

Structuring standards for the photovoltaic manufacturing industry

Win Baylies, Marty Burkhart, Don Cook, Dick Hockett, Matthias Meier & Bettina Weiss, SEMI/PV Group Photovoltaic Standards Committee

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Fab & Facilities

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ABSTRACT

Standards have traditionally been used in other industries, especially semiconductor, to increase efficiencies and reduce costs. This article will illustrate these efforts, as well as acting as a call for participation to become involved in SEMI's standardization developments for PV. Four active task forces have been initiated to tackle these much-needed standards for the PV industry, namely, the Analytical Test Methods Task Force; the PV Equipment Interface Specification Task Force; the PV Gases and Chemical Purity Task Force; and the PV Facilities Task Force. As a follow-up to an article featured in the first edition of *Photovoltaics International* [1], SEMI has prepared this summary regarding the collective efforts of the PV Group's standards developments.

Introduction

Unlike other pre-established industries, where standard activities are mainly initiated by mature companies with clear requirements to standards, the PV industry, with its huge number of newly founded companies, is currently focused on ramping up their production lines and stabilizing their production processes. By structuring and utilizing standards requirements, it is possible to focus resources to the most valuable standards in this critical phase of the fast-growing PV industry. SEMI intends to achieve these goals by proving recommendations for new standards activities, linking experts together to accomplish the deliverables, and speed up the process of standards deployment.

The SEMI Standards and Safety Guidelines directly contribute to bringing the various segments of the manufacturing supply chain together to optimize options, agree on basic parameters, investigate and address safety concerns and introduce new ways of end-of-life treatment for both equipment and materials.

While standardization efforts are being initiated in several regions of the world, this article provides a closer look at particular activities in Europe and North America, and outlines the steps being taken to develop standards for the PV industry.

History

In March of 2007, at the PV Fab Managers' Forum in Leipzig, Germany, industry leaders focused on issues and concerns affecting overall manufacturing costs. Due to the results of their discussions, in July 2007, the European Photovoltaic Committee was approved, and, in January 2008, SEMI announced the details of their Global Photovoltaic (PV) initiatives, including the formation of the SEMI PV Group. In the spring of 2008, a joint SEMI/EPIA PV Needs

Assessment Survey was completed and work began on PV standards assessment and development of new PV-specific documents.

SEMI's PV Group Task Forces

Currently, there are four active task forces working on these items: Analytical Test Methods Task Force, PV Equipment Interface Specification Task Force, PV Gases and Chemical Purity Task Force, and PV Facilities Task Force. The recent and planned efforts of each of these task forces are summarized.

Analytical Test Methods Task Force

The International PV Analytical Test Methods Task Force has a charter to develop standards for analytical test methods for the International photovoltaic industry. The scope of the Task Force includes GDMS and ICP-MS as applied to impurities in silicon feedstock for multicrystalline Si PV. Additional analytical techniques for solid materials will be considered as appropriate for application to both thin-film PV and bulk PV, Si and non-Si, such as SIMS, XPS, AES, TOF-SIMS, SPM, TEM, SEM, EDS, RBS, HFS, PIXIE, TXRF, XRD, XRR, LEXES, FTIR, Lifetime and Raman.

The Task Force has successfully developed a trace element test method [2], follow-up work to which includes a round robin test and a line item ballot to replace the term "photovoltaic-grade" to avoid some confusion on the meaning of this term. Work is planned for a second test method on the use of ICP-MS for measuring trace elements in silicon feedstock. Analysts with experience in the use of ICP-MS, specifically for this material, are encouraged to join the Task Force.

PV Equipment Interface Specification (PV-EIS) Task Force

Looking at other industries, such as semiconductor manufacturing, suitable IT (Information Technology) interfaces

for production equipment have proven to be essential to run factories efficiently and effectively. Data sent and received through these interfaces is not only the prerequisite for line monitoring and control, but also for the implementation of sophisticated quality assurance, traceability and advanced process control strategies. Starting from the first discussions in early 2006 regarding the need for standardized IT interfaces for these purposes in PV, the awareness of the necessity has continuously grown. In September 2007 the European Equipment Interface Specification Task Force (PV-EIS TF) was formed to develop a corresponding framework of standards.

Initially, the taskforce installed two working groups to assess the requirements of the PV industry on the one hand and to review existing IT equipment integration standards and best practices from other industries and the PV industry on the other. The evaluation process based on the results of both working groups led to the decision to build upon the IT integration standard framework developed within the semiconductor industry (SECS/GEM). To facilitate the utilization of these standards within the PV industry, the PV-EIS task force developed the *Guide for PV equipment communication interfaces* (PVECI) that describes how to integrate process, automation and metrology equipment in the PV manufacturing environment. It contains a number of restrictions and clarifications that should simplify the application of SECS/GEM compared to the original version used in semiconductor manufacturing. The document has been submitted for balloting and is expected to be available as an approved SEMI standard in spring 2009. As the next step, the task force plans to initiate a new activity to extend the capabilities of the PVECI guide in terms of material tracking.

PV Gases and Chemical Purity Task Force
 The Gases and Chemical Purity Taskforce is comprised of people from leading industries that produce/manufacture solar cells, gases, liquid chemicals, purification, components and ancillary equipment used in photovoltaic (PV) production. These industry experts come together in a neutral forum to develop common standards and guidelines helpful to the PV industry.

The taskforce is not intent on defining what purity of gases or liquid chemicals are needed to produce solar cells. Rather, like its counterpart started many years ago for the advancement of semiconductor production, we intend to provide to the industry (end-users and suppliers alike) a set of written documents for gases and chemicals that can be used to obtain consistent, specified process materials.

The expected outcome will:

- Remove the ambiguity in what is being produced and provided - the customer gets what is truly needed and the supplier knows what to produce
- Provide a level playing field by preventing low bid possibilities where suppliers might meet the nomenclatural intent of the material but not the actual customer's need

- Avoid customer/supplier discussions about rejected material not performing as expected
- Give the end-user the ability to improve the process by ratcheting up a notch in purity if deemed advantageous.

Our global taskforce constantly seeks producers/process engineers, tool manufacturers, gas and chemical suppliers as well as component manufacturers of gas and liquid distribution systems to provide us with a well-rounded approach within this important forum.

PV Facilities Task Force

The PV Facilities (PV-FAC) Task Force held its initial meeting in October 2008 with participants representing PV industry manufacturing leaders, as well as designers, architects, engineers, tool manufacturers, materials providers and components suppliers. To leverage as much as possible of the existing SEMI Standards portfolio, the Task Force is now assessing about 130 of the 750+ existing SEMI standards as to their applicability to PV manufacturing, regardless of whether the facilities are common to known manufacturing technologies or

unique to specific methodologies. The PV-FAC Task Force will be documenting utility lists, process flows, facilities features, and other characteristics during the assessment.

The PV Facilities Task Force will develop a Prioritization Matrix, including numerical ranking (1-2-3, high-medium-low), of the SEMI Standards assessed in order to determine:

- Applicability of SEMI Standard to PV
- Ease of transition from SEMI to PV
- Urgency to PV industry
- Cost-effective potential
- Environmental, Health Safety (EHS) and/or IP Implications (Intellectual Property).

These priorities will be compared to and matched with the results from the SEMI-EPIA PV Standards Needs Assessment Survey (February 2008), and will support the Photovoltaic PV International Standards Roadmap (ISR-PV) currently in progress. The Task Force anticipates that draft versions of the priority assessment be sent out in December 2008, and that draft PV Facilities Standards will be published for consideration in Q109.

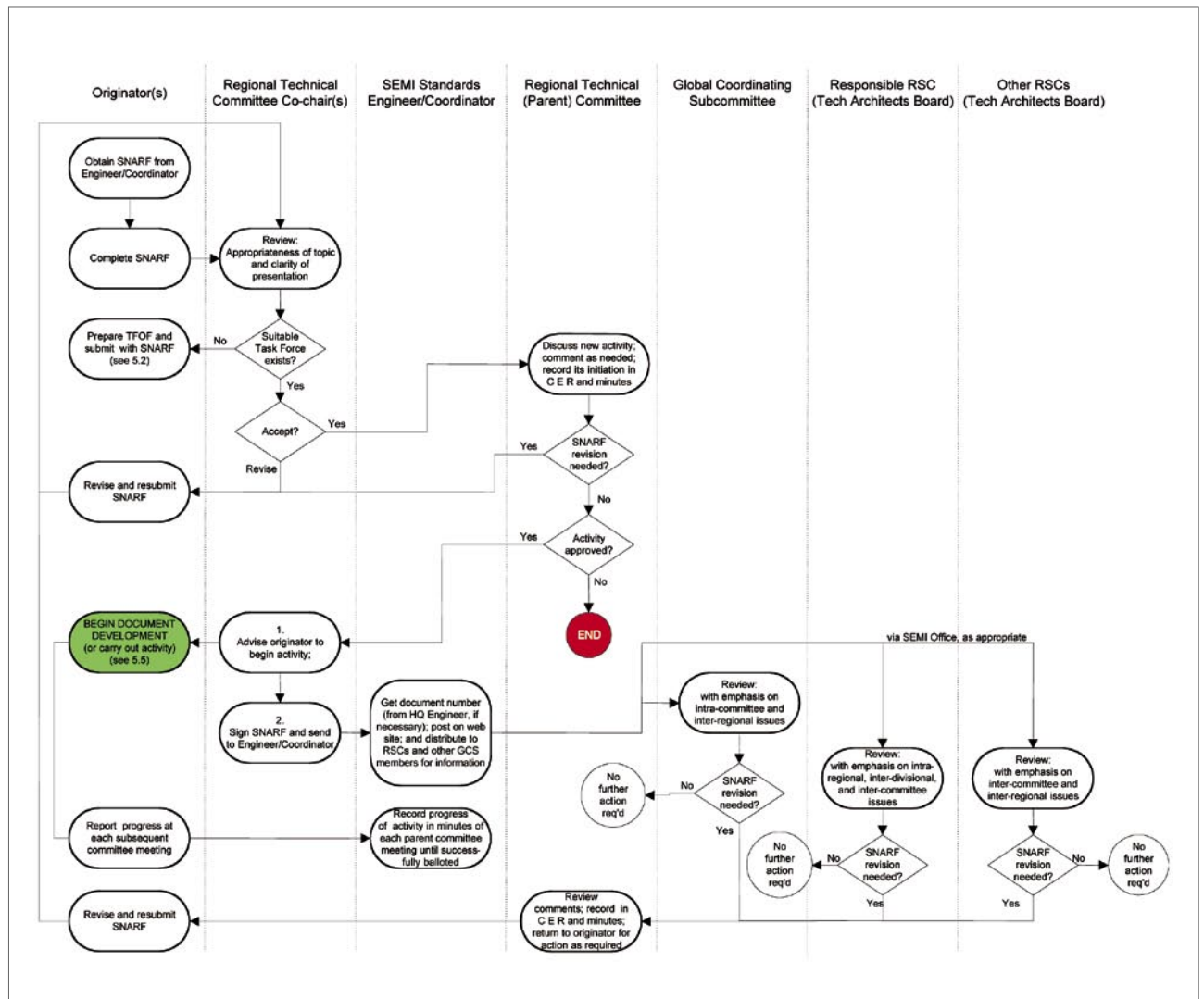


Figure 1. SEMI TFOF and SNARF development process flow.

How SEMI Standards are developed

Successful standards development requires just two ingredients: 1) a consensus of the PV Standards Committee that a standard is needed, and 2) a team that includes experts in that field and in standards development procedures. The SEMI International Standards Program infrastructure supports and guides the team's efforts. Key elements include:

- **Standards Regulations (the "Regs"):** these ensure a level playing field, are "evergreen" to reflect emerging needs, and provide the bedrock for all successful international standards activities. They are the unique responsibility of the International Standards Committee. Regional committee and task force leaders are usually very familiar with these regulations.
- **Procedural Guide:** this practical "how to develop standards" is written for the general standards membership. Its necessary rules and suggestions, including meeting conduct, balloting (development, execution and review of standards), and new activities for documents, provide a means for the group(s) to communicate and interact while maintaining protocol.
- **Document Guide:** through the efforts of the Task Forces, documents are prioritized, developed, and classified based on their application and to the type of standard needed. The practice of using standard specifications numbering, terminology, revision control, and outline is closely adhered to, and meets the intent of most international standardization organizations.

Figure 1 illustrates a SEMI process of how documents are developed through a Standards New Activity Report Form (SNARF) after task forces are created with an approved Task Force Organization Form (TFOF). Please note that larger or electronic versions are available through SEMI, as well as clarification of any terms or abbreviations unique to this particular chart.

Coordination with PV industry and standards organizations

Photovoltaic documentation needs have a host of standards organizations involved where SEMI's PV-related activity will be included. Examples include the following:

- **Product hierarchy:** determining standards for system installations, components of systems (e.g., structural components, inverter, module), components of modules (e.g., cell, substrate, support films, shell), and other PV aspects (e.g., software, operations, maintenance) can be defined by industry leaders as well as end users.

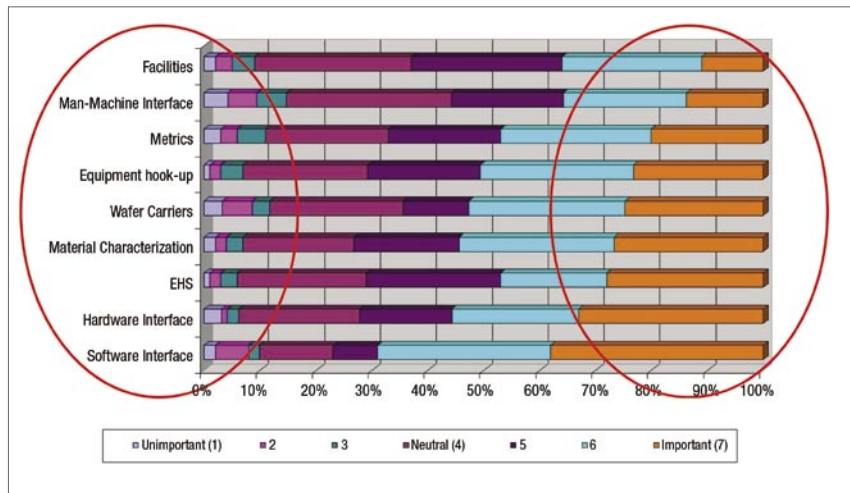


Figure 2. Assessment survey showing the areas where standards can have the most positive impact on the industry.

- **Standards hierarchy:** priority standards need to address performance certification, organizational capability, design approval (e.g., test methods), and product approval (e.g., processing, materials, equipment, and services).
- **Organizational hierarchy:** SEMI has excellent working relationships and continuously coordinates efforts with several organizations pertaining to the following groups: international (e.g., ISO, IEC), national (e.g., ANSI, DIN), services (e.g., UL, TUV, GSQ), SDOs (e.g., ASTM, SEMI, IEEE), and industry associations (e.g., EPIA, JPEA, SEIA).

SEMI's first PV Standard

The first PV standard to be submitted by the SEMI PV Group will be entitled *PV1: [Test Method for Measuring Trace Elements in Photovoltaic-Grade Silicon by High-Mass Resolution Glow Discharge Mass Spectrometry]*. The efforts to create this very important standard began in November 2007. It then went through two ballot cycles throughout 2008, and will be published in February 2009 – a 15-month cycle. Other topics in similar committees have been shorter when consensus and theme were relatively easy or longer when the topic required much discussion, investigation and task force agreement.

A specific topic's affect on the industry, its technical difficulty, and its urgency will directly impact how long it takes from idea and task force creation to it becoming a published document. These criteria are evaluated by the sponsoring Technical Committee prior to granting document development approval. International balloting often improves technical relevance and can sometimes add time.

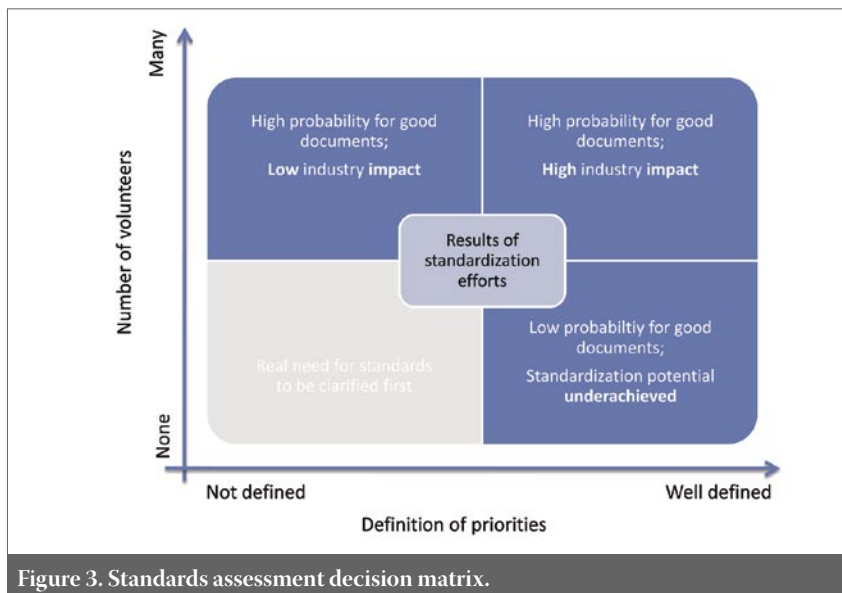
Determining priorities

The SEMI PV Group activities described above were initiated by groups within the PV industry that saw the need

for standardization in a specific area. Coincidentally, most of these activities had a high priority assigned in the various SEMI surveys. For example, the following figure indicates the initial priorities first reviewed at the SEMI - EPIA PV Needs Assessment Survey Priority Ranking at the SEMI North America PV Committee Meeting in May 2008:

“The benefits that occur through global standardization efforts cannot be felt and measured until a document is approved, published and used in the industry.”

However, additional coordination that generates priorities and promotes reuse is expected to boost the standards development process. For this reason, a core team in the SEMI PV Group has been set up to assess priorities and facilitate the transfer of relevant standards from SEMI to PV. In addition to the survey results, Q-Cells provided the SEMI PV Group with a set of objectives regarding SEMI standards, priorities, timelines, and related documents. Based on these inputs, the core team is in the process of determining an International Standards Roadmap (ISRM) and is developing an initial assessment matrix for determining SEMI-based PV-related standards. In addition to the appropriate priority settings, the most critical success factor for standards development for a given industry is the availability of a sufficient number of qualified volunteers who are willing and able to transition the industry requirements into documented standards and to reach consensus over these solutions. Figure 3 further illustrates



the expected correlation between a structured approach and the willingness of an industry to actively participate in the development of standards.

Benefits of standards

As described in the SEMI website, companies accrue two kinds of benefits by participating in the development of standards: immediate and deferred. The immediate benefits are brought about by access to technical resources, communication and networking with peers in the industry, the ability to influence the development of the standard and recognition for participation. The deferred benefits come about when the standard is released and accepted by its user community.

Although it is true that all users of the standard experience these benefits (whether they participated in the development or not), participation ensures that the standard is in fact developed, accelerates the development so benefits begin sooner, and of course, participants get a jump on the implementation of the standard.

Currently, over 2000 volunteers worldwide participate in the SEMI International Standards Program. There are over 200 task forces working in 17 global technical committees. Meetings take place in Europe, Japan and North America. Efforts are just underway in PV, and are expected to grow exponentially in the coming quarters.

Summary and conclusion

Standards development is an up-front investment – of people, skills, time and money. The benefits that occur through global standardization efforts cannot be felt and measured until a document is approved, published and used in the industry.

The semiconductor industry is a shining example of how investments can flourish through application of suitable standards. Millions of dollars have been saved by

collaboratively developing specifications and test methods for critical areas such as wafer diameter, safety, carriers, software interfaces and purity of chemicals, among many others. The semiconductor industry would be absolutely crippled if these standards did not exist or were not used globally by all stakeholders.

The PV industry can benefit greatly by leveraging the work that has already been done. By using existing standards to fill similar needs and allowing sufficient time and energy to investigate those areas truly unique to PV, solutions and approaches can be developed that will help propel the industry forward towards a more efficient, cost-conscious manufacturing process by the industry and for the industry.

References

- [1] Weiss, B. 2008, 'International Standards: a critical step towards reducing PV manufacturing cost,' *Photovoltaics International*, First Edition, pp. 24-26.
- [2] SEMI: 'SEMI PV1-0309 – Test method for measuring trace elements in photovoltaic-grade silicon by high-mass resolution glow discharge mass spectrometry.'

About the Authors

Win Baylies is a specialist in international photovoltaics, flat panel display and semiconductor metrology and measurement technologies. He has authored numerous technical articles, test methods, international round robin tests and related research reports. Mr. Baylies is assisting SEMI in developing photovoltaic standards as co-chair of the N.A. PV Standards Committee, and is aiding in the creation of SEMI's PV International Standards Roadmap (ISRM) as a member of the Core Group. He is a member of SEMI, SID, SPIE and ASTM. Enquiries:winba@comcast.net
Marty Burkhardt is the owner of Hi Pure Tech, which provides high quality technical writing and document review services

as well as consulting in clean production practices and contamination control for companies and individuals in the areas of industry and academia. Between 1992 and 1996, he was employed by Georg Fischer as a technical marketing manager for high-purity products in Switzerland. He also has 13 years' experience with Texas Instruments in Dallas, Texas and has co-chaired several SEMI taskforces.

Don Cook, PE, is President of Cook Engineering, Inc., and is currently the Chairman of the SEMI PV Group Facilities Standards Task Force. Mr. Cook has over 20 years' experience in design, construction, operations, and technological developments for microelectronics and advanced technologies projects. Prior to starting Cook Engineering, Mr. Cook was a Lead Corporate Technologies Engineer for Intel Corporation, as well as Director of Engineering at Kinetics. Mr. Cook holds a B.S.M.E. from the University of the Pacific, and is a registered mechanical engineer in the State of California. Mr. Cook is an active member of SEMI, ASES, SEIA, and the City of San Carlos.

Dick Hockett is Chief Scientist at Evans Analytical Group in Sunnyvale, California. He is Chairman of the SEMI PV Analytical Test Methods Task Force, both for NA and EU. He was previously Chairman of the Surface Analysis Task Force under SEMI's Silicon Wafer Committee in the 1990s, and Chairman of Section C (Surface Analysis) for ASTM F-1.06 (Si Semiconductors), also in the 1990s.

Matthias Meier is Project Manager and researcher at the Ultraclean Technology and Micromanufacturing department of the Fraunhofer Institute for Manufacturing Engineering and Automation (Fraunhofer IPA) in Stuttgart, Germany. His main area of research targets issues in the manufacturing IT environment. Furthermore, he is actively contributing to the emerging PV-related standardization activities within SEMI as a coach of the PV-EIS task force. Mr. Meier holds an M.Sc. in information technologies from the University of Stuttgart, Germany.

Bettina Weiss is Sr. Director, Photovoltaics Segment (North America) for SEMI/PV Group. She has been working with SEMI for 12 years. From November 2003 to March 2008, she served as Director, International Standards as chief staff of the SEMI International Standards Program. Since April 1, 2008, she has held responsibility for all initiatives and activities in SEMI's photovoltaic segment in North America, with continued global responsibility for PV standardization efforts as well as successful execution of the PV Standards Roadmap project. Ms. Weiss is assisted by Kevin Nguyen, Manager of NA Standards Committee for SEMI.

Enquiries

Website: www.semi.org