SEMI PV17-0312
SPECIFICATION FOR VIRGIN SILICON FEEDSTOCK MATERIALS FOR PHOTOVOLTAIC APPLICATIONS

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1 Purpose

1.1 Silicon is one of the key materials in the growing photovoltaic (PV) industry. Solar cells made of silicon will be manufactured for many years to come. New parties supplying or purchasing Si feedstock materials are entering this industry.

1.2 The need for higher volumes and more cost efficient feedstock Si triggered development of metallurgical refining methods. In addition new methods modifying the original Siemens process were investigated and were introduced in high volume manufacturing. In parallel to the development of refining methods a wide variety of crystallization techniques and solar cell designs, each requiring specific material properties, were investigated by industry and research organizations. A multidimensional parameter space would be necessary to describe all the relations between feedstock material quality, single and multicrystalline ingots and finally solar cell performance. These would result in a multitude of interface problems, inhibiting the relations between suppliers and their customers, that is not appropriate for a high volume and fast growing industry.

1.3 Standardized specifications for Si feedstock materials are expected to reduce these interface problems and to enable a common understanding of material properties and terms, allowing reliable manufacturing of ingots of solar cells and benefiting all parties.

2 Scope

2.1 This Specification covers virgin silicon feedstock materials produced by CVD processes, metallurgical refining processes or other processes. CVD processes include the so-called Siemens process, fluidized bed processes, powder processes and other processes using distilled silane or halosilane compounds.

2.2 These specified materials are intended for growing of single crystalline ingots and casting or other methods of growing multicrystalline Si, used for producing Si wafers for solar cells.

2.3 This Specification is not intended for material used for manufacturing thin film solar products such as amorphous or micromorphous Si products, but it may be used if it is appropriate for the specific application.

2.4 This Specification only applies to virgin silicon feedstock and not to scrap or waste material coming from the semiconductor industry.

2.5 This Specification is also not intended for specifying material blends, although it may be used as a guideline for melts from blended materials.

2.6 Relative units ppba and ppma are used for impurity concentration values in this Specification. For conversion to other units see SEMI AUX022.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI M44 — Guide to Conversion Factors for Interstitial Oxygen in Silicon

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SEMI MF28 — Test Method for Minority Carrier Lifetime in Bulk Germanium and Silicon by Measurement of Photoconductivity Decay

SEMI MF84 — Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

SEMI MF391 — Test Method for Minority Carrier Diffusion Length in Extrinsic Semiconductors by Measurement of Steady-State Surface Photovoltage

SEMI MF397 — Test Method for Resistivity of Silicon Bars Using a Two-Point Probe

SEMI MF723 — Practice for Conversion between Resistivity and Dopant or Carrier Density for Boron-Doped, Phosphorous-Doped, and Arsenic-Doped Silicon

SEMI MF1188 — Test Method for Interstitial Oxygen Content of Silicon by Infrared Absorption with Short Baseline

SEMI MF1389 — Test Method for Photoluminescence Analysis of Single Crystal Silicon for III-V Impurities

SEMI MF1391 — Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

SEMI MF1528 — Test Method for Measuring Boron Contamination in Heavily Doped n-Type Silicon Substrates by Secondary Ion Mass Spectrometry

SEMI MF1535 — Test Method for Carrier Recombination Lifetime in Silicon Wafers by Noncontact Measurement of Photoconductivity Decay by Microwave Reflectance

SEMI MF1630 — Test Method for Low Temperature FTIR Analysis of Single Crystal Silicon for III-V Impurities

SEMI MF1708 — Practice for Evaluation of Granular Polysilicon by Melter-zoner Spectroscopies

SEMI MF1723 — Practice for Evaluation of Polycrystalline Silicon Rods by Float-zone Crystal Growth and Spectroscopy

SEMI PV1 — Test Method for Measuring Trace Elements in Silicon Feedstock for Silicon Solar Cells by High-Mass Resolution Glow Discharge Mass Spectrometry

SEMI PV10 — Test Method for Instrumental Neutron Activation Analysis (INAA) of Silicon

4.2 *ANSI/ASQ*[1]

ANSI/ASQ Z1.4-2008 — Sampling Procedures and Tables for Inspection by Attributes

4.3 *DIN Standard*[2]

DIN 50451-3 — Testing of Materials for Semiconductor Technology – Determination of Traces of Elements in Liquids – Part 3: Aluminum (Al), Cobalt (Co), Copper (Cu), Sodium (Na), Nickel (Ni) and Zinc (Zn) in Nitric Acid by ICP-MS

DIN 51002-1 — Inductively Coupled Plasma Mass Spectrometry (ICP-MS) – Part 1: Principles and Definitions

4.4 *ISO Standard*[3]

ISO 2859 — Sampling Procedures for Inspection by Attributes

4.5 *Other Documents*

SEMI AUX022 — Conversion of Units for Impurity Concentrations in Silicon

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

[1] American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA; Telephone: 212.642.4900, Fax: 212.398.0023, http://www.ansi.org

[2] Deutsches Institut für Normung e.V., Available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany; http://www.din.de

[3] International Organization for Standardization, ISO Central Secretariat, 1 rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland; Telephone: 41.22.749.01.11, Fax: 41.22.733.34.30, http://www.iso.ch

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5 Terminology

5.1 Refer to *SEMI Standards Compilation of Terms (COTs)* for a list of the most current terms and their definitions.

5.2 *Abbreviations and Acronyms*

5.2.1 *HRTEM* — high resolution transmission electron microscopy

5.2.2 *ICP-OES* — inductively coupled plasma optical emission spectroscopy

5.2.3 *NAA* — neutron activation analysis

5.2.4 *SEM-EDX* — scanning electron microscopy-energy dispersion x-ray spectroscopy

5.2.5 *XRF* — X-ray fluorescence

5.3 *Definitions*

5.3.1 *chips, polysilicon* — irregularly shaped pieces of polysilicon with a largest dimension less than approximately 50 mm.

5.3.2 *chunks, polysilicon, also called lumps* — lumpy polysilicon of non-spherical shape with irregular surface features. The polysilicon chunks have dimensions typically up to 250 mm.

NOTE 1: Chips as well as chunks are generated by crushing poly-Si rods or pmg-Si bricks. There is no clearcut size limit between them, chips are usually the smaller pieces and chunks the larger ones.

5.3.3 *CVD Processes*

5.3.3.1 *fluidized bed process* — decomposing distilled silane or a halosilane compound in a fluidized-bed reactor by thermolysis to create polycrystalline granules.

5.3.3.2 *powder process* — homogeneously decomposing distilled silane or a halosilane compound in a reactor by thermolysis to create Si powder.

5.3.3.3 *rod CVD process (Siemens process)* — decomposing distilled silane or a halosilane compound in a rod deposition reactor (Siemens reactor) by thermolysis to create fine grained polycrystalline Si (poly-Si) in the form of rods.

5.3.4 *granules, polysilicon, also called beads or pellets* — approximately spherical particulate polysilicon produced in a fluidized bed reactor with a size of typically 0.1 mm to 10 mm.

5.3.5 *halosilanes* — silanes, in which one or more hydrogen atoms are replaced by halogen atoms, such as $SiHCl_3$ or $SiHBr_3$.

5.3.6 *metallurgical grade Si (mg-Si)* — silicon chunks of irregular shapes with a typical purity of 98% or more Si. Mg-Si is obtained by carbothermal reduction of lumpy SiO_2 in submerged electric arc furnaces. It is the raw material for metallurgical refining processes.

5.3.7 *powder, polysilicon, also called fines* — polysilicon particles with a maximum dimension ≤500 µm.

NOTE 2: Powder and granule differ with respect to bulk density and morphology. Powder typically has lower density and dendritic like growth structure and may aggregate to form larger particles.

5.3.8 *purified metallurgical grade Si (pmg-Si), also called upgraded metallurgical grade Si (umg-Si)* — metallurgical silicon that is purified by applying metallurgical processes to Si, such as slagging, filtering, melting with subsequent oriented solidification, leaching or etching.

5.3.9 *rod, polysilicon* — cylindrical or partially cylindrical piece of polysilicon, with a weight typically >5 kg.

5.3.10 *silane* — SiH_4, starting material for ¶¶ 5.3.3.1, 5.3.3.2, and 5.3.3.3.

5.3.11 *trichlorosilane (TCS)* — $SiHCl_3$, starting material for ¶¶ 5.3.3.1, 5.3.3.2, and 5.3.3.3.

NOTE 3: TCS and silane are obtained from a reaction of HCl with mg-Si followed by purifying the volatile compounds by distillation.

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6 Ordering Information

6.1 Purchase orders for Si feedstock materials furnished to this specification shall include the following items. These items are shown in Table 1 together with check boxes, if applicable, for selecting the required characteristic. Open entries, indicated by "____", have to be filled with numbers and appropriate units.

- General Characteristic, specifying manufacturing method, dopants and co-dopants.
- Chemical Characteristics, quantifying acceptable concentrations of acceptors, donors, carbon, and metals as well as other of other impurities.
- Dimensional Characteristics, defining the morphology, size and weight of the product.
- Surface Characteristics, specifying the surface appearance and oxide layer thickness.
- Packaging, specifying material and size of containers.
- Statistical Acceptance Characteristics, specifying test method, sample size and acceptance criteria for qualifying the product.
- Documentation, defining number of certificates and their content.

6.2 Additional items may be specified optionally in addition to those listed above.

6.3 In all cases, it is essential that all choices for the items specified be made in order not to have unspecified parameters that would lead to surprises between supplier and customer.

6.4 In addition, the purchase order must indicate the test method to be used in evaluating each of those items for which alternate test procedures exist.

Table 1 Specification Format for Order Entry

Part 1 General Information		
ITEM	*INFORMATION*	*DATE:*
Customer Name		
Purchase Order Number		
Line Number		
Item Number		
General Specification Number		
Revision Level		
Part Number/Revision		

Part 2 Silicon Feedstock Materials for Photovoltaic Solar Cells			
ITEM		*SPECIFICATION*	*MEASUREMENT METHOD*[#1]
1	**GENERAL CHARACTERISTICS**		
1.1	Manufacturing Method	[ ] CVD-poly; [ ] pmg-Si; [ ] other (specify): ____; [ ] not specified	
1.2	Acceptors	[ ] B; [ ] Al; [ ] other (specify): _____	
1.3	Donors	[ ] P; [ ] As; [ ] Sb; [ ] other (specify):_____	
1.4	Excess Charge Carrier Lifetime	[ ] specify:____µsec; [ ] not specified	[ ] SEMI MF28[#2] [ ] SEMI MF391[#2] [ ] SEMI MF1535[#2] [ ] other (specify):_____

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