Physics of Reliability White Paper

Photovoltaic modules are exposed to severe operating conditions involving temperature, thermal cycling, UV radiation, humidity, environmental weathering, electrical and other stresses. Limited understanding exists on the fundamental degradation mechanisms and how to quantify the service life for encapsulants, solders, interconnections, semiconductor layers, etc. under single or combined stress conditions. Department of Energy's SunShot Initiative envisions possibly having a program to develop physics and mechanistic based understanding of degradation in PV modules. Life prediction based on physics based modeling of degradation mechanisms such as fatigue, creep; diffusion of impurities, drift, moisture diffusion, etc. needs to be developed. It is also very important to understand phenomena like soiling and the effects of shading on degradation rates.

We would seek to fund projects developing fundamental understanding of die attach failures, optics degradation of CPV, encapsulants degradation, semiconductor degradation, moisture sensitivity, etc. Research will establish correlation between degradation mechanisms and lifetime based on test structures, laboratory scale devices or modules depending on the failure mode of interest. The goal is to correlate degradation mechanisms to basic material and device properties to develop early indicators and advanced predictive testing with physics based acceleration factors. Degradation models validated by experimental data also need to be developed.

A few examples of areas of interest are as follows (not a comprehensive list):

1. Packaging issues such as: encapsulation delamination, loss of hermeticity, solder joint and interconnect failures.
2. Metastability, increased recombination at main junction, increased back contact barrier height, shunting, de-adhesion and non-uniformity effects in thin film modules.
3. Weak diodes, shunt spots, moisture sensitivity of TCOs and main junction, etc.
4. Degradation mechanisms under combined stress testing.
5. Physics based models of degradation mechanisms and acceleration factors.
6. Correlation of process parameters with stability based on mechanistic understanding. Relationship between efficiency and stability.

Request for Information (RFI)

Physics of Reliability

Open Date: April 10, 2012
Close Date: 5PM ET, April 24, 2012

Subject: Request for Information on the identification and quantification of failure modes and their causes in photovoltaic technologies.

Description: The U.S. Department of Energy's (DOE) SunShot Initiative seeks feedback from industry, national laboratories, and members of academia relating to the physics of reliability in photovoltaic devices. Due to the wide diversity of deployment conditions for PV systems there exists a variety of failure mechanisms which prevent PV technologies from realizing their full potential. Inability to precisely identify and quantify these mechanisms reduces the capability to simulate real world conditions and provide accurate lifetime information to improve the testing, design, and bankability of PV products.

Questions

1. What are the primary failure (or long-term degradation) modes of c-silicon, thin films (CIGS, CdTe), and CPV?

2. For which failure or degradation modes are the underlying mechanisms not fully understood?

3. Are mechanisms of metastability in thin films understood? Is there a need for fundamental understanding of the same?

4. Which failure or degradation modes would you deem most critical to lifetime prediction?

5. Is there a role for government funding in physics of degradation or does industry have it covered?

6. How can information gathered about failure or degradation mechanisms be disseminated in a way in which individual products are not identified?

7. Beyond the latest model modules from industry, what would be proper materials or material systems to test?

8. How has the semiconductor industry come together to understand basic mechanisms of degradation?

a. **RFI Guidelines**

THIS IS A REQUEST FOR INFORMATION ONLY. THIS NOTICE DOES NOT CONSTITUTE A FUNDING OPPORTUNITY ANNOUNCEMENT (FOA). NO APPLICATIONS OR PROPOSALS ARE CURRENTLY BEING SOUGHT OR CONSIDERED FOR THIS ACTIVITY.

Parties interested in submitting a response to this RFI should review the RFI Guidelines in their entirety before developing and submitting a response. DOE will review and consider all responses in its formulation of program strategies or in potential FOAs. DOE will not reimburse costs associated with preparing any documents for this RFI. Information submitted may be used by SunShot on a non-attribution basis. No material submitted for review will be returned and there will be no formal or informal debriefing concerning the review of the material submitted. All feedback will be considered but SunShot will not respond to individual submissions or publish a compendium of responses. There is no guarantee that a project will be supported as a result of this RFI.

All responses to this RFI must be provided as an attachment (in Microsoft Word format, .doc or .docx) to an e-mail to PhysicsOfReliability@ee.doe.gov.

Respondents should not include any information in the response that might be considered proprietary or confidential but should you choose to do so all responses containing confidential, proprietary, or privileged information must be marked as described below and will not be released publicly. Responses to the RFI must be marked as follows and identify the specific pages containing confidential, proprietary, or privileged information:

> Notice of Restriction on Disclosure and Use of Data: Pages [___] of this document may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes or in accordance with a financial assistance or loan agreement between the submitter and the Government. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: “Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure.” In addition, every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked, for example with highlighting.

Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

Questions may be sent to PhysicsOfReliability@ee.doe.gov with the subject line “Question” before 5PM ET, April 17, 2012

Respondents should provide the following information in their response to this RFI:

- Company/Institutional Name
- Company/Institutional Contact
- Address, phone number, and e-mail address
- Brief description of the operations and mission of business or institution (a few bullet points will suffice).

Responses should be limited to five (5) pages. **Please connect your answers to the specific corresponding question.** Any additional comments that are not responsive to a particular question should be set out separately at the end of your response to this RFI as "Additional Comments."

SunShot thanks you for your assistance and comments in helping build the solar energy industry in the United States.