

PV Module Reliability Workshop – Silicon

Tuesday, February 28, 2012

Denver West Marriott, Golden, Colorado

Agenda

7:30 – Continental Breakfast

Feb. 28 Morning – Introduction

Chair: Sarah Kurtz (NREL), Jennifer Granata (Sandia National Laboratories)

8:00 – Brian Hunter (DOE) – Welcome and Purpose

8:10 – Kazuhiko Kato (AIST) – “PVResQ!” PV Module Failures Observed in the Field

Feb. 28 Morning – Safety

Chairs/Discussion Leaders: Jay Johnson (Sandia), Chris Flueckiger (UL)

8:40 – John Wohlgemuth (NREL) – Module Safety Issues

9:10 – Larry Sherwood (Solar ABCs) – Fire Rating for Modules/Roof Together

9:40 – Discussion: Are we adequately addressing the safety issues?

10:10 – Silicon Poster Session (see next page)

12:00 – Lunch

Feb. 28 Afternoon I – Reliability Predictions through Analytical Modeling

Chairs/Discussion Leaders: Glenn Alers (UC Santa Cruz), David Meakin (Fraunhofer CSE)

1:00 – Charlie Hasselbrink (SunPower) – Module Lifetime Prediction through Integrated Modeling of Known Failure Modes

1:30 – Nick Bosco (NREL) – Modeling of Metal Fatigue as a Key Step in PV Lifetime Prediction

2:00 – Kent Whitfield (Solaria) – Modeling Based on Damp-Heat Testing

2:30 – Discussion: Can modeling give accurate predictions, or is it the thing you don’t know to model that causes the problem? What validation do we need? What is needed in a good model?

3:00 – Break

Feb. 28 Afternoon II – Potential Induced and Other Bias-Related Degradation

Chairs/Discussion Leaders: Mike Kempe (NREL), Jenya Meydbray (PV Evolution Labs)

3:30 – Peter Hacke (NREL) – PID – Considerations for a Standardized Test for Potential Induced Degradation of Crystalline Silicon PV Modules

4:00 – Simon Koch (PI-Berlin) – Potential Induced Degradation Effects and Tests for Crystalline Silicon Cells

4:30 – Govindasamy Tamizhmani (TUV) – 13 to 18-Year-Old PV Power Plant in Arizona: Potential Induced Degradation Analysis of 1900 Individual Modules

4:50 – Discussion: What are the mechanisms involved in PID? What is the best way to test for it? What are the best ways to alleviate it?

5:20 – Adjourn for the day

Evening: Dinner on your own

7:00 – Regional meeting of PV QA Task Group #1: Guideline for QA during manufacturing process of PV modules (organized by Alex Mikonowicz)

Other standards meetings may also be scheduled on the side.

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10:10 A.M. – Silicon Poster Session

Glenn Alers (Univ. California, Santa Cruz) – Highly Accelerated UV Aging of Organic Luminescent Materials
Dohyun Baek (Samsung) – Outdoor PV Module Analysis and Power Estimation
Howard Barikmo (Sunset Technology) – PV Standards: What Does the IEC Have for You?
Didier Binesti (Electricité de France) – Exploring Highly Accelerated Tests with c-Si Modules
Jim Bratcher (Honeywell Performance Materials) – Considerations for Evaluating Backsheets without Fluoropolymer Sun-Facing Layers
Neelkanth Dhere and Ashwani Kaul (FSEC) – Outdoor High-Voltage Bias Testing of PV Modules
Thai Phuong Do (REC Solar) – Performance and Reliability Test Methodology
Dan M.J. Doble, Andrew Kodis, Rob deJong, Karen van de Wetering and Bala Ambravan (Sabic Innovative Plastics) – Improved Plastic Materials for Application in PV Modules
Lawrence Dunn and Michael Gostein (Atonometrics) – Uncertainty Analysis of PV Array Performance Ratio Calculations: Comparing Reference Cells, Reference Modules, and Pyranometers
Yoshihito Eguchi (Sharp) – Task Statement/Japan Regional Task Group
Chris Flueckiger (Underwriters Laboratory) – Current PV Standards – Polymeric Requirement and Test Methods
William Gambogi, Katherine Stika, Alex Bradley, Babak Hamzavy, and Rebecca Smith (Dupont) – Materials Characterization in PV Modules
Melissa Grossman, Mark Raymond, Seth Weiss, and Hector Porras (Genie Lens) – Comparing Anti-Soiling Reliability and Performance on Glass, ETFE, Structured Glass and Film Structured Fusion on PV Panels
Xiaohong Gu, Yongyan Pang, Kaipeng Liu, Tinh Nguyen and Joannie W. Chin (NIST) – Effect of Simultaneous UV Radiation, Temperature and Moisture on Degradation of PV Polymers
Changwoon Han, Nochang Park, and Jaesung Jeong (Korea Electronics Technology Institute) – Lifetime Prediction of Silicon Crystalline Photovoltaic Ribbon Wire in Three Local Weathers
Kusato Hirota, Takashi Arai, Ryuhei Metabi, Michiko Tanaka, Takao Amioka, and Miki Terada (Toray Industries) – Observing Mini PV Module Degradation through Successive Damp Heat Testing and Thermal Cycle Testing Procedure
G.S. Horner, J.E. Hudson, J. Schmidt, L.A. Vasilyev, and K. Lu (Tau Science Corporation) – Hotspot Detection for Cell and Module Production Lines
Yen-Shan Hsu and Steven R. Aubuchon (TA Instruments – Waters LLC), Yi-Hung Chou, Wen-Yao Chou, Yu-Chen Chien, and Shr-Ming Shiu (Delsolar) – Thermoanalytical Characterization of Ethylene Vinyl Acetate Copolymer (EVA) for Lamination Process Simulation and Gel Content Determining in Photovoltaic Modules
Yang Hu, Joseph Karas, and Roger H. French (Case Western Reserve University), David A. Hollingshead, Scott A. Brown, and Mark A. Schuetz (Replex Plastics) – Introduction to the SunFarm Outdoor Test Facilities at the Solar Durability and Lifetime Extension Center in Case Western Reserve University
Jay Johnson (Sandia National Laboratories) – Arc-Fault Detection and Mitigation in PV Systems – Industry Progress and Future Needs
Timothy Johnson (tenKsolar) – TenKsolar Cell-to-Grid Redundant PV System Delivers Unmatched Reliability and Uptime
David Jung (ESPEC) – Test Chamber Brainstorming: Consider All of the Options
Juris Kalejs (American Capital Energy) – Junction Box Design Issues in Reliability
Yi Kang (Avery Dennison) – Fluoropolymer Coated Backsheet for Photovoltaics
Anna Keeley (Dow Corning) – Berger IV Testing for Silicone Encapsulation

Robin Kobren (Dunmore) – Quality Control during the Manufacturing of PV Backsheets: A Fundamental Key Component to the Long-Term Performance of PV Modules

Michael Köhl (Fraunhofer ISE) – The Challenges of Testing the UV Impact on PV Modules

Charles J. Luebke, Birger Pahl, and Thomas J. Schöpf (Eaton Corporation) Jerome K. Hastings (Electric Power Management Consulting) – Enhanced Protection for Photovoltaic Systems

Alex C. Mayer and Jenya Meydbray (PV Evolution Labs) – Increasing Predictability and Investor Confidence in PV Power Plants through Latent Defect Screening

Joseph McCabe (SRA) – Salvage Operation Determines Value of Used Photovoltaics

Michael McNeeley (Transform Solar) – A Novel Insulated Solder Tail Subassembly for Use with Aluminum Core Backsheets

Jenya Meydbray (PV Evolution Labs) and Wenda Zheng (Canadian Solar) – Characterization of Potential Induced Degradation Sensitivity of Crystalline Silicon Panels

Alex Mikonowicz (Powermark) – Manufacturing Quality Systems Guidelines

Clarissa Miller (Momentive) – Silicone Potting Materials to Reduce PV Module Field Failures

Fernando Novoa and Reinhold H. Dauskardt (Stanford University), David Miller, Mike Kempe, Nick Bosco, and Sarah Kurtz (NREL) – Quantifying Adhesion and Debonding of EVA-TPE Encapsulants for Solar Modules

Gregory S O'Brien, Amy Lefebvre, Steven Hahn, and Anthony Bonnet (Arkema) – Ranking PV Materials for Weathering Performance

Kaoru Ohshimizu (Mitsui Chemical) – Estimation of Amount of Free Acetic Acid Desorbed in EVA Encapsulant with Infra-Red Spectrum

Corinne Packard (Colorado School of Mines; NREL), John Wohlgemuth, and Sarah Kurtz (NREL) – Development of a Visual Inspection Checklist for Evaluation of Fielded PV Module Condition

Paul Robusto (Intertek) – Performance & EL Studies on Single Crystalline Silicon Modules from Three Different Manufacturing Sites Exposed to TC 500 and Damp Heat 2000 Hours

M.W. Rowell, S.J. Coughlin, D.W.J. Harwood, (D2Solar) – Impact of Module Construction in Providing Reliability Redundancy through Accelerated Lifetime Testing

Fatih Sabuncuoglu, Larry Pratt, and Martin Plass (CFV Solar) – Variability in NOCT Standard Test Results as a Function of Day, Time of Day, and TC location

Kenneth Sauer (Yingli Americas) – Systematic Approaches to Determining Degradation Rates from Continuous Meteorological and System Production Data

Herbert Schueneman (Westpak), Kent Whitfield (Solaria), Tanya Dhir (MiaSolé), and Matt Muller (NREL) – Solar Wind: Reproducing the Effects of Wind Induced Vibration on Field Mounted PV Modules Using Response Spectrum Analysis

Oliver Schultz-Wittmann (Tetrasun) – Silicon Cracking in Cu plated Crystalline Silicon Solar Cells

Tsuyoshi Shioda and Hirofumi Zenkoh (Mitsui Chemicals) – Influence of Elastic Modulus of Encapsulant on Solder Bond Failure of c-Si PV Modules

N. R. Sorensen, J. R. McElhannon, and M. A. Quintana (Sandia National Laboratories) – The Effect of Na on the Electrical Breakdown of EVA

Chris Stapelmann (SolarWorld Industries) – The Impact of Different c-Si Module Encapsulants on Wet Insulation Resistance Performance

Tadanori Tanahashi (ESPEC) – Photovoltaic Module Reliability Testing: 400°C/hr

Ryan Tucker and Joseph Woods (STR Solar) – 15-year Review of Field Performance of EVA-based Encapsulants

Yasunori Uchida (JET) – Japanese TG4 activities of QA Forum

Robert Uselton (Lennox Industries) – Hail Gun for Solar PV Module Testing

PV Module Reliability Workshop – Standards

“One small step for man, one giant leap for mankind” – Neil Armstrong

Leaping forward for the QA Task Force

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Agenda

7:00 Continental Breakfast

Feb. 29 Morning – Materials Testing

Chairs: Kurt Scott (Atlas), Michael Koehl (Fraunhofer ISE)

8:00 – Mike Kempe (NREL) – Testing Protocol for Module Encapsulant Creep

8:20 – David Miller (NREL) – A Proposed Junction-Box Stress Test (Using an Added Weight) for Use during the Module Qualification

8:40 – Chris Flueckiger (UL) – Summary of Materials Work

9:10 – Discussion

9:35 – Break

10:00 – Quality Assurance Overviews of Proposed Tests

10:00 – Introduction to PV QA Task Force and Plan for Day – John Wohlgemuth and Sarah Kurtz (NREL)

10:20 – IEC 61215: What it is and isn't – John Wohlgemuth

Proposed Test Protocols – IEC 61215 on Steroids:

10:40 – A New Approach for Holistic PV Module Quality Assurance by Extended Stress Testing and Production Monitoring – Danny Cunningham (BP)

10:45 – The Thresher Test – Alelie Funcell (Renewable Energy Test Center)

10:50 – PVEL's Reliability Demonstration Test – Jenya Meydbray (PV Evolution)

10:55 – Review of PV Durability Initiative Test Protocol – David Meakin (Fraunhofer CSE)

11:00 – NREL's Test-to-Failure Protocol – Peter Hacke (NREL)

11:05 – Long-Term Sequential Testing – Govindasamy Tamizhmani (TUV)

Proposed Test Protocol – Accelerated Simulation of the Weather:

11:10 – Atlas's PV Long Term Durability Test – Kurt Scott (Atlas)

Proposed Test Protocols – New Tests:

11:15 – UV-Thermal Combined Stress Acceleration Test – Kusato Hirota (Toray)

11:20 – Accelerated TC Test – Tadanori Tanahashi (ESPEC)

11:25 – Duplicating Wind-Induced PV Module Response in the Laboratory without a Wind Tunnel – Herb Schueneman (Westpak)

11:30 – Mechanical Load Testing of PV Modules in Mounting Structures – Thomas Friesen (SUPSI)

11:35 – HV Bias Testing – Neelkanth Dhare (FSEC), presented by John Wohlgemuth (NREL)

PV Quality Assurance Task Force Plans

11:40 – Task Group 2 Thermal and mechanical fatigue – Chris Flueckiger (UL)

11:45 – Task Group 3 Humidity, temperature, and voltage – John Wohlgemuth (NREL)

11:50 – Task Group 4 Diodes, shading, and reverse bias – Vivek Gade

11:55 – Task Group 5 UV, temperature, and humidity – Michael Koehl (Fraunhofer ISE)

12:00 – Lunch

Feb. 29 Afternoon – Quality Assurance Rating Test Development Discussion

1:00 – Summary of Proposed Test Methods (see handout) – Ian Aeby (Emcore)

1:15 – Consensus Building – Can we agree on general items? What we can learn from proposed tests? Can we agree on detailed inputs for the Task Groups?

2:45 – Break

3:15 – Continuation of discussion

4:30 – Next steps; Action items

5:00 – Adjourn

Evening: Dinner on your own, standards meetings

PV Module Reliability Workshop – Thin-Film Modules

Thursday, March 1, 2012

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Agenda

7:00 – Continental Breakfast

Mar. 1 Morning – Metastabilities

Chairs/Discussion Leaders: Chris Deline (NREL), Govindasamy Tamizhmani (TUV)

8:00 – Kannan Ramanathan (NREL) – CIGS Material/Device Stability Issues

8:30 – Lawrence Dunn and Michael Gostein (Atonometrics) – Light Soaking Effects in Commercially Available CIS/CIGS Modules

9:00 – Tony Sample (European Commission: DG-JRC) – Preconditioning of Thin-Film PV Modules through Controlled Light Soaking

9:30 – Discussion: Can modules be engineered to avoid metastability issues? How much does it matter for real-world performance?

10:00 – Thin-Film Poster Session (see next page)

12:00 – Lunch

Mar. 1 Afternoon I – Keeping the Moisture Out

Chairs/Discussion Leaders: Dennis Coyle (GE), Arrelaine Dameron (NREL)

1:00 – Mike Kempe (NREL) – Predicting the Performance of Edge Seal Materials for PV

1:30 – Tracie Berniard (3M) – Demonstrating Reliability of Ultra Barrier Solar Films for Flexible PV Applications

2:00 – Discussion: What questions must be addressed before moisture ceases to be an issue for thin-film modules? Can cells be hardened without reducing efficiency? After hardening, what are the packaging requirements?

2:30 – Break

Mar. 1 Afternoon II – Reliability Issues with Thin-Film Modules

Chairs/Discussion Leaders: Shubhra Bansal (DOE), Tony Sample (JRC)

3:00 – Jason Hevelone, Nikesh Dhar, and Chris Richardson (Abound) – Metal Buss Tape Reliability

3:30 – Jim Lloyd (SUNY Albany CNSE) – PVMC Reliability Efforts

4:00 – Discussion: What are the key issues that need to be addressed for thin-film modules?

4:30 – Adjourn

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10:00 A.M. – Thin-Film Poster Session

Howard Barikmo (Sunset Technology) – PV Standards: What Does the IEC Have for You?
Dennis Coyle (GE) – The Effect of Copper on Accelerated Life Test Performance of CdTe Solar Cells
Tanya Dhir and Brian McNamara (Miasole) – Test-to-Failure Program for Photovoltaic Modules
Sascha Dietrich, Martin Sander, Matthias Pander, and Matthias Ebert (Fraunhofer CSP) – Derivation of Quality Specifications of Glass by Probabilistic Evaluation of Mechanical Module Reliability
P. Gallina, A. Bonucci, and Rder Wel (SAES Getters) – Edge Sealing Tape with Getter fro PV Modules: Very Long Breakthrough Time and Mechanical Properties at High Temperature
Christian Honeker, Maryann Kenney, and Ricky Santoso (Saint-Gobain) – Adhesion of Encapsulating Films Used in PV Module Manufacturing
Dirk Jordan (NREL) – Data Filtering Impact on PV Degradation Rates and Uncertainty
Elsa Kam-Lum, Fadong Yan, Jorma Peltola, Stephen Wicks, Srinu Balasubramanian (Konarka) – Meeting IEC 61646 Requirements with OPV
M. Münch, Mike Röllig, * A. Reithe, M. Wachsmuth, and M. Meißner (Solarion) – Flexible CIGS Modules – Selected Aspects for Achieving Long-Term Stable Products
S. Jayanarayanan, L. Cao, A. Kamer, N. Staud, D. Nayak, B. Metin, E. Lee, and M. Pinarbasi (Solopower) – Performance of CIGS Flexible Module Arrays on Different Field Mountings
Laure-Emmanuelle Perret-Aebi, C. Schlumpf, V. Chapuis, H.-Y. Li, and C. Ballif (EPFL/IMT/PVLAB) – Which Polymer for Reliable Silicon Thin-Film PV Module?
Adam Stokes, John Wohlgemuth, Chris Deline, Sarah Kurtz, Steve Rummel, Alan Anderberg, Matt Webber (NREL) – Light Soaking Behavior and Alternate Stabilization Method For CIGS/CIS Modules
Samar Teli (Adco Products) – Solar Edge Sealant with Optimized Sealing and Application Properties
Christopher Thompson, Steve Hegedus (University of Delaware) Peter Carcia, R. Scott McClean (DuPont) – The Effects of Device Geometry and TCO/Buffer Layers on Damp Heat Accelerated Lifetime Testing of Cu(In,Ga)Se₂ Solar Cells
Doug Weishaar (Evonik) – FLEXOSKIN – Front Barrier Film for Flexible Solar Modules

PV Module Reliability Workshop – CPV

Thursday, March 1, 2012

Denver West Marriott, Golden, Colorado

Agenda

7:00 – Continental Breakfast

Mar. 1 Morning – CPV Module Reliability – Accelerated Testing and Field Experience
Chairs/Discussion Leaders: Peter Hebert (Spectrolab), Paul Lamarche (Solar Junction)

8:00 – Matthew Muller (NREL) – Experience with CPV Module Failures at NREL

8:30 – David Miller (NREL) – The Durability of Polymeric Encapsulation Materials for Concentrating Photovoltaic Systems

8:50 – Michael R. Winter, Ian Aeby, and James Foresi (Emcore) – Performance and Reliability of Silicone Polymers in 1000X Concentration CPV Applications

9:10 – Robert MacDonald and Mehrdad Roosta (Skyline Solar) – Lessons Learned from Development of Silicon CPV Modules

9:30 – Discussion: Where are the holes in our current understanding of CPV reliability? What are the challenges/opportunities for testing at high flux? Are encapsulants problematic? How do we determine whether PMMA is adequately durable?

10:00 – CPV Poster Session (see next page)

12:00 – Lunch

Mar. 1 Afternoon I – Standards

Chairs/Discussion Leaders: Kenny Villegas (Solar Compliance), Robert MacDonald (Skyline Solar)

1:00 – Matt Muller (NREL) – Overview of Progress on the IEC Tracker Design Qualification Standard

1:15 – Ian Aeby (Emcore) – CPV Cell Qualification Standard

1:30 – Sarah Kurtz (NREL) – Cell Data Sheet Specification

1:40 – Sandheep Surendran (Surya Design) – Standard Conditions for CPV and Energy Rating Proposal

2:00 – Discussion: General discussions of the standards. What standards are still needed?

2:30 – Break

Mar. 1 Afternoon II – Modeling of CPV Reliability Issues

Chairs/Discussion Leaders: Nick Bosco (NREL), Scott Burroughs (Sempruis)

3:00 – Tim Silverman (NREL) – Comparison of Accelerated Testing with Modeling to Predict Lifetime of CPV Solder Layer

3:30 – Rebeca Herrero (IES-DEF) – Thermal Effects and Other Interesting Issues with CPV Lenses

4:00 – Discussion: Value of modeling

4:30 – Adjourn

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10:00 A.M. – CPV Poster Session

- R. Beal, S. Chow, F. Asselin-Guay, J.F. Wheeldon J.E. Haysom, K. Hinzer (University of Ottawa SUNLAB) – High Intensity Light-Cycling and Early-Life Failure Detection for HCPV Cell Assemblies Using the XT-30 Solar Simulator
- Ling Cheng (Semprius) – Solar Cell Grid Finger Failure due to Micro-cracking
- Blake Coughenour, Brian Wheelwright, David Lesser, and Roger Angel (University of Arizona) – Reliability Characterization of an Exposed Spherical Ball Lens in a Dish-Based CPV System
- Peter Colburn (Evonik) – Acrylic Materials in PV Applications
- Roger H. French, Laura S. Bruckman, Myles, P. Murray, Samuel Richardson, and Esther Deena (Case Western) Scott A. Brown, Mark A. Schuetz (Replex Plastics) – Solar Durability and Lifetime Extension Center at Case Western Reserve University: Degradation of Acrylic Polymer and Acrylic Mirrors
- Sager Gadkari (Greenfield Solar) – Use of Thermal Imaging as a Tool for CPV Module Development and Production Testing
- Eckart Gerster (Soitec Solar) – Reliability of Concentrix CPV Modules
- K. Kiriluk, P. Banda, J.A. Perez, A. de Dios, F. Celaya (Abengoa Solar) – Abengoa Solar CPV Field Testing Capabilities
- Paul LaMarche (Solar Junction) – Reliability Testing of Triple Junction Solar Cells with a GaInNAs Bottom Layer using Dilute Nitrides
- Stefan Myrskog, Pascal Dufour, Yi Guo, Kristine Drew (Morgan Solar) – Reliability of PMMA under Concentration
- Paul Norum (Amonix) – Lessons Learned from Flat Panel PV Modules that Could be Applied to CPV
- Sandheep Surendran (Surya Design) – Standard Conditions for CPV
- Kenny Villegas (Solar Compliance) – Overview of CPV Tracker Safety