

SEMI PV90-0319

GUIDE FOR MATERIAL REQUIREMENTS OF INTERNAL FEEDERS USED IN MONOCRYSTAL SILICON GROWERS

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1 Purpose

1.1 An internal feeder is a device that enables the loading of additional polycrystalline silicon into the crucible of a crystal grower for either top-up or recharge purposes, while still maintaining full furnace vacuum and temperature conditions.

1.2 Internal feeders are widely used in the photovoltaic industry for growing monocrystalline silicon. During the feeding process the high purity polycrystalline silicon is in close contact with parts of the feeder. Therefore, the materials used in the construction of the internal feeders may contaminate the polycrystalline silicon, thus adversely affecting the quality of the silicon crystal.

1.3 Internal feeders work in a high temperature environment. Its construction materials need to maintain adequate mechanical strength under such an environment.

1.4 Many material suppliers, semiconductor device manufacturers, equipment makers, and crystal producers are involved in the manufacturing and utilization of internal feeders. Thus, a guide for material requirements is needed to assure product quality.

1.5 The purpose of this technical guide is to make the best practice recommendations regarding materials used in the construction of internal feeders, so that the feeders can perform well in the challenging working environment, while minimizing contamination to the polycrystalline silicon material.

2 Scope

2.1 This Guide covers internal feeders that are used to grow single crystal silicon for the photovoltaic industry.

2.2 This Guide quantifies the impurity levels which are potentially transferred into the silicon melt from various construction materials used for internal feeders. It also provides guidance for selecting appropriate construction materials for internal feeders.

2.3 This Guide lists the impurities typically found in polycrystalline silicon, and describes shortly the effects these impurities may have on finished solar cells.

2.4 This Guide also describes the different temperature regions of an internal feeder and the temperature limits of the materials used in each region.

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 The materials recommended in this guide are appropriate for internal feeders for Czochralski silicon single crystal growers. This Guide may not be appropriate for other growth methods for silicon single crystals.

3.2 The construction materials recommended in this Guide are not intended to be exhaustive. It may be possible to find other materials appropriate for internal feeders besides those recommended in this Guide.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI PV17 — Specification for Virgin Silicon Feedstock Materials for Photovoltaic Applications

4.2 ASME Standard¹

ASME SA-240/SA-240M — Standard for Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

4.3 ASTM Standards²

ASTM A959-2009 — Standard Guide for Specifying Harmonized Standard Grade Compositions for Wrought Stainless Steels

ASTM B387-10 — Standard Specification for Molybdenum and Molybdenum Alloy Bar, Rod, and Wire

ASTM D4894-15 — Standard Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials

4.4 DIN Standard³

DIN 50150 — Hardness Conversion Chart

4.5 JEITA Standard⁴

JEITA EM-3601A — Standard Specification for High Purity Polycrystalline Silicon

4.6 SAC Standard⁵

GB/T 25074-2010 — Solar-Grade Polycrystalline Silicon

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

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 PTFE — polytetrafluorethylene

6 Internal Feeders, Basic Components and Mode of Operation

6.1 An internal feeder is a usually cylindrical container. One end of it, the upper end, is open and at the other, lower end there is a gate that can be opened from the outside of the growth chamber (see Figure 1).

6.2 This container is filled with the required amount of feedstock and then suspended from the cable or rod, by which the silicon ingot was pulled from the melt in the crucible.

6.3 It is then lowered in the growth chamber of the puller and the gate is opened, allowing the feedstock to drop in the crucible.

6.4 The feedstock then can be melt and a new silicon ingot can be grown.

6.5 During the filling process the feedstock pieces (chunks, pellets or powder) are moving with respect to the container walls and the valve components, thereby abrading material from them that is also introduced in the crucible.

¹ American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA; Telephone: +1.973.882.1170, Fax: +1.973.882.1717, <https://www.asme.org>

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, <http://www.astm.org>

³ Deutsches Institut für Normung e.V., Available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany; <http://www.din.de>

⁴ Japan Electronics and Information Technology Industries Association, Ote Center Building, 1-1-3, Otemachi, Chiyoda-ku, Tokyo 100-0004, Japan; <http://www.jeita.or.jp>

⁵ SAC Standardization Administration of the People's Republic of China, N0. 9 Madian Donglu, Haidan District, Beijing, China 100088, <http://www.sac.gov.cn>

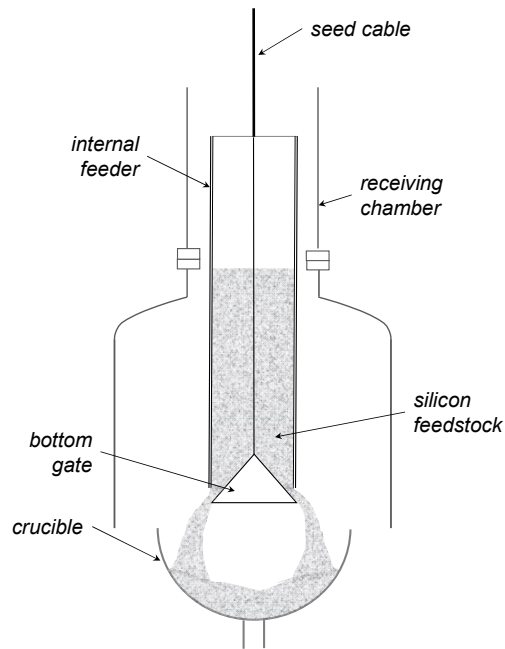


Figure 1
Schematic Cross Section of an Internal Feeder Illustrating its Working Process
in an Equipment for Growing Single Crystal Silicon

7 Impurity Elements and Their Influence on the Solar Cell

7.1 Impurity elements, such as oxygen, carbon, iron, and other metals, introduced into the silicon crystal may impact the conversion efficiency of solar cells negatively. Therefore, contamination has to be minimized during the feeding process.

7.2 The maximum tolerable amount of various impurities in solar grade and electronic grade polycrystalline silicon feedstock is published in several standards (GB/T 25074-2010, JEITA EM-3601A and SEMI PV17) and is summarized in Table 1.

7.3 Metallic impurities, in particular transition metals, significantly reduce the performance of solar cells⁶ and semiconductor devices, even when their concentrations are controlled to less than 10^{13} atoms/cm³, by reducing the minority charge carrier diffusion length due to their recombination activity.

7.4 Metals in high concentration can also form precipitates that may shunt the *p-n* junction of a solar cell.⁷

7.5 Isolated carbon or oxygen atoms in silicon are not electrically active. In sufficiently high concentrations they may, depending on the thermal history of the semiconductor device, form precipitates⁸ that again may degrade the performance of solar cells.

⁶ Davis, Jr., J. R., Rohatgi, A., Hopkins, R. H., Blais, P.D., Rai, Choudhury, P., McCormick, J.R., Mollenkopf, H.C., IEEE Trans. on Electron Devices **ED-27** (1960): pp. 677–687.

⁷ Queisser, H. J., Solid-State Electronics **5** (1962): pp. 1–10.

⁸ Borghesi, A., Pivac, B., Sassella, A., Stella, A., Appl. Phys. Reviews **77** (1995): pp. 4169–4244.