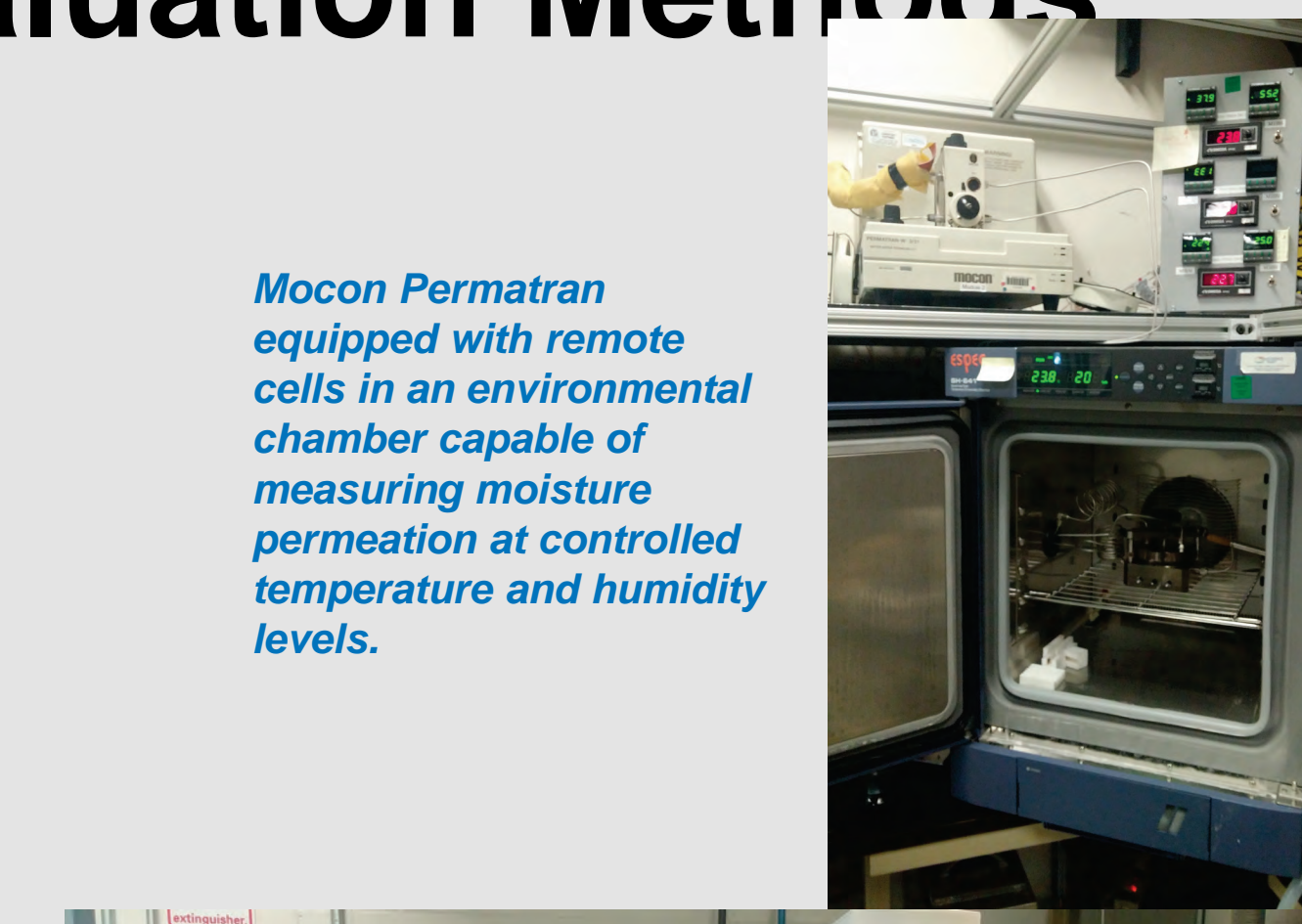


Resistivity measuring equipment placed in a humidity chamber to enable measurement of resistivity at controlled heat and humidity.

Materials Evaluation Methods



Instron puller for measuring adhesion or mechanical properties of materials.



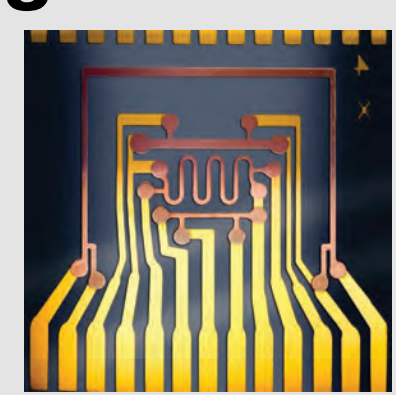
Mocon Permatran equipped with remote cells in an environmental chamber capable of measuring moisture permeation at controlled temperature and humidity levels.



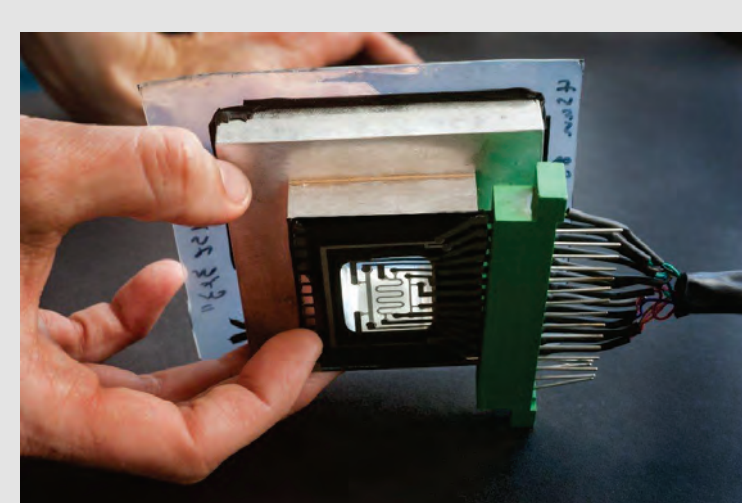
TA Instruments rheometer used for measuring the mechanical moduli of PV materials.

Moisture Ingress Measurement

With many PV technologies moisture ingress is problematic and must be reduced or eliminated. We have several Mocon permeation measurement instruments useful for determining the diffusivity and solubility of water in packaging materials. We also have a custom built instrument capable of measuring permeation rates around 10^{-6} g/m²/day. This is a unique instrument based on a patented method where the resistivity of Ca traces changes are used as an indicator for moisture ingress.



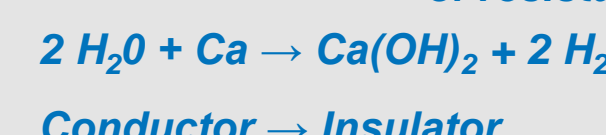
Test card with Ca traces for which resistance changes are used to measure moisture permeation rates.



Ca-test card attached to edge card connector for measurement of resistance changes.

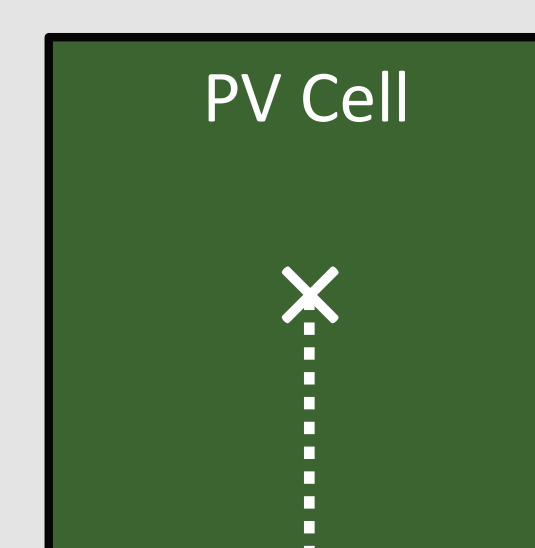
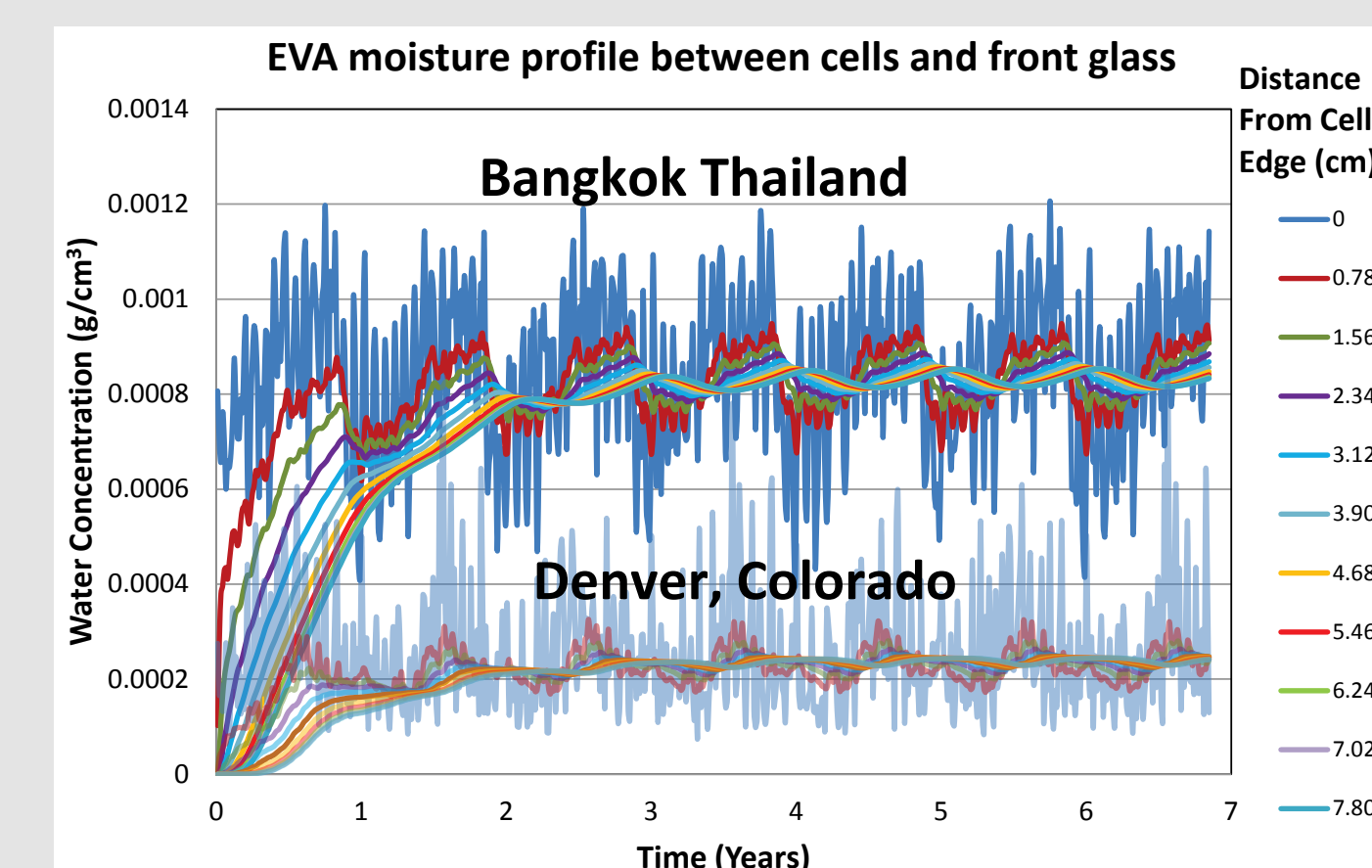


Chamber equipped for simultaneous measurement of up to 32 films at once.



Environmental Characterization

Using the transient permeation profile of polymeric materials, one can extract the solubility and diffusivity of water in the various PV components. This can then be used to determine the amount of moisture in a PV module as a function of time, location, and position within the module. An accurate understanding of the exposure conditions is needed to evaluate degradation kinetics.



Profiles along this line are plotted.

Overview

NREL has access to a large number of materials preparation and evaluation equipment suitable for test PV packaging materials.

- Custom Construction of material specimens or mini-modules.
- IV curve measurement
- Surface and Volume Resistivity of materials
- Hail Ball impact
- Rheometry and mechanical properties
- Adhesion
- Differential Scanning Calorimetry (DSC)
- Thermogravimetric Analysis (TGA)
- Moisture Permeation
- Optical Spectroscopy
- Fourier Transform Infrared-Attenuated Total Reflection spectroscopy (FTIR-ATR)
- And much more