



Overview of PV Standards Activities at SEMI

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Senior Director, Standards and EHS
July 2011

SEMI and the Foundation of the PV Group

- **Who is SEMI?**

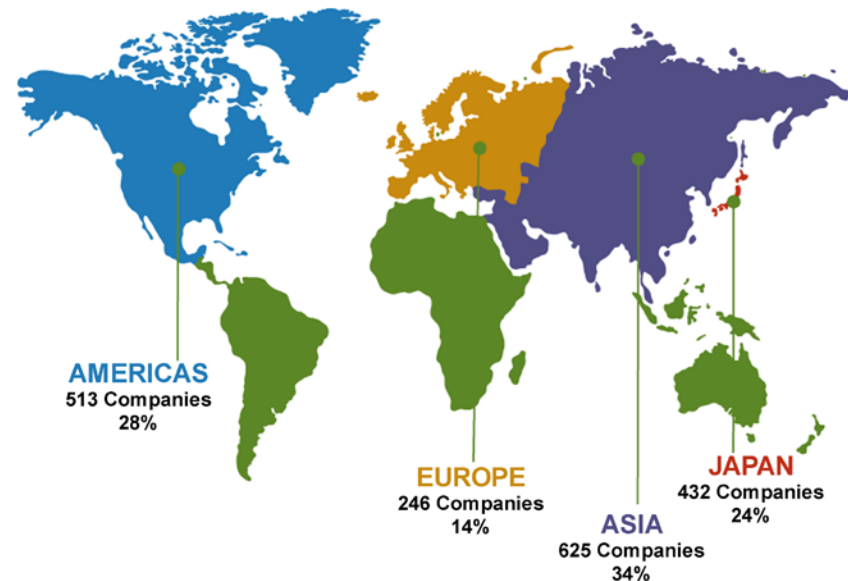
- Global industry trade association with offices in US, Belgium, Germany, France, China, Taiwan, Singapore, Korea, Japan, Russia, and India
- 1800+ member companies (500+ PV)
- Established 1970 to serve the semiconductor manufacturing supply chain
 - Expanded into the PV market segment in 2008
- Today we serve members in:
 - Semiconductor, Photovoltaic, Emerging Markets – MEMS, LED/SSL, Printed Electronics, and Nanotechnology and Flat Panel Display

SEMI Membership Worldwide

SEMI Member Companies participate in the global manufacturing supply chains of:

- Semiconductor
- **Photovoltaic**
- Flat Panel Display
- Nanotechnology
- MEMS
- LED / SSL

Member Companies by Region



SEMI PV Group - An Introduction

- **Our member companies** provide cells, modules, equipment and materials to the global manufacturing supply chain.
- **Our mission** is to advance the growth and profitability of PV Group members through sustained long term growth of the global PV Energy Industry with focus on:
 - Continuous manufacturing cost reductions
 - Global market transformation
 - Sustainable business practices
- **We accomplish our mission through**
 - International standards development
 - Networking events
 - Public Policy advocacy
 - Environmental, Health & Safety support
 - Market information & Statistics
 - Technology Roadmap development

Our Focus is Manufacturing



- **All SEMI core manufacturing competencies extended to PV**
Standards | Public Policy | Market intelligence | EHS | Education | Events
- **500+ SEMI member companies form the PV Group**
 - Many with expertise in semiconductor manufacturing
- **Over 100 PV member companies focused primarily on solar**
(pure play)

SEMI International Board of Directors Energy/PV Solar Standing Committee

- M. Splinter, President & CEO **Applied Materials** – Committee Chair
- S. Kohyama, President & CEO **Covalent Materials** Corporation
- E. Weber, Director **Fraunhofer-Institute** for **Solar** Energy Systems
- Z. Shi, Founder, Chairman & CEO **Suntech** Power Holdings
- T. Higashi, Chairman & CEO **Tokyo Electron** Ltd.

PV Group – Progress Through Collective Industry Engagements



Partial list, June, 2010

Regional PV Advisory Committees provide strategic guidance to deliver on specific objectives and tasks.

Committees established in Europe, North America, China, India, Taiwan and Korea.

US PV Advisory Committee focus

- Manufacturing /Jobs
- Public policy / Energy policy
- EH&S / Sustainability

Outline

- **The need for SEMI PV Standards**
- Global SEMI PV Standards Organization
- Published SEMI PV Standards
- SEMI Safety Guidelines for PV
- How to Get Involved
- Background

The Need for PV Standards

- The PV industry has few standards to support the **manufacturing** process and help achieve cost reduction and process efficiency goals
- The PV market, already large, is growing rapidly, with many new companies entering the manufacturing supply chain
- Different applications and processes lead to diverse manufacturing challenges –this is where industry standards can play a critical role by:
 - Bringing the global supplier and customer communities together
 - Collectively reducing the number of options in a given process
 - Agreeing on common parameters and terminology

Why SEMI?

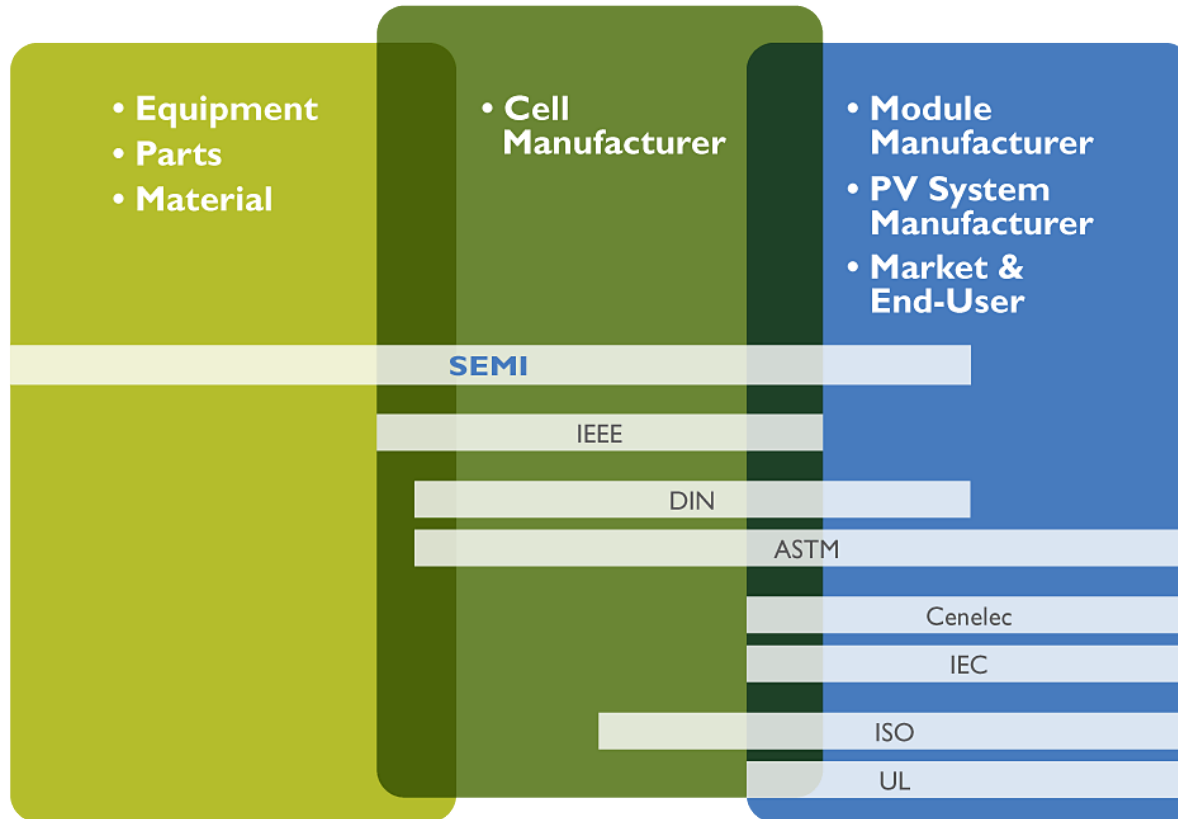
- Similarity between semiconductor, FPD and PV manufacturing – many SEMI Standards immediately applicable
- Well-established (35+years), transparent process for developing international consensus manufacturing Standards
- Global infrastructure serving major PV manufacturing regions
- Over 500 volunteer experts working in SEMI PV Standards Activities, led by PV industry veterans

Outline

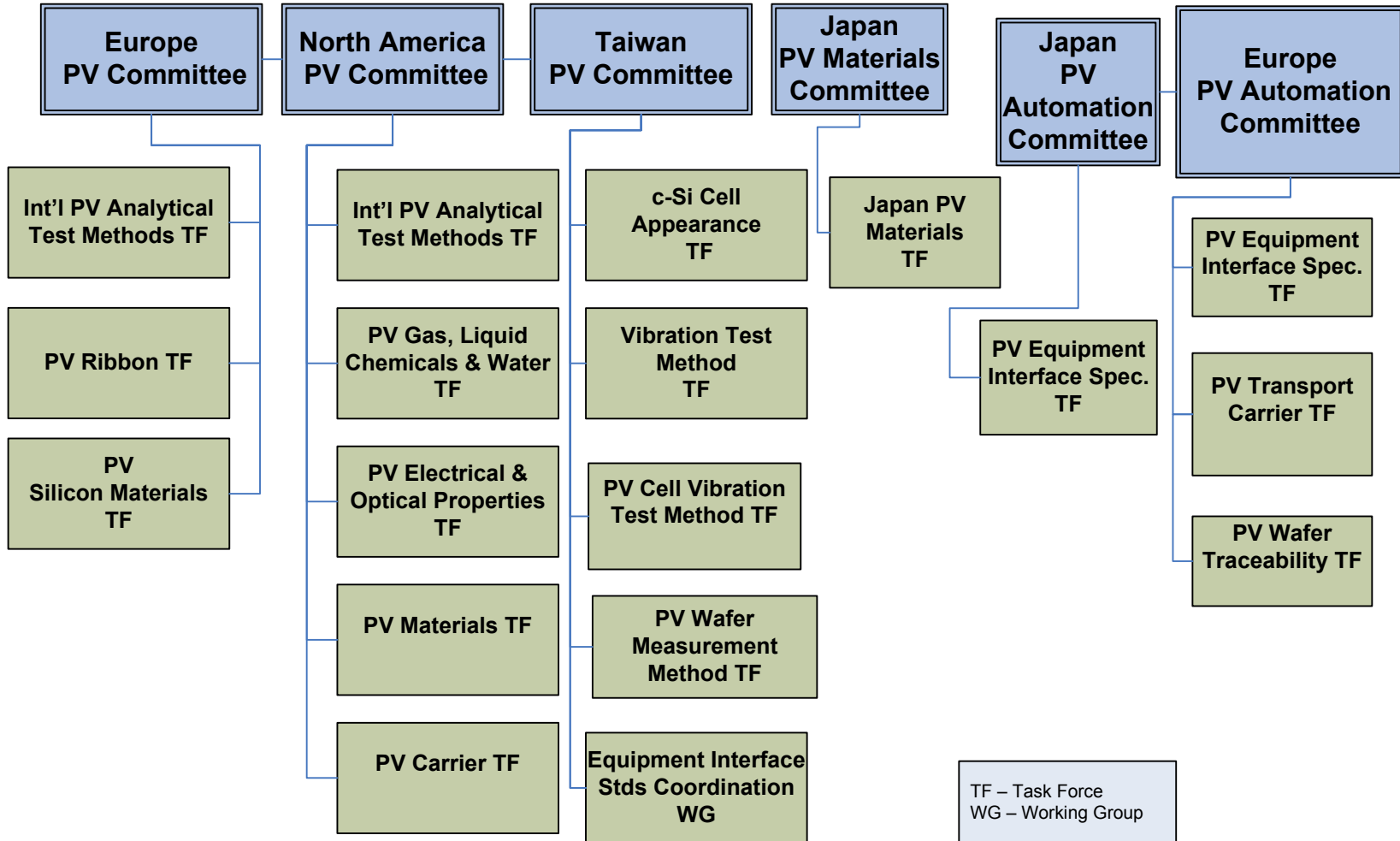
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PV Standards Developing Organizations

Application of International Standards in the Photovoltaic Industry



SEMI PV Standards Organization



Notable Companies Involved in Developing SEMI PV Standards

acp-IT AG
Air Liquide
Air Products
AIS Automation Dresden GmbH
AIST
Applied Materials
Asahi/America, Inc.
ATMI
Bosch Solar Energy AG
BP Solar
Brewer Science
CA Solar
Canon ANELVA Corporation
CH2M Hill
China Sunergy
Chroma ATE INC
Cimetrix
Corning
Covalent Materials Corporation
Daihen Corporation
Dainichi Shoji K.K.
DAINIPPON
Delsolar
Despatch Industries
Deutsche Solar AG
Dow Corning
DuPont
Entegris, Inc.
Evans Analytical Group
Ever Energy Co. Ltd.

Evergreen Engineering
First Solar
Fraunhofer
Freiberg
GCL
George Fischer
GT Solar
Hemlock Semiconductor
Hirata Corporation
Hitachi Kokusai Electric Inc.
Hynix Semiconductor Inc.
ICL Performance Products LLC
IMEC
ITRI
Japan Solar Silicon
Jonas&Redmann Automation
KANEKA CORPORATION
KLA-Tencor
Korea Institute of Lighting Technology
LDK
LG. Display
Linde LLC
M+W Zander FE GmbH
Manz Automation AG
Matheson Tri-Gas
MEMC Electronic Materials, Inc.
Meyer Burger
Mitsubishi Heavy Industries, LTD
Motech (Solar Division)
Nippon Steel Corp.

Nisshinbo Mechatronics Inc.
NIST
NREL
OC Oerlikon Balzers AG
OCI
Pall Corporation
Parker Hannifin
PEER Group GmbH
Q-Cells SE
REC Silicon
RENA GmbH
Renesola
Roth & Rau - Ortner GmbH
Schiller Automation
Schott Solar AG
Semilab
Sinton Instruments
Solar World
SUMCO
Sunicon AG
Suntech
Swagelok
Tokuyama corporation
Tokyo Electron Ltd.
Trina Solar
TUV
UL
ULVAC
Wacker Chemie AG

Current High Profile Standards Activities

- Silicon Feedstock Materials for PV Application
 - [Document 4805B](#), Specification for Virgin Silicon Feedstock Materials for Photovoltaic Applications
 - Developed with input from major suppliers around the world
 - Feedback received from SUMCO, GCL, LDK, and other major Chinese companies
 - **APPROVED, PUBLISHED as SEMI PV17-0611**
- Silicon Wafer for PV Application
 - [Document 4826C](#), Specification for Silicon Wafers for Use as Photovoltaic Solar Cells
 - Feedback received from GCL, LDK, and Trinasolar
 - Approved at committee meeting during Intersolar NA

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SEMI PV Standards History

- SEMI M6: Specification for Silicon Wafers for Use as Photovoltaic Solar Cells, published in 1981
- PV Committee formed in 2007, initially in Europe and North America, now also in Japan and Taiwan
- PV Automation Committee formed in 2009 to focus on equipment automation issues
- PV Materials Committee formed in 2010
- Increased interest from China, WG in process of formation

SEMI PV Standards [1/3]

- PV1-0211: Test Method for Measuring Trace Elements in Silicon Feedstock for Silicon Solar Cells by High-Mass Resolution Glow Discharge Mass Spectrometry
 - First standard test method that specifically addresses the evaluation of some types of PV Silicon feedstock.
- PV2-0709E: Guide for PV Equipment Communication Interfaces
 - Unified communication standard between PV production equipment and the shop floor
- PV4-0211: Specification for Range of 5th Generation Substrate Sizes for Thin Film Photovoltaic Applications
 - Provides a range of substrate sizes for equipment applicable to 5th generation substrates

SEMI PV Standards [2/3]

- High Purity Water
 - PV3-0310: Guide For High Purity Water Used In Photovoltaic Cell Processing
- Chemicals
 - PV5-1110: Guide for Oxygen (O₂), Bulk, Used In Photovoltaic Applications
 - PV6-1110: Guide for Argon (Ar), Bulk, Used In Photovoltaic Applications
 - PV7-1110: Guide for Hydrogen (H₂), Bulk, Used In Photovoltaic Applications
 - PV8-1110: Guide for Nitrogen (N₂), Bulk, Used In Photovoltaic Applications
 - PV14-0211: Guide For Phosphorus Oxychloride, Used In Photovoltaic Applications
- Acids
 - PV11-1110: Specifications for Hydrofluoric Acid, Used In Photovoltaic Applications
 - PV12-1110: Specifications for Phosphoric Acid, Used In Photovoltaic Applications



SEMI PV Standards [3/3]

- PV9-1110: Test Method For Excess Charge Carrier Decay In PV Silicon Materials By Non-Contact Measurements Of Microwave Reflectance After A Short Illumination Pulse
 - Quantifies test method to obtain consistent results from the measurement of silicon materials
- PV10-1110: Test Method For Instrumental Neutron Activation Analysis (INAA) Of Silicon
 - Defines explicitly sample preparation, measurement procedure and data analysis of silicon
- PV13-0211: Test Method for Contactless Excess-Charge-Carrier Recombination Lifetime Measurement in Silicon Wafers, Ingots, and Bricks Using an Eddy-Current Sensor
 - Carrier lifetime measurements provide one of the most sensitive metrics for evaluating feedstock quality
- PV15-0211: Test Method for Measuring BRDF Metrics to Monitor the Surface Roughness and Texture of PV Materials
 - Provides a way to communicate BRDF (light scatter) specifications. Light scatter is a sensitive indicator of surface roughness or texture

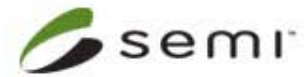


Other SEMI Standards Applicable for PV Manufacturing [1/2]



- SEMI E10 - Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)
- **SEMI F47 - Specification for Semiconductor Processing Equipment Voltage Sag Immunity**
- SEMI F108 - Guide for Integration of Liquid Chemical Piping Components for Semiconductor, Flat Panel Display, and Solar Cell Manufacturing Applications
- SEMI M6 - Specification for Silicon Wafers for Use as Photovoltaic Solar Cells
- SEMI M44 - Guide to Conversion Factors for Interstitial Oxygen in Silicon
- SEMI MF391 - Test Method for Minority Carrier Diffusion Length in Extrinsic Semiconductors by Measurement of Steady-State Surface Photovoltage
- SEMI MF1188 - Test Method for Interstitial Oxygen Content of Silicon by Infrared Absorption With Short Baseline

Other SEMI Standards Applicable for PV Manufacturing [2/2]



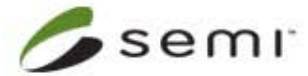
- SEMI MF1619 - Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with p-Polarized Radiation Incident at the Brewster Angle
- SEMI MF1708 - Practice for Evaluation of Granular Polysilicon by Melter-Zoner Spectroscopies
- SEMI MF1727 - Practice for Detection of Oxidation Induced Defects in Polished Silicon Wafers
- SEMI MF1809 - Guide for Selection and Use of Etching Solutions to Delineate Structural Defects in Silicon
- SEMI MF1810 - Test Method for Counting Preferentially Etched or Decorated Surface Defects in Silicon Wafers
- **SEMI S2** - Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment
- **SEMI S26** - Environmental, Health, and Safety Guideline for FPD Manufacturing System



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- Published SEMI PV Standards
- **SEMI Safety Guidelines for PV**
- How to Get Involved
- Background

EHS Standards - Opportunities for PV



- PV industry has some common ground with semiconductor (c-SI) and FPD (thin film) industry
- This provides opportunities through use/adaptation of existing SEMI EHS Standards
 - to avoid major environmental events and regulatory interference
 - to learn from these industries' failures AND successes
- SEMI S2 - Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment
- SEMI S8 - Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment
- SEMI S26 - Environmental, Health, and Safety Guideline for FPD Manufacturing System

SEMI “S” Guidelines for PV?

- SEMI “S” Guidelines currently cover:
 - Capital manufacturing equipment
 - Facilities and support equipment
 - Documentation
 - Environmental impact/planning
 - Personnel training/site EHS management
 - EHS vendor management



SEMI S2

- SEMI S2 – Environmental Health and Safety Guideline for Semiconductor Manufacturing Equipment
 - 27 Sections cover all hazards:
 - Electrical, Mechanical, Chemical, Radiation, Ergonomics, Environmental, Ventilation & Exhaust, Fire Risk, Hazardous Energy Control, Seismic, Lasers, Sound Pressure Level
 - One of the most universally recognized and implemented SEMI Standards in the industry

SEMI S8

- Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment
 - Ergonomics and Human Factors is one of the most frequent causes of workplace injuries for the Semiconductor Industry
 - Directly applies to Substrate Handling, Module Handling, Cell Carriers, Equipment Maintenance, Elevated Work Areas
- S8 and S2 are the two most essential guidelines for the PV industry.



SEMI S26

- Environmental, Health and Safety Guideline for FPD Manufacturing System
- FPD-specific version of SEMI S2
- S2 modified by EHS Committee's FPD System Safety Task Force to address specific concerns with FPD
- Key Differences:
 - system integration issues
 - shared hazards
 - material handling
 - automation

SEMI EHS Guidelines a Benefit to the PV Industry?

- Standardization allows Suppliers and End-Users to become more efficient
 - Common design approaches reduce negotiations and delays
 - Fewer “Specials”
 - Faster delivery of equipment
 - Fewer inspections
 - Less end-user and supplier resource drain
 - Each has the opportunity to provide input to the standards (committee work, ballot review)

Risks of Doing Nothing?

- Major event in a PV fab
 - Fire, environmental release or death
 - Insurance pressure will likely increase
 - Environmental event would tarnish “Green” industry reputation
 - Criminal/civil prosecution
 - Future financing may be put in jeopardy



Risks (Continued)

- Increased Regulatory Involvement
 - Industry input often not considered by governments creating new regulations
 - Equipment may be forced to meet requirements not intended for the PV Application
 - New Certifications
 - e.g. Oregon Field Labeling
 - CE Marking +
 - PV industry could be inviting increased regulatory involvement unless it demonstrates the ability to "self-regulate."

Opportunities?

- Improve time to delivery
- Reduce duplicated efforts
- Common language and approach
- Design flexibility
- Industry specific requirements
- Reduce cost for design, manufacturing, test and install
- Improve repeatability/reliability



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Get involved!

- Get your company's support
- Register at www.semi.org/standardsmembership
- Establish contact with other regions' Technical Committees and Task Forces
 - Gather information on activities and trends
 - Attend regional meetings
- Use SEMI Standards
 - Benefit from cost reduction and efficiency improvements
 - Purchase a *SEMIViews* license

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www.pvgroup.org/standards

www.semi.org/standards

Contact Information

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- PV Standards – Korea
 - Natalie Shim (eshim@semi.org)
- PV Standards – India
 - Vijay Kundaji (vkundaji@semi.org)

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- SEMI Safety Guidelines for PV
- Case Study: SEMI PV2
- How to Get Involved
- **Background**

Why Standards?

- Define interfaces (hardware and software)
- Clearly characterize materials
- Improve supply chain communication
- Optimize environment, health and safety for the operators and others in the industry
- Results
 - Cost reduction
 - Focus on product differentiation
 - Acceleration of product development
 - Accepted verification procedures (test methods)



Economic Impact of Standards

- US National Institute of Standards and Technology (NIST) Study
 - Calibration, Standard Test Methods, and Software Standards
 - \$9.6 billion in benefits between 1996 and 2011
- Association Française de Normalisation (AFNOR) Study
 - Over 70% of companies participating in standardization reported that it enabled them to anticipate future market requirements
- German Industry Study (DIN)
 - Standards contribute more to economic growth than patents and licenses
- UK Department of Trade and Industry
 - Standards contribute £2.5 billion annually to economic growth in the UK

SEMI International Standards Program History



- Key Topics

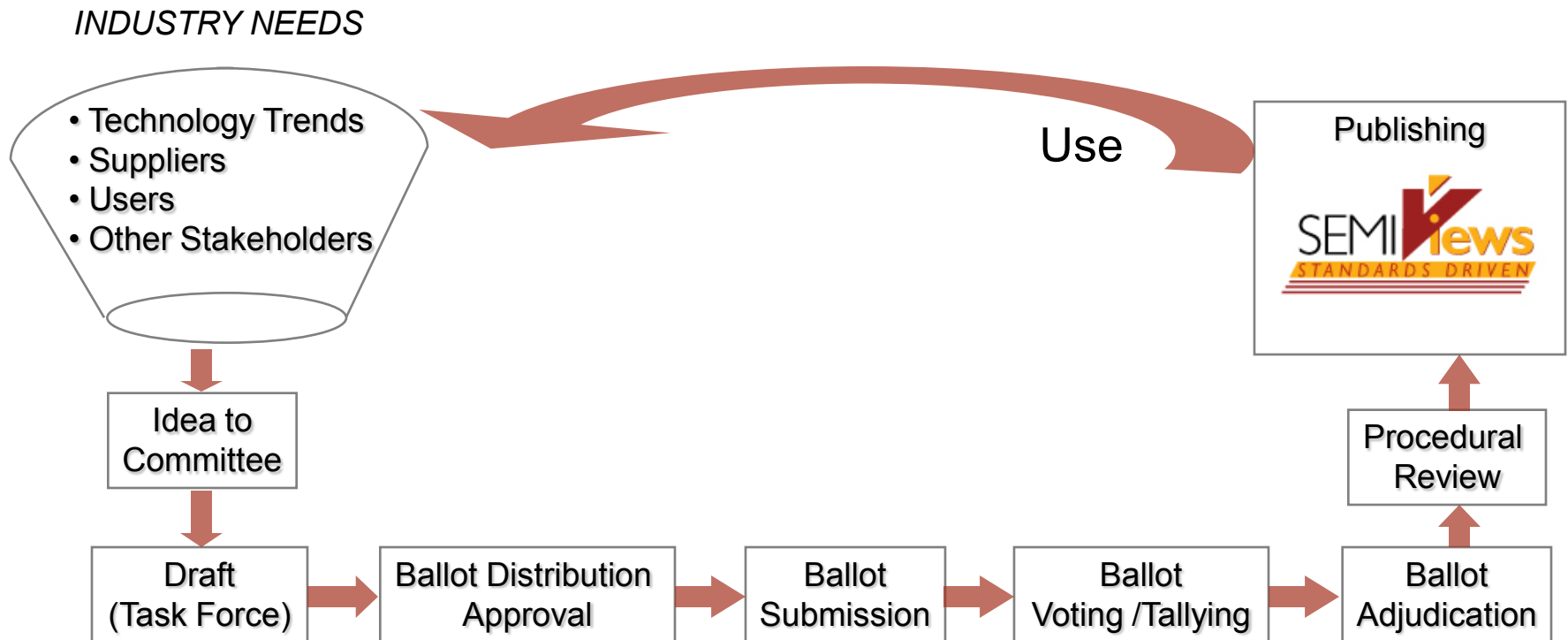
- 1973
 - Silicon Wafers
- Late 1970's
 - Chemicals and Gases
 - Metrology
 - Facilities
- Late 1980's
 - Factory Automation
- Early 1990's
 - Safety Guidelines
- 1994
 - 300mm
- 2007
 - Photovoltaics
- 2008
 - 450mm
- 2011
 - HB LED and 3DS-IC

- New Regions

- 1973
 - United States
- 1980's
 - Japan
 - Europe
- 1990's
 - Taiwan
 - Korea
- 2010
 - China



Document Development Path



The SEMI Standards Program Today



- All aspects of an automated fab are addressed
- Over 3,500 volunteer experts
 - 23 global technical committees
 - 200 task forces
- Currently over 800 SEMI Standards and Safety Guidelines available

High Profile SEMI Standards

- Wafer Dimensions
- Metrics
 - Factory efficiency, equipment reliability, and availability
- Equipment Interface
 - SEMI Equipment Communication Standards (SECS)
 - Generic Equipment Model (GEM)
- Environmental, Health and Safety
 - Safety for semiconductor (S2) and FPD (S26)
 - Energy conservation (S23)
- 300 mm, 450 mm
 - Automated Material Handling Systems
- Photovoltaic
 - Materials, equipment communications
- Anti-counterfeiting / Product Authentication



Organizational Structure

SEMI Board of Directors	Oversees the SEMI Standards Program
International Standards Committee	Develops and maintains the SEMI Standard Regulations. Oversees program coordination among geographical regions
Regional Standards Committee	Provides continuing supervision of standards development in a given geographical area
Technical Committees	Provides the technical expertise in the standards process
Subcommittees	Oversees task force activities and submits their reports to the technical committee
Task Forces	Develops and maintains most of the standards

Complete list - Companies Involved in Developing SEMI PV Standards [1/2]



6N Silicon Inc
a2peak power Co.,Ltd.
Accademia Europea Bolzano
acp-IT AG
Adema Technologies Inc
advanced clean production Information Tech
Air Liquide
Air Products
Air Products and Chemicals, Inc.
AIS Automation Dresden GmbH
AIST
Applied Materials
Applied Spectra, INC
Asahi/America, Inc.
Ascari Limited
Atelier Ishikawa
ATMI
BayTech Group
BEIJING SEVENSTAR ELECTRONICS CO.LTD
Bosch Solar Energy AG
BP Solar
Brewer Science
Bruce Technologies Inc
BT Imaging
CA Solar
camLine
Canon ANELVA Corporation
centrotherm photovoltaics Asia
Centrotherm Thermal Solutions GmbH + Co.
C-Gerhards GmbH i.G
CH2M Hill

Chroma ATE INC
CI Industrial Safety Consulting, LLC
CIS Forschungsinstitut für Mikrosensorik un
CMS/ITRI
Conexant Systems
Cook Engineering, Inc.
Covalent Materials Corporation
Daewon SPIC
Daihen Corporation
Dainichi Shoji K.K.
DAINIPPON
Delsolar
Despatch Industries
Deutsche Solar AG
Dow Corning
DuPont De Nemours International S.A.
DuPont Teijin Films
ECN Solar Energy
Energy Innovation Associates
ENSpring
Entegris, Inc.
Evans Analytical Group
Ever Energy Co. Ltd.
Evergreen Engineering
Exponent Inc.
Fraunhofer
Freiberg
Fuji Electric Advanced Technology Co., Ltd.
GEASOL Ltd
Gintech Energy Cooperation
Gnostic Systems

Gnostic Systems
GTsolar
Haas Training Solutions
Hager + Elsässer
Heltina AG
Hemlock Semiconductor Corporation
Hirata Corporation
Hitachi Kokusai Electric Inc.
Hong Ming Technology Co., Ltd.
Hynix Semiconductor Inc.
IAPMO
ICL Performance Products LLC
IE&S GmbH
IIT Roorkee
Industrial Technology Research Institute
InnoLas Semiconductor GmbH
InReCon AG
Institut für Solarenergieforschung
Instituto Tecnológico Superior de Irapuato
ITRI
Japan Radio Co.,Ltd.
Japan Solar Silicon
JC's Chunson Limited
Jonas&Redmann Automationstechnik GmbH
KANEKA CORPORATION
KesslerConsult
KEYENCE
King Design Industrial Co., Ltd.
KLA-Tencor

Companies Involved in Developing SEMI PV Standards [2/2]



Korea Institute of Lighting Technology
Lanco Solar Pvt Ltd
Lewis Bass International Inc
LG Electronics, Inc.
LG. Display
Linde LLC
M+W Zander FE GmbH
Malema Engineering
Manz Automation AG
Materials & Metrology
Matheson Tri-Gas
MEMC Electronic Materials, Inc.
Meyer Burger AG
Micronit
Mitsubishi Electric Corporation
Mitsubishi Heavy Industries,LTD
Mitsuishi Bussan Corporation Limited
Mizuho Information & Research Institute, Inc
MOSERBAER PHOTOVOLTAIC LIMITED
Motech (Solar Division)
Nippon Steel Corp.
Nisshinbo Mechatronics Inc.
NIST
Nokia Siemens Networks
NREL
NS Solar Material Co., Ltd.
NSN
OC Oerlikon Balzers AG
OCI

Omron
Op-tection GmbH
OptiSolar
Orient Service Corporation
Pall Corporation
Parker Hannifin
PEER Group GmbH
Polar Star Research, LLC
Prediktor AS
PVTC/ITRI
Q-Cells SE
QSES Inc.
R.A.Smythe, Management Consultants
RAPT Industries, Inc.
Raytex Corporation
REC Silicon
RENA GmbH
Roth & Rau - Ortner GmbH
RTS Corporation
Safe Techno Limited
Salmon Leap Associates India (p) Ltd
Salus
Schott Solar AG
Semilab
Semisol
SEMITRAC
Sentech Instruments GmbH
Sigma-Aldrich
Silicon Solar
Siliken Chemicals
SINTEF Materials and Chemistry
Sinton Instruments

SITEX 45 SRL
Sixtron Advanced Materials
Solar World
SolarTech
Solland Solar Cells GmbH
SPIL
SUMCO
Sunicon AG
Suntech Power Holdings Co., Ltd.
Swagelok
Tainergy Tech Co., Ltd
TAIYO NIPPON SANZO CORPORATION
The Scatter Works, Inc.
TNO Industrie en Techniek
Tokuyama corporation
Tokyo Electron Ltd.
Toray Research Center,Inc.
Tronic International Pte Ltd
TUV
ULVAC
Underwriters Laboratories Taiwan
UNI3 Ssystem Co., Ltd.
Universidad Carlos III de Madrid
University of Oxford
Voltaix. LLC
VQC
Wacker Chemie AG
Yaskawa Electric Corporation

Crystalline Technology and Manufacturing (CTM) Group

- European group of eight crystalline solar cell manufacturers (Q-Cells, Deutsche Cell, Bosch Solar Energy, Schott Solar, Sovello, Sunways, SolarWatt and Solland) is working together within SEMI in a pre-competitive environment to address the technology challenges facing the photovoltaic industry.
- The priority of the CTM Group will be the definition of the development processes for raw materials, cell technology and cell manufacturing.
- http://www.semi.org/en/Press/ctr_035592?id=highlights

Crystalline Technology and Manufacturing (CTM) Group (2)

- The CTM Group has established a crystalline solar cell technology roadmap up to the year 2020
 - www.itrpv.net
- SEMI Contact:
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 - sraithel@semi.org

