Table R1-3 Temperature Dependence. (Area = $1mm^2$, J = $0.1 A/cm^2$)

Temp. (degree)	Failure (%)	Qbd (C/cm^2) at Weibull = 0
r.t.	15.1	19.2
85	14.3	9.2
125	14.8	5.2

SEMI M61-0705
SPECIFICATION FOR SILICON EPITAXIAL WAFERS WITH BURIED LAYERS

This standard was technically approved by the global Silicon Wafer Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on May 20, 2005. It was available at www.semi.org in June 2005 and on CD-ROM in July 2005.

1 Purpose

1.1 Some silicon epitaxial wafers are supplied with buried layers under the epitaxial film. This specification covers the properties of such epitaxial wafers that pertain to the buried layer.

2 Scope

2.1 This specification defines the properties of silicon epitaxial wafers with buried layers that relate to the characteristics of photolithography, buried layer, and buried layer pattern after the deposition of the epitaxial layer.

2.2 This specification is intended to be used with the polished wafer specification (SEMI M1) and the epitaxial wafer specification (SEMI M2), which define the properties of the substrate and the epitaxial layer, respectively.

2.3 The EDI Code List for items appropriate to epitaxial wafers with buried layers is given in SEMI M18.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Referenced Standards and Documents

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specifications for Silicon Epitaxial Wafers for Discrete Device Applications

SEMI M18 —Format for Silicon Wafer Specification Form for Order Entry

SEMI M20 — Practice for Establishing a Wafer Coordinate System

SEMI M59 — Terminology for Silicon Technology

SEMI MF26 — Test Methods for Determining the Orientation of a Semiconductive Single Crystal

3.2 *ANSI Standard*[1]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.3 *JEITA Standard*[2]

EM-3501 — Standard methods for determining the orientation of a semiconductor silicon single crystal

NOTICE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 General terminology for silicon wafers and silicon technology is covered in SEMI M59 to be published in March).

4.2 Terms related to epitaxial wafers with buried layers are as follows:

4.2.1 *alignment precision* — pattern displacement in first mask photolithography process.

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1 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org.

2 Japan Electronics and Information Technology Industries Association, 3rd floor, Mitsui Sumitomo Kaijo Bldg. Annex, 11, Kanda-Surugadai 3-chome, Chiyoda-ku, Tokyo 101-0062, Japan. Tel:81.3.3518.6434; Fax:81.3.3295.8727 Website:www.jeita.or.jp

4.2.2 *buried layer* — a diffused region in a substrate that is, or is intended to be, covered with an epitaxial layer.

4.2.3 *pattern distortion ratio* — absolute magnitude of the quotient of (1) the difference between the width of the pattern on the substrate and the width of the pattern on the top surface of the epitaxial layer and (2) the thickness of the epitaxial layer.

4.2.4 *pattern shift ratio* — lateral distance between the center point of the pattern on the surface of the substrate and the center point of the pattern on the surface of the epitaxial layer divided by the epitaxial layer thickness.

4.2.5 *pattern step height* — difference in vertical position of the diffused (buried layer) surface and the original substrate surface, after removal of oxide.

5 Ordering Information

5.1 Purchase orders for silicon epitaxial wafers furnished to this specification shall include the items indicated in sections 4-1 through 4-3 of Part 4 of the Specification Format for Order Entry (for Epitaxial Wafer with Buried Layer) shown in Table 1. Other specified characteristics, as required, may be added in section 4-4 of the format.

5.2 In addition, the purchase order shall include

- the material in Part 1 (General Information) of the Specification Format for Order Entry, in SEMI M1,
- specifications for the substrate wafer of the appropriate characteristics as defined in Part 2 (Polished Wafer or Substrate) also in SEMI M1, and
- specifications for the epitaxial layer as defined in SEMI M2.

NOTE 1: Note that the orientation of single crystal is differently specified in SEMI MF26 and JEITA EM-3501.

5.3 The following items must also be included in the purchase order:

5.3.1 Lot acceptance procedures.

5.3.2 Certification (if required).

5.3.3 Packing and marking requirements.

Table 1 Specification Format for Order Entry

Part 4 Epitaxial Wafer with Buried Layer

ITEM			*SPECIFICATION*
1. PHOTOLITHOGRAPHY CHARACTERISTICS			
	4-1.1	Mask ID	[ ] Number: [ ]; [ ]None
	4-1.2	Alignment Precision	X max [ ] µm, Y max [ ] µm; Reference Point (Wafer Coordinate System): x [ ] mm, y [ ] mm; θ max [ ]°
	4-1.3	Pattern Line Width Tolerance	Tolerance ± [ ] µm
2. BURIED LAYER CHARACTERISTICS			
	4-2.1	Dopant	[ ]B; [ ]P; [ ]Sb; [ ]As
	4-2.2	Diffusion Depth (x_j)	Nominal [ ] ± Tolerance [ ] µm
	4-2.3	Sheet Resistance	Nominal [ ] ± Tolerance [ ] Ω/sq
	4-2.4	Pattern Step Height	Nominal [ ] ± Tolerance [ ] nm
	4-2.5	Defect Density (Before Epi)	Not greater than [ ]/cm^2
3. BURIED LAYER PATTERN CHARACTERISTICS AFTER EPI			
	4-3.1	Pattern Shift Ratio	Nominal [ ] ± Tolerance [ ]
	4-3.2	Pattern Distortion Ratio	Max. [ ]
4. OTHER CHARACTERISTICS			

ITEM			SPECIFICATION

6 Requirements

6.1 *General Characteristics*

6.1.1 The epitaxial wafers with buried layers shall meet all requirements specified in the purchase order including those requirements related to both the substrate wafer and epitaxial layer properties.

6.2 *Photolithography Characteristics*

6.2.1 The identified mask shall be used in making the pattern for the diffused layers.

6.2.2 The alignment precision shall meet the specified requirements as follows:

6.2.2.1 The values of X and Y, the displacement of the center of the pattern from a reference position defined in the wafer specification in terms of the wafer coordinate system defined in SEMI M20, shall not exceed the maximum values specified.

6.2.2.2 The value of θ, the angle between the x-axis of the pattern and the primary orientation flat (see Figure 1) shall not exceed the maximum value specified.

6.2.3 The pattern line widths (see Figure 2) shall be within the specified tolerance of the desired values.

6.3 *Buried Layer Characteristics*

6.3.1 The dopant shall be the element specified: boron (B), phosphorus (P), antimony (Sb) or arsenic (As).

6.3.2 The diffusion depth shall fall within the tolerance of the nominal value specified in micrometers (μm).

6.3.3 The sheet resistance of the diffused layer shall fall within the tolerance of the value specified in ohms per square (Ω/sq).

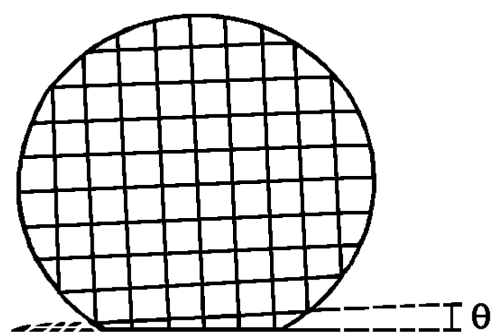

Figure 1
First Mask Showing Angular Displacement θ

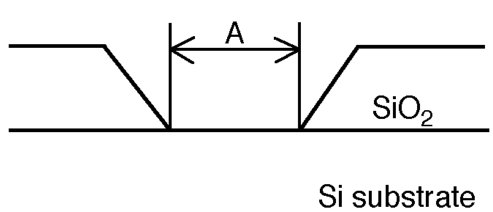

Figure 2
Schematic Diagram Showing Line Width, *A*, of Pattern on Substrate Wafer

6.3.4 The pattern step height *A* as shown in Figure 3, shall meet the nominal value *X* within the tolerance ±*Y*, as specified in nanometers (nm).

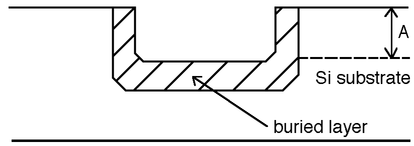

Figure 3
Cross-Sectional View of Epitaxial Substrate After Oxide Removal but Before Deposition of the Epitaxial Layer Showing the Pattern Step Height, *A*

6.3.5 The defect density on the surface after deposition but before growth of the epitaxial layer shall not exceed the density specified in number of defects per square centimeter.

6.4 *Buried Layer Pattern Characteristics after Growth of the Epitaxial Layer*

6.4.1 The pattern shift ratio *d/t* (see Figure 4) shall meet the specified requirements for nominal value *X* and tolerance ±*Y,* both of which are dimensionless because both *d* and *t* are in micrometers (µm).

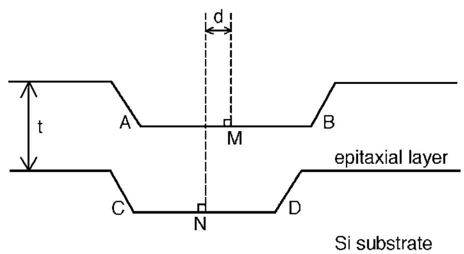

Figure 4
Cross-Section View of Epitaxial Wafer Showing the Pattern Shift, *d*.
Not to scale: AM = MB and CN = ND

6.4.2 The pattern distortion ratio shall not exceed the maximum value specified. This dimensionless ratio is equal to

$$\text{pattern distortion ratio} = \frac{a - b}{t} \quad (1)$$

where:

a = width of pattern on epitaxial layer,

b = width of pattern on substrate, and

t = thickness of epitaxial layer

as shown in Figure 5

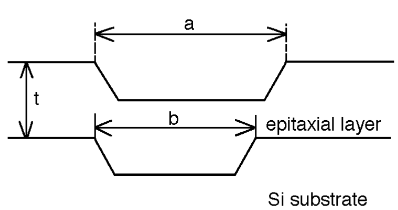

Figure 5
Cross-Section View of Epitaxial Layer Showing the Pattern Widths, *a*,
at the Epi Surface, and *b*, at the Layer-Substrate Interface

6.5 Wafers shall meet all requirements related to other characteristics, if any such requirements are specified in the purchase order.

7 Sampling

7.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) or lot tolerance percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL or LTPD values. Inspection levels shall be agreed upon between the supplier and the customer.

8 Test Methods

8.1 Because no test methods have been standardized and identified in Table 1, all tests to be made to assure that the wafers meet the required characteristics shall be agreed upon between supplier and customer.

9 Certification

9.1 Upon request of the customer in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

9.2 In the interest of controlling inspection costs, the supplier and the customer may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests. However, if the customer performs the test and the material fails to meet the requirement, the material may be subject to rejection.

10 Product Labeling

10.1 The wafers supplied under these specifications shall be identified by appropriately labeling the outside of each box or other container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include as a minimum the nominal diameter, conductivity type, dopant, orientation, resistivity range, and lot number. The lot number, either (1) assigned by the original manufacturer of the wafers, or (2) assigned subsequent to wafer manufacture but providing reference to the original lot number, shall provide easy access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the manufacturer's facility for at least one month after that particular lot has been accepted by the customer.

11 Packing

11.1 Special packing requirements shall be subject to agreement between the supplier and customer. Otherwise, all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination and in accordance with the best industry practices to provide ample protection against damage during shipment.

SEMI PR9-0705
PROPOSED GUIDE FOR STANDARD PERFORMANCE, PRACTICES, AND ASSEMBLY FOR ULTRA HIGH PURITY MICROSCALE FLUIDIC SYSTEMS FOR USE IN SCALABLE PROCESS ENVIRONMENTS

This proposed guide was technically approved by the global MEMS Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on April 17, 2005. It was available at www.semi.org in June 2005 and on CD-ROM in July 2005.

1 Purpose

1.1 This document provides guidelines for generic fluidic I/O design and fabrication that can reduce redundant engineering effort and lead to improved design, manufacturability, testing and operation.

2 Scope

2.1 This includes guidance for performance, practices, and assembly of microscale fluidic components. This document will provide guidance to users involved in design and development of standard fluidic interfaces.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This guide is a work in progress. Some sections require further development. Suggestions for improvement are welcome.

4 Referenced Standards and Documents

4.1 *SEMI Standards*

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

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

5 Terminology

(Refer to SEMI's Compilation of Terms (COT) for a list of the most current terms and their definitions.)

5.1 *Abbreviations and Acronyms*

5.1.1 *MEMS*— Microelectromechanical systems

5.1.2 *TLA* — Three Letter Acronym

5.2 *Definitions*

5.2.1 *Microscale* — 10^{-6} meters.

5.2.2 *Microfluidics* — fluid transport, physics, and chemistry on microscale dimensions.

5.2.3 *Micro Sealing Dimensions* — flow channel cross sections having an effective diameter of <25 micrometers; optionally flow channel cross sections having an effective diameter of 25 to 100 micrometers.

5.2.4 *Macro Sealing Dimensions* — flow channel cross sections having an effective diameter of >100 micrometers.

5.2.5 *Microfluidic Components* — fluidic components functioning at the scale of 1-100 micrometers. Examples: micro flow channels, microvalves, micro pumps.

5.2.6 *Microsealing Systems*

5.2.7 *Macro to Micro Sealing* — sealing that connects the micro regime with the macro regime.

5.2.8 *Microsealing* — sealing on components at the microscale.

5.2.9 *Wafer Level Sealing* — bonding of wafers by anodic, silicon direct, eutectic, or adhesive means.

5.2.10 *Macrosealing* — sealing on components at the macroscale.

5.2.11 *Static Seals* — seals that operate with non-moving surfaces.

5.2.12 *Dynamic Seals* — seals that operate with moving surfaces.

5.2.13 *high-purity* — of a system, subsystem, or component used for the control of chemicals (gases or liquids), designed and constructed in such a manner that it does not introduce significant impurities, particulate or molecular, into the flow stream it controls or regulates.

NOTE 1: Such systems, subsystems, or components are designed and constructed such that, if an impurity is introduced into the flow path, it can be readily purged to an insignificant level.

5.3 *leak* — a path (or paths) in a sealed system that will pass tracer gas when a pressure differential, a concentration differential, or diffusion path exists. There are two leak mechanisms: a mechanical passage and a material through which gas can diffuse or permeate. A leak may have both mechanisms operating in parallel.

5.4 *leakage, inboard* — leakage from outside to inside occurring when the internal pressure is less than the external pressure acting on a component or the concentrations of a given component are different inside and outside generating a non-zero chemical potential. Inboard leakage is typically determined by introducing a tracer gas around the exterior of the piping system or component under test.

NOTE 2: Inboard leak tests are easier tests to conduct to high sensitivity levels, but are typically not indicative of pressurized operating conditions. It is difficult to correlate an inboard leak test to the performance of a component, subsystem, or system when under internal pressure. Also, the internal collapsing forces created by external pressure may mask leaks which may exist under pressurized operating conditions.

5.5 *leakage, internal* — leakage occurring within a component across a flow barrier, such as the seat of a closed valve.

5.6 *leakage, outboard* — leakage from inside to outside occurring when the internal pressure is greater than the external pressure acting on a component. Outboard leakage is typically determined by introducing a tracer gas into the interior of the piping system or component under test.

5.7 *Microfluidic Subsystesm* — a "microfluidic subsystem" in a fluidic system may contain one or many MEMS components. The subsystem contains control and signaling elements. The subsystem, in turn, is attached fluidically to a larger system or subsequent process. e.g. mass flow controller for fluid delivery, lab-on-a-chip.

5.7.1 *Fluidic Adapter* — a physical interconnecter that fluidically links a microfluidic component to another micro- or macro-scale fluidic device.

6 Design Guidelines

6.1 *Purpose* — Define basic design criteria for micro-fluidic interconnections, considering factors such as fluid type, pressure, flow rate, surface conditions, materials and their compatibilities, etc. Establish a recommended standard scaling rule for dimensions of such interconnections.

6.2 *Scope* — Micro-sealing connections as defined in ¶5.2.3 above, for applications in two pressure ranges: below one atmosphere and 0–125 psig, and in three temperature ranges: <0 C, 0–100 C, and >100 C.

6.3 *Define Design Parameters*

6.3.1 Overall dimension and weight constraints: MEMS component, subsystems, system, fittings, manifolds.

6.3.2 For different materials used to join parts check that the differences in thermal expansion coefficients are acceptable for the temperature range that the component or system will be used in.

6.3.3 For different materials used to join parts check material chemical characteristics are compatible (see materials §7 below).

6.3.4 Fluid types to be used with MEMS, define gases and liquids, reference SEMI F79 (Gas Compatibility with Silicon). List all materials in wetted path.

6.3.5 Electrical configuration, digital or analog IEEE standards?

6.3.6 Volumes should be minimized (internal, connecting, interface/interconnection, dead volumes), give relation to time and process response, give dry-down constraints.

6.3.7 Surface roughness requirements.

6.3.8 Design for shock and vibration criteria, Reference MIL-STD 810.

6.3.9 Leak integrity: permeability, across the seat, and inboard. Reference SEMI F1.

6.3.10 Accuracy, repeatability, control range requirements.

6.3.11 Purging capability, number of times of full scale should flow for purging, turnover requirement.

6.3.12 Direction of flow

6.3.13 Upstream filtration requirements, particle requirements, moisture, other contamination characteristics. Reference SEMI E49 for high purity and ultrahigh purity systems.

6.3.14 Attitude constraints

6.3.15 Design for reliability requirements, MTTF, MTTR

6.3.16 Temperature limits

6.3.17 Pressure (proof, burst, inlet) limits

6.3.18 Flow ranges

6.3.19 Scaling rule for dimensions of interconnections[1]

6.3.19.1 Consider scaling rule to be different for different industrial applications. For example gas and liquid cannot use the same scaling rule.

6.3.20 Adapter guidelines for smooth transition from Macro to Micro. This is for the case the MEMS system is to replace an existing device, and there is a mismatch of the dimensions. A flexible transition may be considered if space is limited.

6.3.21 Surfaces that come into contact with samples, process gasses, or chemicals must not adsorb or react with them. Select components or tubing that is: 1) inherently compatible, 2) can be treated (water rinsed, O^2 ashing, acid clean...) or 3) coated (Teflon®, SiO^2, ...), to be compatible. Consider protein materials where the quantity of biomaterial sticking to surfaces will be dependent upon the wetted surface area and how well the fluid adsorbs to the surface.

7 Materials Guidelines

7.1 *Purpose* — Provide a Matrix of Materials Compatibility for commonly used materials and provide examples of applying the matrix to designs.

7.2 *Scope* — Use of this guide is limited to materials types known to be commonly used such as: silicon, polymers, glass, metals, ceramics and plastics.

7.2.1 This guideline applies to materials which may be used in fluidic devices in large or small form factors. It is assumed the material is in the wetted flow path as either a thin surface film or bulk material. Standard temperature (0ºC) and pressure (1 atm) are conditions considered in this table unless otherwise stated. Physical, mechanical, thermal, microstructural, and electrical properties of materials can be found in materials selection handbooks or material supplier datasheets. Breadth of details for chemical compatibility and materials properties varies widely within these literature and care must be taken to consider relevant information. unlikely that a single source of information would be suitable.

7.2.2 The intended use of the compatibility matrix is to provide a general resource to the user. Detailed research into materials compatibility with specific chemicals is an important part of any product development program. In depth research into materials and fluid analysis are beyond the scope of this guide and will be required in most circumstances.

1 Hsu, Tai-Ran; MEMS and Microsystems Design and Manufacture; McGraw-Hill, 2002 Section 6.7.

7.2.3 The reader is specifically requested to consult the Materials Safety Data Sheet (MSDS) and the manufacturer's recommended practices for any fluid or component prior to use and to follow the suggestions prescribed. In addition, the acceptable degree of chemical and material incompatibilities are relative to conditions of use. For instance, microscopic corrosion may be intolerable in one application yet may be quite tolerable in another. A list of such considerations is well documented in materials selection handbooks[2, 3, 4].

7.3 In Service Considerations are partially listed below.

7.3.1 Operating pressure

7.3.2 Operating temperature

7.3.3 Chemical environment: dry, moist, corrosive

7.3.4 Loads-magnitude, nature-tension, bending, torsion

7.3.5 Loads-nature-static, dynamic, impact

7.3.6 Mating part materials

7.3.7 Attachment points/ mechanisms

7.3.8 Presence of potential crevices

7.3.9 Allowable deflections /rotation

7.3.10 Allowable failure modes

7.3.11 Dimensional stability needed-short and long term

7.3.12 Frequency of assembly and disassembly

7.3.13 Insulation-thermal/electrical

7.3.14 Isolation-RF, thermal, electrical

7.3.15 Chemical Potential

7.4 Manufacturing Considerations are partially listed below.

7.4.1 Cost

7.4.2 Availability of material

7.4.3 Stock shapes-availability

7.4.4 Weldability

7.4.5 Formability

7.4.6 Expected consumption rate

7.4.7 Machinability

7.4.8 Achievable surface finishes

7.5 Assembly/Transport/Shipping consideration partially listed below.

7.5.1 G Forces-allowable shock and vibration

7.5.2 Allowable Moisture

7.5.3 Allowable Temperature

7.5.4 Allowable Pressure

7.5.5 Total Weight

2 Cheremisinoff, Nicholas, P., Materials Selection Deskbook, William Andrew Publishing/Noyes, 1996, p.p. 18-36.

3 Kutz, M, Handbook of Materials Selection, 2002

4 Ashby, MF, Materials Selection in Mechanical Design, 2000

7.5.6 Overall Dimensions

7.6 Possible root causes for chemical/materials incompatibility are partially listed below.

7.6.1 Cleanliness of fluid system

7.6.2 Outgassing of materials from solid surfaces into process fluid

7.6.3 Process fluid purity (trace chemical impurities)

7.6.4 Process fluid cleanliness (particulate)

7.6.5 Permeability of chemicals in solid materials

7.6.6 Infectious biomaterial

7.6.7 Corrosion-Erosion

7.7 *Classification of materials and fluids*

7.7.1 *Fluids*

7.7.1.1 Classification of Gases[5] (with examples)

7.7.1.1.1 *Inerts* — argon, helium, krypton, neon, radon, xenon

7.7.1.1.2 *Hydrogen* — deuterium, hydrogen, tritium

7.7.1.1.3 *Hydrocarbons* — acetone, acetylene, hexane, propane

7.7.1.1.4 *Halogenated Hydrocarbons* — carbon tetraflouride, octafluorocyclobutane

7.7.1.1.5 *Hydrides* — silane, germane, phosphine, arsine

7.7.1.1.6 *Halogens, other than Fluorine* — chlorine, iodine

7.7.1.1.7 *Halides, other than Fluorides* — hydrogen chloride, hydrogen bromide, hydrogen iodine

7.7.1.1.8 *Fluorine and Fluorides* — F_2, XeF_2, NF_3, BF_3,WF_6

7.7.1.1.9 *Organo — Metallic and Siloxanes*

7.7.1.1.10 *Oxygen, Oxides and Sulfides*

7.7.1.1.11 *Nitrogen and Nitrogen Compounds*

7.7.1.1.12 *Acids* — hydroflouric acid, nitric acid, sulfuric acid

7.7.1.1.13 Nano structures and compounds

7.7.1.2 *Liquids*[6]

7.7.1.2.1 *Water* — de-ionized, distilled

7.7.1.2.2 *Inorganic Acids* — hydrochloric acid, hydrofluoric acid, nitric acid

7.7.1.2.3 *Bases* — sodium hydroxide, potassium hydroxide, ammonium hydroxide

7.7.1.2.4 *Organic acids* — glacial acetic, trichloroacetic

7.7.1.2.5 *Hydrocarbon solutions* — toluene, iso-octane

7.7.1.2.6 *Alcohols* — ethyl, isopropanol, methyl

7.7.1.2.7 *Amines* — aniline, ethylenediamine

7.7.1.2.8 *Ethers* — tetrahydrofuran

7.7.1.2.9 *Ketones/Aldehydes* — acetone, benzaldehyde, methyl ethyl ketone

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5 SEMI F79-0703 Guideline for Gas Compatibility with Silicon used in Gas Distribution Components

6 http://www.entegrisfluidhandling.com

7.7.1.2.10 *Esters* — dimethylphthalate

7.7.1.2.11 *Chlorinated Solvents* — methylene chloride, perchloroethylene, carbon tetrachloride

7.7.1.2.12 Freon® — Freon — TF, Freon — TMC, Freon TMS

7.7.1.3 Classification of Materials; Common materials are considered[7] as follows (including in the nanometer size regime):

7.7.1.3.1 *Silicon* — Element 14 (and all isotopes), single crystal, doped, polycrystalline, amorphous

7.7.1.3.2 *Polymers* — PCTFE, PTFE, Polyimide, Chemraz®, Kalrez, Viton®

7.7.1.3.3 *Glassy Materials* — Silicon dioxide, Pyrex®, silicon nitride

7.7.1.3.4 *Metals* — Aluminum, stainless steel 316L, Hastelloy® c-22, Elgiloy®, Nickel 200

7.7.1.3.5 *Ceramics* — Alumina, Macor®

7.7.1.3.6 *Plastics* — Polyethylene, PVC

7.7.1.3.7 *Graphitic* — nanotubes, C60, graphite, pyrolytic graphite, diamond-like carbon

7.7.1.3.8 Suspended Nano structures and compounds

7.7.1.4 *Biological Materials*

7.7.1.4.1 tissue

7.7.1.4.2 Viruses

7.7.1.4.3 DNA

7.7.1.4.4 Proteins

7.7.1.4.5 Polypeptides

7.7.1.4.6 Cellular materials

7.8 *Materials/Chemical Compatibility*

7.8.1 The compatibility chart below, is presented as a broad cross-section of materials and fluids that may be used as a springboard for further development of fluidic devices and/or interfaces.

	Silicon	*Polymers*	*Glass*	*Metals*	*Ceramics*	*Plastics*
Inerts	A	A	A	A	A	A
Hydrogen	5	7		7		7
Hydrocarbons	5	5,7		7		7
Halogenated Hydrocarbons	5					
Hydrides	5	7		7		7
Halogens, other than Fluorine	5	7		7		7
Halides, other than Fluorides	5	7		7		7
Fluorine and Fluorides	U/5	7		7		7

7 http://www.airproducts.com/specgases/safety/70008.htm

	Silicon	*Polymers*	*Glass*	*Metals*	*Ceramics*	*Plastics*
Organo-Metallic and Siloxanes	5					
Oxygen, Oxides and Sulfides	5	7		7		7
Nitrogen and Nitrogen Compounds	5	7		7		7
Acids	U	6		7		7

#1 A = Acceptable. This combination of fluid and material is acceptable or generally acceptable use when small effects of permeation are inconsequential to use.

#2 U = Unacceptable in most applications where material and chemical interaction are significant.

#3 number = see footnote.

7.8.2 *Example of How to Use This Chart and Guide*

7.8.2.1 An engineering team is tasked to design a portable, matchbox-sized analytical system to detect, quantify, and transmit data on abnormal airborne bio excursions.

8 Component Specific Guidelines

8.1 *Purpose* — To provide guidance on connection (methods) of discrete and integrated fluidic interconnects."

8.2 *Scope* — These methods are limited to connections from microfluidic components to other microfluidic components, and from microfluidic components to fluidic adapters.

8.3 *Category* — discrete and/or integrated components that provide interconnects on chip or between chips. Examples of applications include: pressure sensor, flow sensor, temperature sensor, valves and pumps, as well as adaptors. They can integrate with fluidic interconnect components.

8.4 *Fabrication method* — This section mainly discusses wafer-level interconnect fabrication methods.

8.4.1 Fusion bonding for Si wafers. Suitable for wafers that can tolerate high processing temperature

8.4.2 Anodic bonding for Si/Glass. Suitable for wafers that can tolerate high temperature and strong electrical field

8.4.3 Polymer bonding with intermediate layers such as SU-8, polyimide, PMMA, and BCB. Low temperature bonding technique that is suitable for bioassays and post CMOS device integration with MEMS components. The bonding chemical environment may be harmful to some biochemical chip functions and must be managed carefully.

8.4.4 Double side tape with pressurized press. Assembly method to make components, subsystems or system.

8.4.5 Thermocompression bonding. Use metal intermediate layer. Suitable for fluids containing organic solvents.

8.5 *Adapters*

8.5.1 End fittings (VCR®, Swagelok). Refer to manufacturer's instructions. They are typically comprised of a nut and a ferrule—have the important function of providing the physical connection of tubing throughout a chip and between chips.

8.6 *Testing and Validation*

8.6.1 The following are guidelines for validation and testing of the integrity of the components

8.6.2 Standard pull test. This evaluates the bonding strength, but not sealing quality. Refer to tool manufacturer's manual from suppliers such as Instron, Zwick and MTS.

8.6.3 Pressurized test. Test the maximum pressure the component can survive according to the specifications of the designed device.

8.6.4 Fluid leak test. Visual inspection, pressure drop test (time to lose pressure).

8.6.5 Helium leak test (any existing standards we can refer to?)

8.6.6 Temperature cycles. Cycle parts in the expected application environments that the components will be exposed to or in an acceleration chamber with controlled temperature.

8.6.7 In case of disposable devices, only a small sample size from a product lot can be tested. Detailed test plans can be found in subsystem guidelines.

8.7 An example with a diagram is desired. See Figures 1–4.

9 Subsystem Guidelines

9.1 *Purpose* — Provide guidance for assembly and testing of Microfluidic subsystems, considering applicable performance and operating specifications. Examples of performance characteristics are response time, accuracy, reliability, drydown, and cleanliness.

9.2 *Scope* — These guidelines are limited to macro sealing and macro to micro sealing. It specifically excludes wafer-scale testing. They address interconnection (fluidic, electrical, and other) of the microfluidic subsystem to the external system. They also address interconnection of individual components within the microfluidic subsystem.

9.3 *Assembly and Test Preparation*

9.3.1 Visually inspect parts under microscope before assembly. Perform any testing possible at the MEMS component level as characterization or to determine failures before integrating.

9.3.2 Assemble under hoods or in cleanroom. Wear gloves. Use electrostatic protection. Assembly should be in the same class environment as required by user. See SEMI E129.

9.3.3 Follow manufacturer's instructions for tightening fittings and seals and connecting parts. If applicable, measure torque or other assembly parameters. Subsystem should have means or method to hold part being tightened to not compromise the structural integrity of the part.

9.3.4 Seals used to connect components should be considered for thermal performance, cleanliness, and material compatibility. See ¶9.4.?.

9.3.5 Test systems should have filters installed upstream of the device under test. Select pore size similar to pore size used in final application.

9.4 *Verification and Validation*

9.4.1 The following are guidelines for verification and validation. Some may also apply to production testing.

9.4.2 Test for particles and for other contamination characteristics such as moisture dry down as required by end user as a system. See ASTM F1394 (particle), SEMI E66 (particle), ASTM F1397 (moisture).

9.4.3 Test for applicable performance parameters such as accuracy using NIST traceable standards. Time or process response characterizations should model system and connection volumes, based on specification designed for. If the final application can not be duplicated, consider final system in the data analysis. For faster process time minimize volume and surface area between the flow control system and chamber. Test in gas or liquid that it will be used with or list substitute/test gas or liquid on test report.

9.4.4 Cycle parts in environment that they will be used in or in an accelerated mode. This is to model mean time to failure or other parameters of reliability. At intervals test for most important performance or operating parameters. See ASTM F1394, ASTM F1373.

9.4.5 Leak test mechanical connections using inboard leak detection method. For positive shut-off components test for leak across the seat. Reference SEMI F1.

9.4.6 Test for performance at maximum and minimum temperatures based on product specifications.

9.4.7 Test for performance at maximum and minimum pressures (input and output) based on product specifications.

9.4.8 Test for burst and proof pressures**,** Reference SEMI E28.

9.4.9 Test for shock and vibration. Check for operation and leak integrity before and after testing.   MIL-STD 810

9.4.10 Test for performance at maximum and minimum voltages based on product specifications.

9.4.11 Perform electrical testing and validation. Check for power consumption, response time, noise, dielectric breakdown, resistance fluctuations, others?

9.4.12 Test for compatibility with typical, operating and/or specified fluids for validation testing.

9.4.12.1 See Figures 1–4 of a MEMS System with subsystem fluidic interface features.

9.4.12.2 Courtesy Redwood MicroSystems

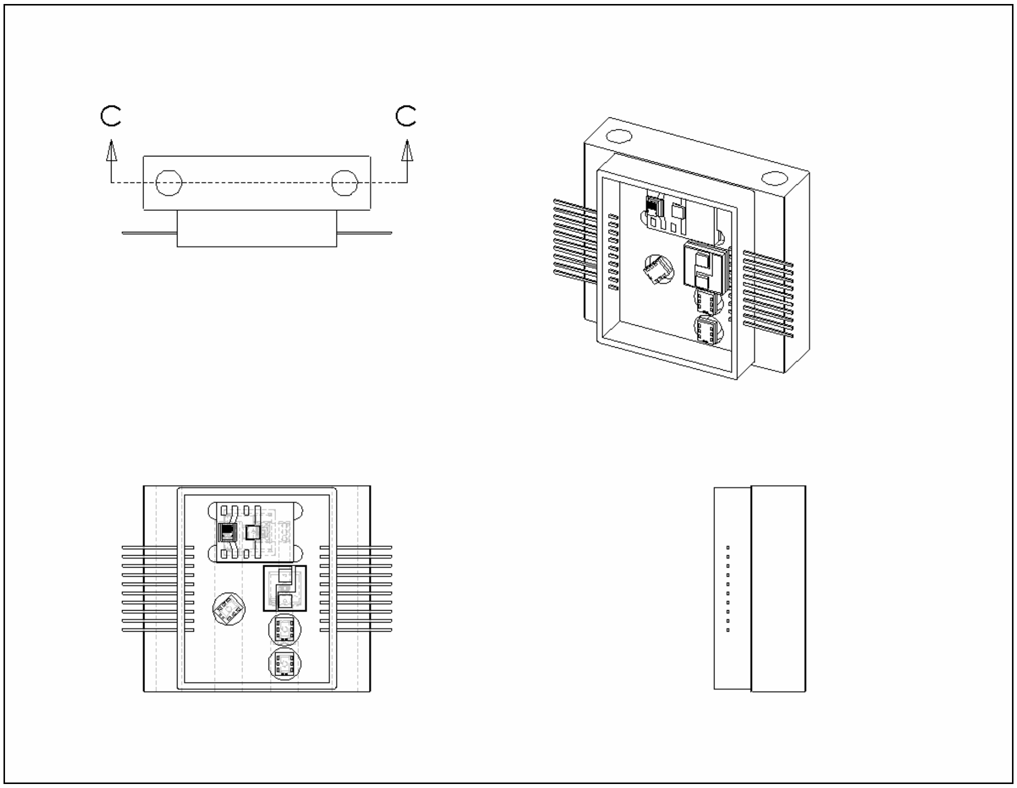

Figure 1
Mechanical Drawing Showing MEMS System

(A)
Package with Shut-off Valve and Mass Flow Controller

(B)
Panel in Enclosure Consistency of Six Packages. Applications Include Gas Chromatography, Analytical Instrumentation, Semiconductor Processing.

Figure 2

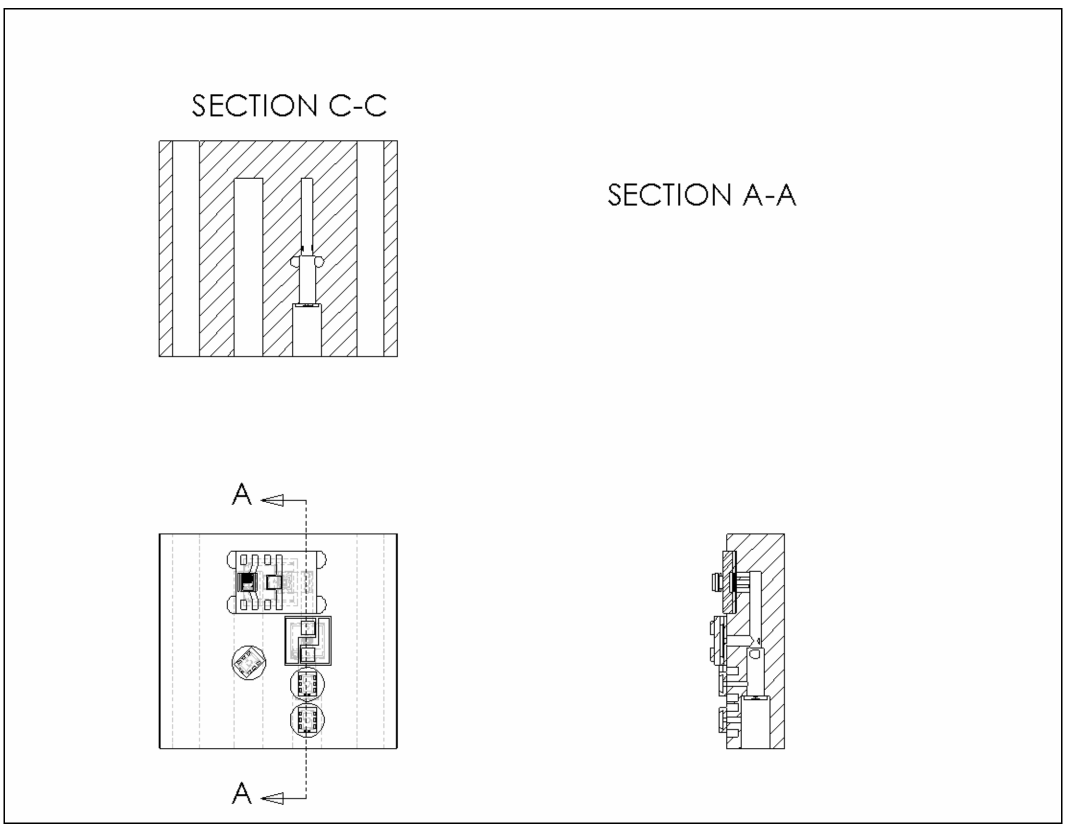

Figure 3
Mechanical Drawing Showing MEMS Subsystem and Fluidic Adaptor

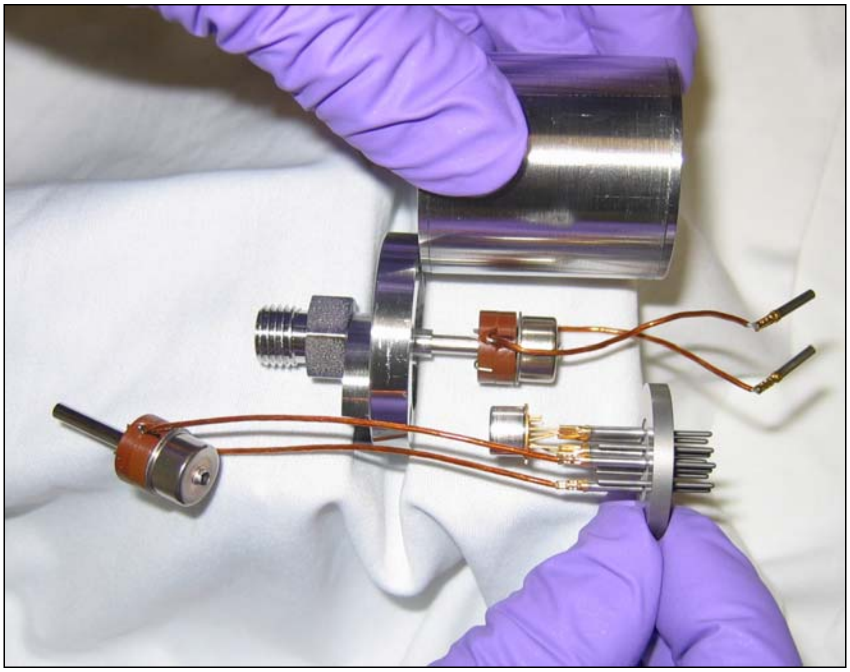

Figure 4
Microvalve in Fusion Reactor

9.5 *Purpose* — To be developed.

9.6 *Scope* — To be developed.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

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SEMI P1-1101
SPECIFICATION FOR HARD SURFACE PHOTOMASK SUBSTRATES

This specification was technically approved by the Global Micropatterning Committee and is the direct responsibility of the North American Micropatterning Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1981; previously published February 1999.

1 Purpose

1.1 This specification covers the general requirements of the glass substrate for hard surface photomasks.

2 Scope

2.1 This document covers square photomasks up to 7 inches in length. 230 mm substrates are excluded from this standard and can be found in SEMI P33.

2.2 This document also gives specifications for the following materials:

- High Thermal Expansion (HTE),
- Medium Thermal Expansion (MTE),
- Low Thermal Expansion (LTE),
- Ultra Low Thermal Expansion (ULTE)
- Durable Fused Silica (DFS) glass for 193 nm wavelength
- Modified Fused Silica (MFS) glass for 157 nm wavelength.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI P33 — Provisional Specification for Developmental 230 mm Square Hard Surface Photomask Substrates

3.2 *ASTM Standards*[1]

ASTM E 228 — Test for Linear Thermal Expansion of Rigid Solids with a Vitreous Silical Dilatometer

3.3 *ANSI/ASQC Standards*[2]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.4 *ISO Standard*[3]

ISO 14644-1 — Cleanrooms and Associated Controlled Environments Part 1: Classification of Air Cleanliness

4 Terminology

4.1 Selected terms relating to photomasking are given for information only in “Terms and Definitions Relating to the Microlithography Industry” found at the end of SEMI P33 “RELATED INFORMATION”. Definitions may be found in what was ASTM F 127.

5 Ordering Information

5.1 Purchase orders for hard surface photomask substrates furnished to this specification shall include the following:

5.1.1 Nominal edge length, nominal thickness dimension, and edge criteria (see Section 6);

5.1.2 Material (see Section 7);

5.1.3 Flatness quality area and flatness (Total Indicated Reading, T.I.R.) see Section 8);

5.1.4 Visual quality area and defect limits (see Section 9); and

5.1.5 Lot acceptance criteria (see Section 10).

6 Dimensions and Permissible Variations

6.1 The square substrates shall conform to the dimensional tolerances appropriate to the nominal edge length and thickness as listed in Table 1. Dimensions are illustrated in Figure 1 and a fixture for measuring the diagonal dimensions is shown in Figure 2.

6.2 Substrates shall have chamfered or rounded edges. The edges shall conform to the dimensional tolerances

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202, USA

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 Website: www.iso.ch

appropriate to the nominal thickness listed in Table 2. Dimensions are illustrated in Figures 3 and 4.

7 Material Specifications

7.1 Substrate materials shall be specified as high thermal expansion (HTE), medium thermal expansion (MTE), low thermal expansion (LTE), ultra low thermal expansion (ULTE), durable fused silica (DFS), or modified fused silica (MFS). Examples of HTE materials are white crown and soda lime glasses, of MTE materials are borosilicate and aluminosilicate glasses, of LTE materials are aluminosiliate glasses, and of ULTE, DFS, and MFS materials are quartz (silica).

7.2 Substrate materials shall conform to thermal expansion and optical transmittance characteristics specified in Table 3.

7.2.1 DFS shall maintain the transmittance given in Table 3 within 0.3% change at least accumulated dosage of 100 kJ/cm^2 of 193 nm wavelength irradiation.

7.3 Selected physical properties of HTE, MTE, LTE, ULTE, DFS, and MFS materials are provided for information only in Appendix 1.

8 Flatness Specifications

8.1 Substrates shall be supplied with one side having a flatness (TIR) of 0.25, 0.5, 1, 2, 5, 10, or 20 µm over a circular or square quality flatness area as defined in Figures 5 and 6.

9 Visual Criteria

9.1 A visual quality area, which may or may not correspond with the flatness area, shall be agreed upon between the user and supplier.

9.2 Each plate shall not have more defects than listed in Table 4. This table includes limits for the following types of defects:

9.2.1 Internal defects in the quality area,

9.2.2 Frontside surface defects,

9.2.3 Backside surface defects, and

9.2.4 Defects outside the quality area.

9.3 Glass substrates shall be identified with notches on the backside corner as shown in Figure 7. Soda lime and white crown (HTE) glasses are marked with one corner notch (Figure 7a). Borosilica and Aluminosilicate (MTE) glasses are marked with three corner notches (Figure 7b). Aluminosilica (LTE) glass is marked with two adjacent corner notches (Figure 7c). Quartz (ULTE) is marked with two diagonal corner notches (Figure 7d). Quartz (DFS) is marked with one corner notch (Figure 7e), that is the same as specified for HTE. Quartz (MFS) is marked with one non-isosceles triangle corner notch (Figure 7f). Dimensions of notches shall be as specified in Figure 8. If desired, and so specified in the contract or order, notches are positioned to identify the squareness origin corner.

10 Sampling

10.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired, and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL values. Inspection levels shall be agreed upon between user and supplier.

11 Test Methods

11.1 *Thermal Expansion* — Determine in accordance with ASTM E 228.

11.2 Transmission (to be agreed upon between user and supplier).

11.3 Irradiation durability (to be agreed upon between user and supplier).

11.4 Flatness (to be agreed up between user and supplier).

11.5 Visual (to be agreed upon between user and supplier).

12 Handling

12.1 Substrates are to be handled on the edges only. Substrates are to be handled with gloves approved for cleanroom use.

13 Certification

13.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

14 Packing and Marking

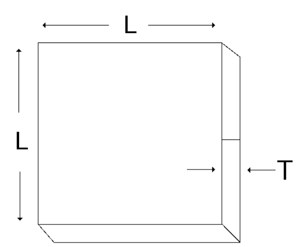
14.1 Substrates shall be packed in a class 100 environment as defined by ISO 14644-1. Containers shall be designed to prevent glass-to-glass contact, and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the acceptable flatness side toward the front of the box. This orientation shall be indicated on each container. Packaging shall comply with the applicable internal, national, state, and local laws and regulations required for shipping.

14.2 Containers shall be labeled “Warning: Open and Handle Under Cleanroom Conditions Only”: as well as identified by user purchase order number (if applicable), drawing number (if applicable), quantity, supplier lot number, and material identification.

Table 1 Specifications for Edge Length, Squareness, and Thickness for Square Substrates

Nominal Edge Length	*Edge Length Min.*	*Edge Length Max.*	*Squareness*	*Thickness Min.*	*Thickness Max.*	*Units*
2 1/2" Sq.	62.7	63.50	0.05/25.40	1.40	1.60	mm
3" Sq.	75.4	76.2	0.05/25.40	1.40	1.60	mm
3 1/2" Sq.	88.1	88.9	0.05/25.40	1.40	1.60	mm
4" Sq.	100.80	101.6	0.05/25.40	1.40	1.60	mm
				2.20	2.40	mm
5" Sq.	126.2	127.0	0.05/25.40	2.20	2.40	mm
				3.70	3.90	mm
				6.25	6.45	mm
6" Sq.	151.6	152.4	0.05/25.40	2.20	2.40	mm
				2.95	3.15	mm
				3.70	3.90	mm
				6.25	6.45	mm
7" Sq.	177.0	177.8	0.05/25.40	2.95	3.15	mm
				3.70	3.90	mm
				6.25	6.45	mm

NOTE: HTE squareness is 0.08/25.40



Note: L = Edge Length
T = Thickness

Figure 1
Square Hard Surface Photomask Substrate

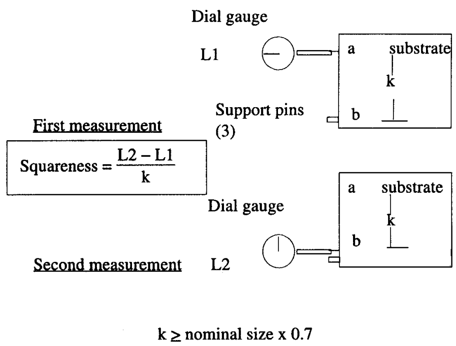


Figure 2
Measurements to Determine Substrate Squareness

Table 2 Specifications for Chamfered and Rounded Edge Dimensions

T	*A*	*A*	*B*	*B*	*C*	*C*	*D*	*D*	*E*	*E*	
Nominal	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Units*
1.50	0.20	0.50	0.20	0.50	0.30	0.70	2.00	3.00	0.25	0.60	mm
2.30	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
3.05	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
3.80	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
4.57	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
6.35	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm

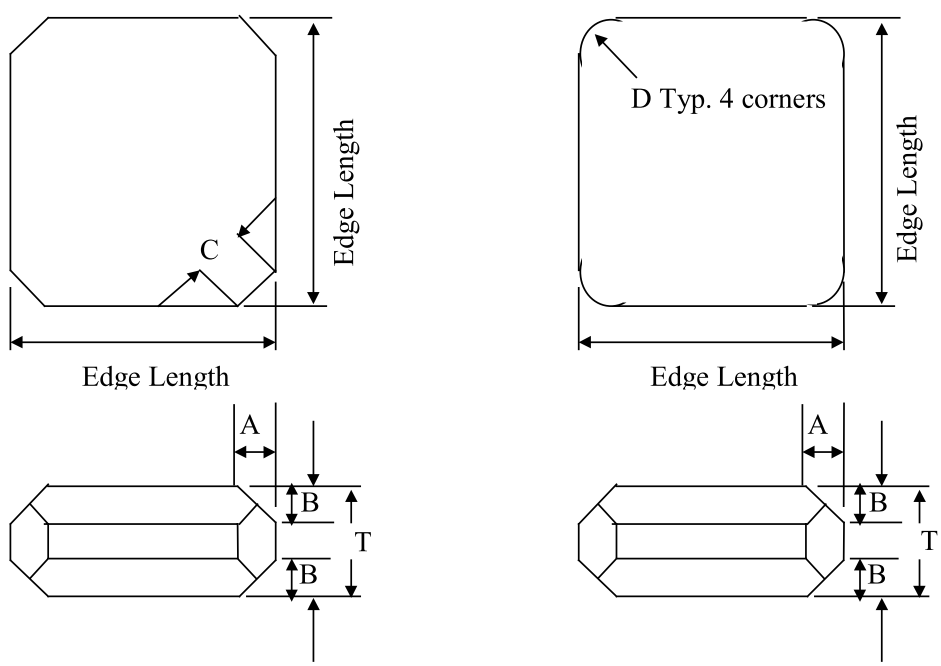


Figure 3
Chamfered Edge Dimensions

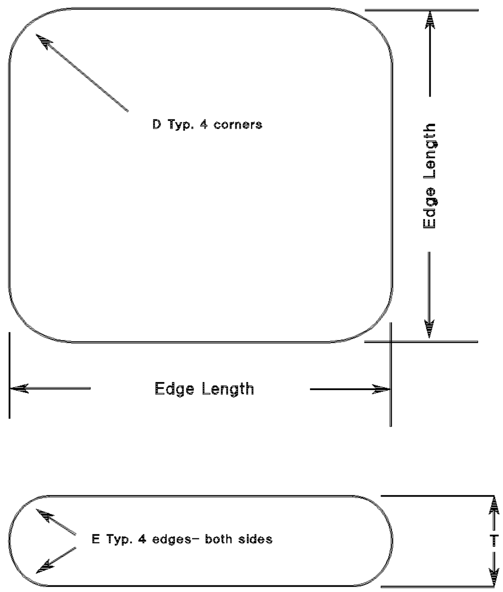


Figure 4
Rounded Edge Dimensions

Table 3 Substrate Material Characteristics

	Coefficient of Expansion ($°C^{-1}$) Between 0 °C and 300 °C	*Minimum Transmittance (%) of 1.5 mm Thick Substrate at Wavelengths of:*						
Glass Type		157 mm	193 mm	230 nm	254 nm	365 nm	405 nm	436 nm
HTE	80 to 100 × 10^{-7}	NA	NA	NA	NA	80	85	90
MTE	40 to 60 × 10^{-7}	NA	NA	NA	NA	80	85	90
LTE	30 to 39 × 10^{-7}	NA	NA	NA	NA	80	85	90
ULTE	< 7.5 × 10^{-7}	NA	NA	90	90	90	90	90
DFS	< 7.5 × 10^{-7}	NA	87	90	90	90	90	90
MFS	< 7.5 × 10^{-7}	82	87	90	90	90	90	90

Table 4 Glass Substrate Defect Limits per Plate

INTERNAL DEFECTS IN THE QUALITY AREA

	Opaque Spots	*Bubble*	*Total Defects (per cm.^{2})*	*Notes*
HTE Glass	> 10 µm	> 10 µm	0	1 and 2
	≤ 10 µm	≤ 10 µm	0.0465	
MTE Glass	> 5 µm	> 7 µm	0	
	≤ 5 µm	≤ 7 µm	0.0465	
LTE Glass	> 5 µm	> 5 µm	0	
	≤ 5 µm	≤ 5 µm	0.031	
ULTE Glass	> 2 µm	> 2 µm	0	
	≤ 2 µm	≤ 2 µm	0.0078	
DFS Glass	> 1.5 µm	> 1.5 µm	0	
	≤ 1.5 µm	≤ 1.5 µm	0.0078	
MFS Glass	> 1.2 µm	> 1.2 µm	0	
	≤ 1.2 µm	≤ 1.2 µm	0.0078	

SURFACE DEFECTS IN THE QUALITY AREA

Frontside	*Residue*	*Scratch Size*	*Total Scratch Defects*	*Sleek Size*	*Total Sleeks Defects (per cm^2)*	*Opaque Spot Size*	*Total Opaque Spot Defects (per cm^2)*
HTE Glass	None	> 1.0 µm	0	> 2 µm	0	> 5 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–5 µm	0.0465
MTE Glass	None	> 1.0 µm	0	> 2 µm	0	2.5 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–2.5 µm	0.0465
LTE Glass	None	> 1.0 µm	0	> 2 µm	0	2.5 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–2.5 µm	0.0465
ULTE Glass	None	> 1.0 µm	0	> 2 µm	0	2.0 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–2.0 µm	0.0155
DFS Glass	None	> 1.0 µm	0	> 1.5 µm	0	1.5 µm	0
		≤ 1.0 µm	no limit	1–1.5 µm	0.0310	1–1.5 µm	0.0110
MFS Glass	None	> 1.0 µm	0	> 1.2 µm	0	1.2 µm	0
		≤ 1.0 µm	no limit	1–1.2 µm	0.0155	1–1.2 µm	0.0052

Backside

HTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
MTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
LTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
ULTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
DFS Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
MFS Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit

DEFECTS OUTSIDE THE QUALITY AREA

Edge Chips	*Defect Limit*	*Total Number*	
Radial Depth	≥ 0.76 mm	None	Note
Peripheral Cord	≥ 0.76 mm	None	
Other	Shall be negotiated between vendor and supplier	Shall be negotiated between vendor and supplier	

NOTE l: The size of internal defects shall be determined by 1/2 (long axis + short axis).

NOTE 2: This table is based on the assumption that defects < 3 µm will fail outside the focal depth of the lens systems and should not print.

NOTE 3: None of any size permitted that break the surface.

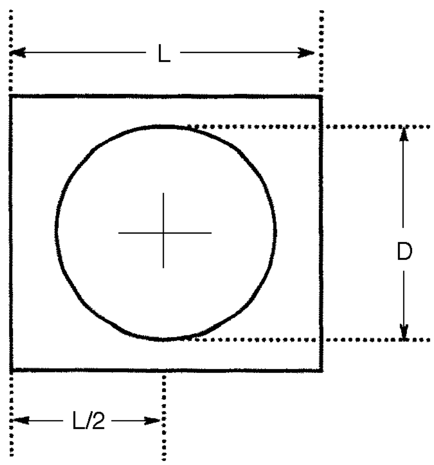


Figure 5
Circular Quality Area

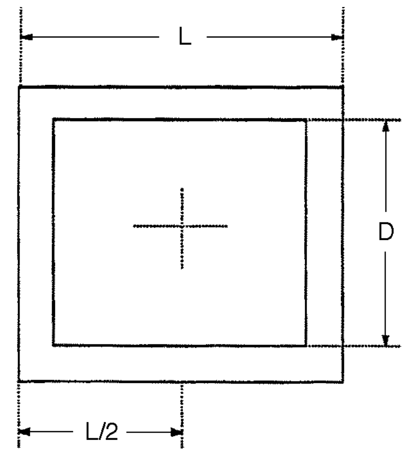


Figure 6
Square Quality Area

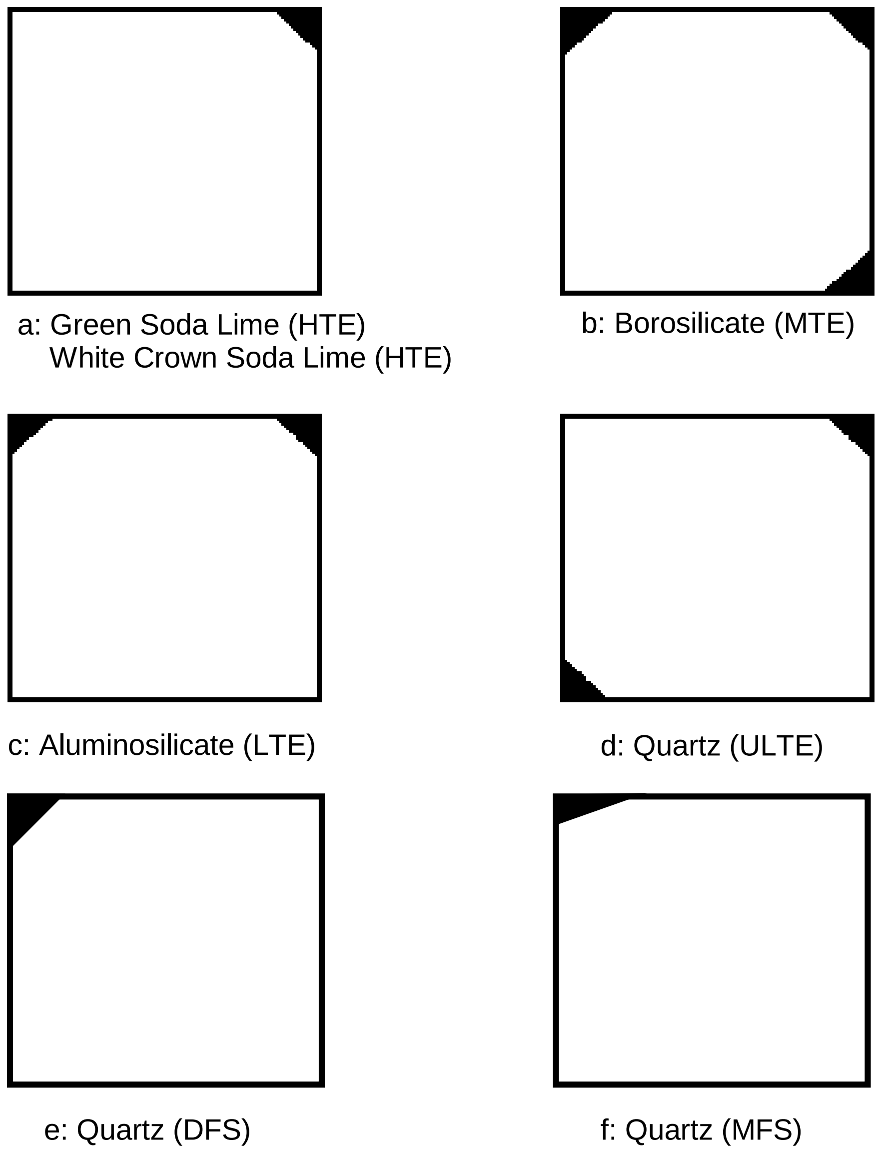
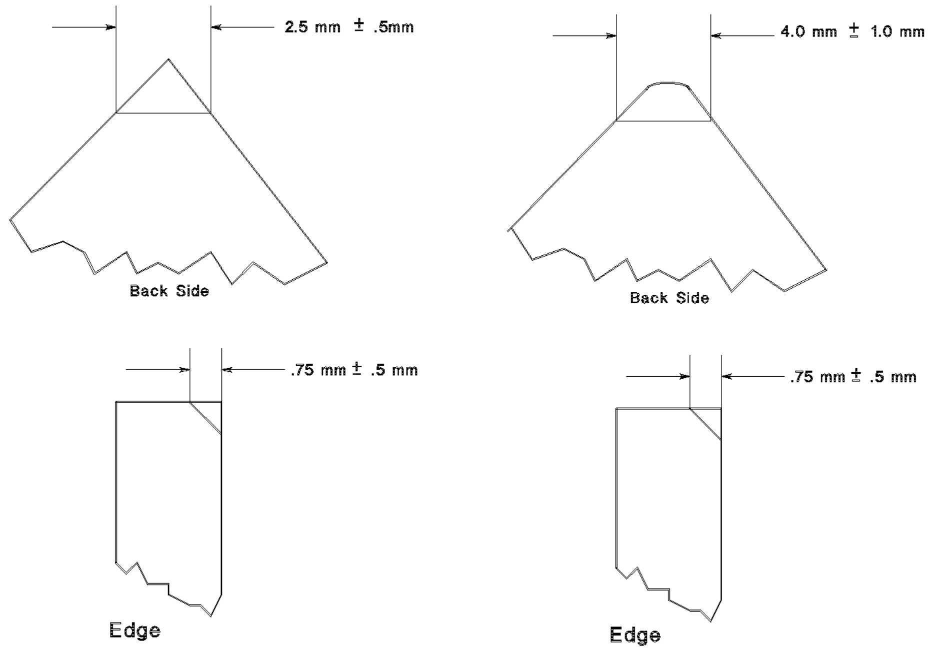


Figure 7
Glass Substrate Identification by Notches



Square Corner Round Corner

Figure 8a
Dimensions of Notches for HTE, MTE, LTE, ULTE, DFS

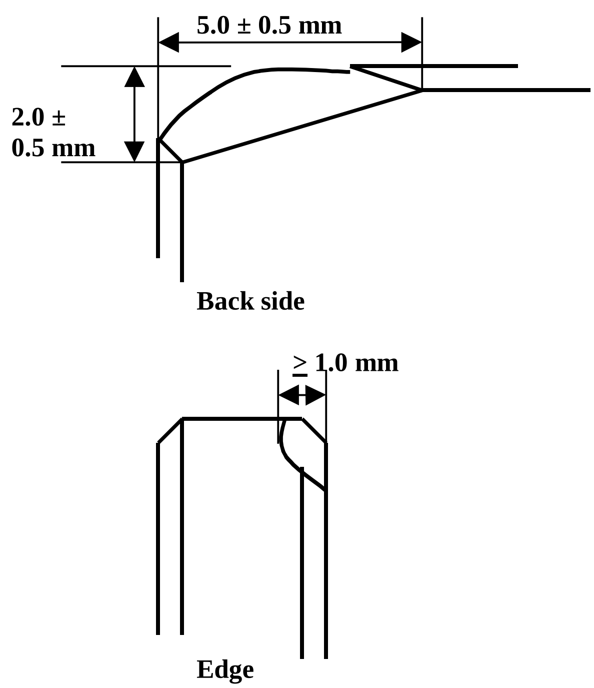


Figure 8b
Dimension of Notches for MFS

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI P1 and was approved by full letter ballot procedures on August 3, 2001.

A1-1 Hard Surface Photomask Glass Properties

GLASS PROPERTIES

Property	
HIGH THERMAL EXPANSION (HTE)	
Modulus of Elasticity	$7.0–7.3 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.22–0.23
Specific Gravity	2.50–2.56 g/cm^3
Index of Refraction	1.52
MEDIUM THERMAL EXPANSION (MTE)	
Modulus of Elasticity	$7.1–9.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.18–0.26
Specific Gravity	2.36–2.87 g/cm^3
Index of Refraction	1.49–1.57
LOW THERMAL EXPANSION (LTE)	
Modulus of Elasticity	$7.5–8.7 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.24
Specific Gravity	2.52–2.58 g/cm^3
Index of Refraction	1.53–1.56
ULTRA LOW THERMAL EXPANSION (ULTE)	
Modulus of Elasticity	$6.7–7.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.19
Specific Gravity	2.18–2.20 g/cm^3
Index of Refraction	1.46
DURABLE FUSED SILICA (DFS)	
Modulus of Elasticity	$6.7–7.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.19
Specific Gravity	2.18–2.20 g/cm^3
Index of Refraction	1.46
MODIFIED FUSED SILICA (MFS)	
Modulus of Elasticity	$6.7–7.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.19
Specific Gravity	See NOTE 1.
Index of Refraction	See NOTE 1.

NOTE 1: Specific Gravity and Index of Refraction of MFS shall be agreed upon between user and supplier.
NOTE 2: Index of Refraction on this table is the value at 587 nm wavelength.

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SEMI

SEMI P2-0298
SPECIFICATION FOR CHROME THIN FILMS FOR HARD SURFACE PHOTOMASKS

1 Purpose

This specification covers the general requirements of the chrome thin film for hard surface photomasks.

2 Referenced Documents

2.1 *SEMI Specification*

SEMI P1 — Specification for Hard Surface Photomask Substrates

2.2 *ASTM Standard*[1]

E 122 — Choice of Sample Size to Estimate the Average Quality of a Lot or Process

2.3 *Federal Standard*[2]

209D — Clean Room and Work Station Requirements, Controlled Environment

2.4 *Military Specification*[3]

MIL-STD-105 — Sampling Procedure and Tables for Inspection by Attributes

3 Terminology

3.1 *defects, photomask* — Any flaw or imperfection in the opaque coating or functional pattern of a photomask that will reproduce itself in a photoresist film to such degree that it is pernicious to the proper functioning of the microelectric device being fabricated.

3.2 *fingerprint* — For the purposes of this practice, residual surface contamination deposited during handling.

3.3 *pinhole* — A small opening extending through a cover as a photoresist coating or an oxide layer.

4 Ordering Information

4.1 Purchase orders for hard surface photomasking substrates furnished to this specification shall include the following:

Optical Density	to be agreed upon by the user and supplier
Reflectivity	High reflective — Above 40% Medium Reflective — 2– 40% Low Reflective — Below 25%
Material	to be agreed upon by the user and supplier
Etchability	to be agreed upon by the user and supplier
Defects	to be agreed upon by the user and supplier
Lot Size	to be agreed upon by the user and supplier

5 Material Specifications

The material specifications are to be agreed upon by the user and supplier.

6 Visual Criteria

6.1 *Visual Quality Area*

6.1.1 *Circular Visual Quality Area* — (See SEMI P1, Figure 6, for available flatness limits of hard surface photomask substrates.)

6.1.2 *Square Visual Quality Area* — (See SEMI P1, Figure 7, for available flatness limits of hard surface photomask substrates.)

7 Defects

Definitons of defects and the allowable number of each type are listed in Table 1. The number of defects is indicated by plate size, chrome grades, and defect size.

8 Sampling

Unless otherwise specified, Recommended Practice ASTM E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with MIL-STD-105. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with MIL-STD-105 definitions for critical. Major and minor classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the user and supplier.

9 Handling

Substrates are to be handled on the edges only.

10 Certification

Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 General Services Administrator, 4th and D Streets, SW, Room 6039, Washington, DC 20407

3 Military Standards, Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120

material was manufactured and tested shall be in accordance with this specification.

11 Packing and Marking

11.1 Substrates shall be packed in a Class 100 environment. Containers shall be designed to prevent glass-to-glass contact and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the coated side facing toward the same end of the box. This orientation shall be indicated on each container. Packaging shall comply with the applicable international, national, state laws, and local regulations required for shipping.

11.2 Containers shall be labeled, “Warning: Open and Handle Under Clean Room Conditions Only.” Each shipment shall be identified by user purchase order number, drawing number (if applicable), quantity, supplier lot number, and material identification.

Table 1 Total Allowable Defects for Unsensitized Photoplates

Defects in the Circular Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 μm*	*5.1–10 μm*	*10 μm*
4" AA	0	0	0
4" A (Master)	2	0	0
4" B	3	1	0
4" C (Test)	N/A	N/A	10
5" AA	0	0	0
5" A (Master)	2	0	0
5" B	4	1	0
5" C (Test)	N/A	N/A	15
6" AA	0	0	0
6" A (Master)	3	0	0
6" B	6	2	0
6" C (Test)	N/A	N/A	20

Defects in the Square Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 μm*	*5.1–10 μm*	*10 μm*
4" AA	0	0	0
4" A (Master)	2	0	0
4" B	4	1	0
4" C (Test)	N/A	N/A	10
5" AA	0	0	0
5" A (Master)	3	0	0
5" B	6	2	0
5" C (Test)	N/A	N/A	15
6" AA	0	0	0
6" A (Master)	4	0	0
6" B	8	2	0
6" C (Test)	N/A	N/A	20

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SEMI

SEMI P3-0298
SPECIFICATION FOR PHOTORESIST/E-BEAM RESIST FOR HARD SURFACE PHOTOPLATES

1 Purpose

1.1 This specification covers the general requirements on the photoresist and e-beam resist coating for hard surface photoplates. See SEMI P1 and SEMI P2 for requirements on physical characteristics of the photoplate substrate and the chrome coating on it.

2 Referenced Documents

2.1 *SEMI Specifications*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P2 — Specification for Chrome Thin Films for Hard Surface Photomasks

2.2 *ASTM Standard*[1]

ASTM E 122 — Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

2.3 *Federal Standard*[2]

209D — Clean Room and Work Station Requirements, Controlled Environments

2.4 *Military Specification*[3]

MIL-STD-105 — Sampling Procedure and Tables for Inspection and Attributes

3 Terminology

3.1 *comets* — buildup of resist in the form of a comet, generated by a defect.

3.2 *defect, photomask* — any flaw or imperfection in the opaque coating or functional pattern of a photomask that will reproduce itself in a photoresist film to such a degree that it is pernicious to the proper functioning of the microelectric device being fabricated.

3.3 *fingerprint* — for the purposes of this practice, residual surface contamination deposited during handling.

3.4 *photoresist lifting* — the loss of adhesion of a photoresist coating to its substrate.

3.5 *pinhole* — a small opening extending through a cover as a photoresist coating or an oxide layer.

3.6 *residue* — any undesirable material remaining on a substrate after any process step.

3.7 *resist rings* — buildup of resist in round, multicolored rings, generated by particles or bubble bursts.

3.8 *stress marks* — radial, colored, thin lines starting in the center of the plate and extending out.

4 Ordering Information

4.1 Purchase orders for resist-coating for hard surface photoplate substrates furnished to this specification shall include the following in addition to the information called for in SEMI P1 and SEMI P2:

4.1.1 Resist Material

4.1.2 Resist Thickness and Tolerance in the Quality Area

4.1.3 Resist Uniformity across the Quality Area

4.1.4 Resist Consistency — from Plate to Plate

4.1.5 Resist Baking Time and Temperature

5 Visual Criteria

5.1 *Visual Quality Area*

5.1.1 *Circular Visual Quality Area* — (See SEMI P1, Figure 6, for Available Flatness Limits of Hard Surface Photomask Substrates.)

5.1.2 *Square Visual Quality Area* — (See SEMI P1, Figure 7, for Available Flatness Limits of Hard Surface Photomask Substrates.)

6 Defects

6.1 Definitions of defects and the allowable number of each type are noted in Table 1. The number of defects is indicated by plate size, chrome grades, and defect size.

7 Sampling

7.1 Unless otherwise specified, Recommended Practice ASTM E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with MIL-STD-105. Each quality

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1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 General Services Administrator, 4th and D Streets, SW, Room 6039, Washington, D.C. 20407

3 Military Standards, Naval Publication and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with MIL-STD-105. Definitions for critical, major, and minor classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the user and supplier.

8 Handling

8.1 Resist-coated substrates are to be handled on the edges only with approved finger cots or gloves under clean room conditions.

9 Certification

9.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification shall be provided.

10 Packaging and Marking

10.1 Resist-coated substrates shall be packed in a Class 100 environment as defined in Federal Standard 209D. Containers shall be designed to prevent movement and glass-to-glass contact and to protect the substrates from contamination in handling and transit. Orientation of the coated side shall be indicated on each container. Packaging shall comply with the applicable international, national, state, and local laws and regulations required for shipping.

10.2 Each shipment shall be identified by user purchase order number, drawing number (if applicable), quantity, supplier lot number, material identification, bake time and temperature, resist type, resist lot number, and date of applying resist.

10.2.1 *Photoresist* — Containers shall be labeled, "Warning: Open and Handle Under Safe Yellow Light in Clean Room Conditions Only."

10.2.2 *E-Beam Resist* — Containers shall be labeled, "Warning: Open and Handle Under Clean Room Conditions Only. DO NOT X-RAY."

Table 1 Total Allowable Defects for Unsensitized Photoplates

Defects in the Circular Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 µm*	*5.1–10 µm*	*10 µm*
4" AA	0	0	0
4" A (Master)	4	0	0
4" B	6	2	0
4" C (Test)	N/A	N/A	20
5" AA	0	0	0
5" A (Master)	4	0	0
5" B	8	2	0
5" C (Test)	N/A	N/A	30
6" AA	0	0	0
6" A (Master)	6	0	0
6" B	12	4	0
6" C (Test)	N/A	N/A	40
Defects in the Square Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 µm*	*5.1–10 µm*	*10 µm*
4" AA	0	0	0
4" A (Master)	4	0	0
4" B	8	2	0
4" C (Test)	N/A	N/A	20
5" AA	0	0	0
5" A (Master)	6	0	0
5" B	12	4	0
5" C (Test)	N/A	N/A	30
6" AA	0	0	0
6" A (Master)	8	0	0
6" B	16	2	0
6" C (Test)	N/A	N/A	40

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SEMI P4-92 (Reapproved 0299)
SPECIFICATION FOR ROUND QUARTZ PHOTOMASK SUBSTRATES

This specification was technically reapproved by the Mask & Mask Equipment Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1983; previously published in 1996.

Editorial changes were made to the following: Sections: 2.2, 6.2, and 13.1, Tables 3, 4 and 5, and Figure 5.

General Requirements

1. Preface

This specification covers the general requirements of the quartz round substrate for hard surface photomasks.

2. Applicable Documents

2.1 *ASTM Standards*[1]

ASTM E 122 — Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

ASTM E 228 — Standard Test Method for Linear Thermal Expansion of Rigid Solids with a Vatreous Silical Dilatometer

2.2 *ISO Standard*[2]

ISO 14644-1 — Cleanrooms and Associated Controlled Environments Part 1: Classification of Air Cleanliness

2.3 *Military Specifications*[3]

MIL-STD-105 — Sampling Procedure and Tables for Inspection and Attributes

3. Terminology

None.

4. Ordering Information

Purchase orders for hard surface photomask substrates furnished to this specification shall include the following:

Dimensions	(See Section 5)
Material	(See Section 6)
Flatness Criteria	(See Section 7)
Visual Criteria	(See Section 8)
Lot Acceptance	(See Section 9)

5. Dimensions and Permissible Variations

The material shall conform to the dimensions and dimensional tolerances as specified in Tables 1 and 5, Dimensions for Round Quartz Photomask Substrates.

6. Material Specifications (ULTE glass only)

6.1 *Thermal Characteristics 0–300°C*

6.1.1 *100% Quartz Material* — Coefficient of expansion 5.5×10^{-7}/°C.

6.1.2 *Less Pure Quartz* — Coefficient of expansion less than 7.5×10^{-7}/°C.

6.2 *Transmission Characteristics*[4]

Wave Lengths	*Minimum % @ 1.5 mm Thickness*
200 nm	To be agreed upon between user and supplier.
230 nm	To be agreed upon between user and supplier.
254 nm	To be agreed upon between user and supplier.
365 nm	To be agreed upon between user and supplier.
405 nm	To be agreed upon between user and supplier.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 ISO Central Secretariat, 1, rue de Varembé, C.P. 56, CH-1211 Genève 20, Switzerland

3 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

4 After correction for surface reflection

6.3 *Physical Properties* — Information on the following properties is provided for information only. (See Appendix 1.)

6.3.1 Poisson' s Ratio

6.3.2 Density

6.3.3 Young' s Modulus

6.3.4 Modulus of Elasticity

6.3.5 Index of Refraction

6.3.6 Volume Restivity

7. Flatness Area (for one side only)

7.1 *Flatness Quality Area*

7.1.1 *Circular Flatness Quality Area* — (See Tables 2 and 5.)

8. Visual Criteria (one side only)

8.1 *Quality Area* — (See Tables 2 and 5.)

Plate Diameter	*Quality Area (Diameter)*
125 mm	113 mm
150 mm	138 mm

8.2 *Defect Limits* — Defects and allowable number of each type are listed in Table 4.

8.2.1 *Terminology for SEMI P4* — Unless otherwise noted, the SEMI Terms and Definitions Relating to the Microlithography Industry shall be used.

8.2.2 *Minimal Conditions or Dimensions* — Mini-mal conditions or dimensions for defects are listed in Table 4 and shall be used for determining substrate acceptability unless other minimal limiters are agreed upon by the interested parties.

8.2.3 *Photomask Substrate Edge Criteria* — (See Table 3.)

8.3 *Identification* — To be agreed upon between the user and supplier.

9. Sampling

Unless otherwise specified, ASTM E 122 shall be used. When so specified, appropriate samples sizes shall be selected from each lot in accordance with MIL-STD-105D. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with MIL-STD-105D. Definitions for critical, major and minor classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the user and supplier.

10. Test Methods

10.1 *Thermal Expansion* — Determine in accordance with ASTM E 228.

10.2 *Transmission* — (To be agreed upon between the user and supplier).

10.3 *Flatness* — (To be agreed upon between the user and supplier).

10.4 *Visual* — (To be agreed upon between the user and supplier.)

10.5 *Roundness* — 2 readings at 90° with appropriate tool such as Vernier Caliper or equivalent. Roundness values not specified at this time.

11. Handling

Substrates are to be handled on the edges only. Substrates are to be handled only with clean room approved gloves.

12. Certification

Upon request of the purchaser in the contract or order, a manufacturer' s or supplier' s certification that the material was manufactured and tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment.

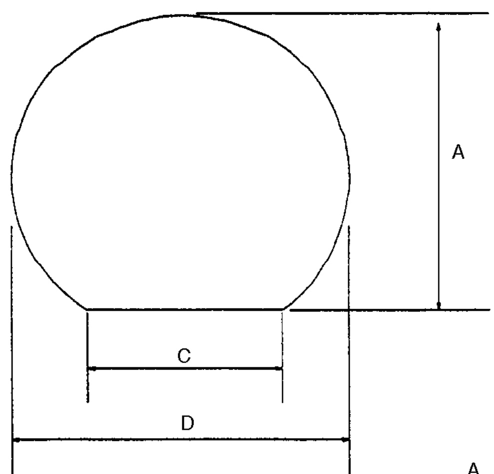
13. Packing and Marking

13.1 Substrates shall be packed in a class 100 environment as defined by ISO 14644-1. Containers shall be designed to prevent glass-to-glass contact and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the acceptable flatness side toward the front of the box. This orientation shall be indicated on each container. Packaging shall comply with the applicable international, national, state, and local laws and regulations required for shipping.

13.2 Containers shall be labeled " Warning: Open and Handle Under Clean Room Conditions Only." Each shipment shall be identified by user purchase order number, drawing number (if applicable), quantity, vendor lot number and material identification.

Table 1. Dimensions for Round Quartz Photomask Substrates

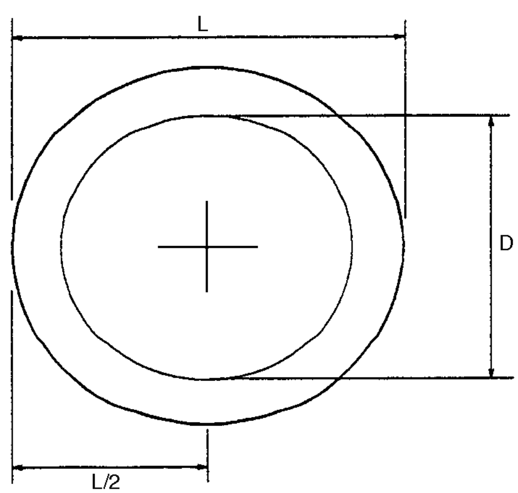
PLATE SIZE	*ROUNDNESS (T. B. A. Later Date)*	*PLATE THICKNESS*			
Dimension (D)		*Dimension*	*Tolerance Min.*	*Tolerance Max.*	*Units*
125 Diameter 125 ± .3	—	2.3	2.17	2.43	mm
150 Diameter 150 ± .3	—	2.3	2.17	2.43	mm
	—	3.0	2.87	3.13	mm



D 125 ± .3 mm
150 ± .3 mm

	A	
	Min.	Max.[1]
125 ± .3 mm	122.19	123.48
150 ± .3 mm	146.24	147.59

NOTE 1: equivalent to C = 32.5 ± 2.5 mm
NOTE 2: equivalent to C = 42.5 ± 2.5 mm



Circular Quality Area
D = L − 12 mm

L	D
125 mm	113 mm
150 mm	138 mm

Table 1

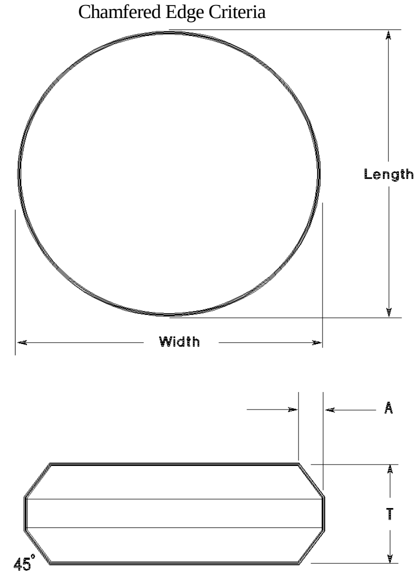
Flatness Limits

125 mm 5 µm **TIR**
2 µm **TIR**
150 mm 5 µm **TIR**
3 µm **TIR**

Table 2

Table 2. Flatness Limits for Round Quartz Photomask Substrates

Chamfered Edge Criteria



T	A
2.3 mm (.090")	.10 mm (min.) - .6 mm (max.)
3.0 mm (.120")	.10 mm (min.) - .6 mm (max.)

Table 3. Edge Criteria for Round Quartz Photomask Substrates

Table 4. Glass Substrate Defect Limits per Plate — Internal Defects in the Quality Area

	OPAQUE SPOT	*BUBBLE*	*TOTAL DEFECTS (per inch^2)*	*NOTES*
ULTE Glass	≥ 2 µm	≥ 2 µm	0.05	1 & 2

Surface Defects in the Quality Area

	RESIDUE	*SCRATCH SIZE*	*TOTAL DEFECTS*	*SLEEK SIZE*	*TOTAL DEFECTS (per in.^{2})*	*OPAQUE SPOT SIZE*	*TOTAL DEFECTS (per in.^{2})*
FRONTSIDE — ULTE Glass	None	≥ 1.0 mm	0	≥ 2 µm	0	≥ 2.0 µm	0
		< 1.0 µm	No limit	1-2 µm	0.1	1-2.0 µm	0.1
BACKSIDE — ULTE Glass		≥ 3.0 µm	None	≥ 3.0 µm	None	≥ 10 µm	0.3

Defects Outside the Quality Area

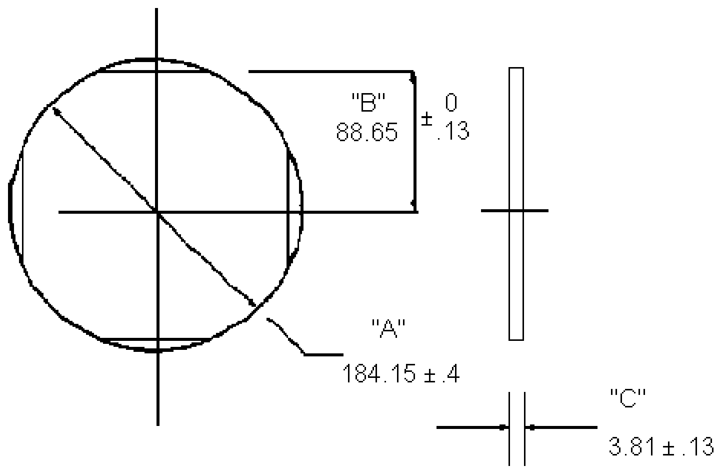
EDGE CHIPS	*Defect Limit*	*Total Number*
Radial Depth	≥ .030"	None
Peripheral Cord	≥ .030"	None
Other	Shall be negotiated between vendor and supplier.	Shall be negotiated between vendor and supplier.

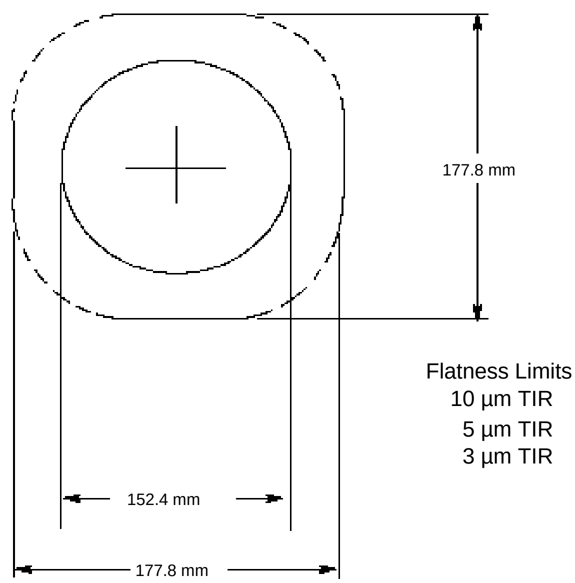
NOTES:

1. The size of internal defects is defined as 1/2 (long axis + short axis).
2. This table is based on the assumption that defects < 2 µm will fall outside the focal depth of the lens system and should not print.

Table 5. Specification for Diameter, Flat Depth, and Thickness for Round Substrates (proposed)

Nominal Diameter	*Diameter (A) Min.*	*Diameter (A) Max.*	*Flat Depth (B) Min.*	*Flat Depth (B) Max.*	*Nominal Thickness (C)*	*Thickness Min.*	*Thickness Max.*	*Units*
7 1/4"	183.75	184.55	88.52	88.65	3.81	3.69	3.94	mm
7 1/4"	7.234	7.266	3.485	3.490	0.150	0.145	0.155	in.





APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI P4 by full letter ballot procedure.

Hard Surface Photomask Glass Properties — Quartz Properties

Property

Ultra Low Thermal Expansion Ulte	
Modulus of Elasticity	6.7-7.4 × 10^3 Kg/mm^2
Poisson' s Ratio	0.18-0.19[1]
Specific Gravity	2.18-2.20 g/cm^3
Index of Refraction	1.46

NOTE: These properties are not absolute requirements. For more specific information, contact your individual supplier.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer' s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI P5-0704
SPECIFICATION FOR PELLICLES

This specification was technically approved by the Global Micropatterning Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee on April 22, 2004. Initially available at www.semi.org June 2004; to be published July 2004. Originally published in 1986; previously published in 1994.

NOTICE: This document was completely rewritten in 2004 to combine SEMI P5, SEMI P5.1, and SEMI P5.2.

1 Preface

1.1 This specification covers requirements for pellicles used on photomasks or reticles in photolithographic exposure systems. This specification covers pellicles for use in either broadband, polychromatic or monochromatic exposure systems.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

2 Referenced Standards

None.

3 Terminology

3.1 Additional terms are listed for information only in the glossary, SEMI Compilation of Terms.

3.2 *Selected Definitions*

3.2.1 *pellicle* — a thin, optically transparent film, typically of a polymer, attached to and supported by a frame, and attached to a photomask (or reticle). Its purpose is to seal out contaminants and reduce printed defects caused by contamination in the image plane of an optical exposure system with a minimum decrease in the quality of optical transmission.

3.2.2 *film adhesive* — adhesive between frame and film.

3.2.3 *frame adhesive* — adhesive between frame and photomask.

3.2.4 *mechanical strength* — the physical condition a pellicle must meet to withstand a specified force from a blow-off gun without suffering any damage to the film due to stretching or breakage.

3.2.5 *film defects* — inconsistencies in the integrity and planarity of the film, including particles, pinholes, scratches, dirt, and a minute quantity of solid.

3.2.5.1 *particle* — materials that can be distinguished from the film whether on the film surface or embedded in the film.

3.2.5.2 *dirt* — fingerprint; mark left behind after operator handling; stain from liquid.

3.2.5.3 *pinhole* — a small opening completely through a polymer film.

3.2.5.4 *scratch* — long, narrow, shallow groove or cut below the established plane of the surface.

3.2.6 *adhesive stringer* — Any detectable protrusion from the edge of the adhesive.

3.2.7 *light resistance* – Minimum cumulative exposure energy a pellicle can withstand without (or within specified) change in performance.

4 Ordering Information

4.1 Purchase orders of pellicles furnished to this specification shall include the following:

4.1.1 *Shape, Size, and Standoff of Pellicle* — The information relating to the Shape, Size, and Standoff of a pellicle may be combined into a single frame part number, or must be provided separately. For any given model of stepper or mask aligner the manufacturer will specify a recommended shape, size and standoff. The user for inter-operability reasons may specify alternative values.

4.1.1.1 *Shape* — This is determined by agreement between the user and the supplier.

4.1.1.2 *Size* — This is determined by agreement between the user and the supplier. Any expression of tolerance is as follows:

Outer edge tolerance: +0, -x

Inner edge tolerance: +x, -0

4.1.1.3 *Standoff* — This is determined by agreement between the user and the supplier. Any expression of tolerance is +0, -x.

4.1.2 *Film Characteristics*

4.1.2.1 *Type* — An anti-reflective (AR) coating may be applied to either the inside or outside surfaces of the polymer film. Which surfaces, if any, require the presence of an AR-coating is determined by agreement between the user and the supplier.

4.1.2.2 *Exposure Range or Wavelength* — The wavelength(s) of the exposure system(s) must be specified. Table 1 shows the typical exposure wavelengths.

Table 1 Typical Exposure Wavelengths

Terminology	*Exposure Wavelength(s)*
Broadband	360 nm–440 nm
g-line	436 nm
h-line	405 nm
i-line	365 nm
DUV	248 nm
DUV 193	193 nm

4.1.2.3 *Optical Transmission* — There are two types of optical transmission depending on the film type. These are measured at an incident angle of 90° from the surface of the pellicle at the specified wavelength(s). The acceptable values are specified in Tables 2 and 3. The Minimum Transmission given in Table 3 apply to all wavelengths the film is specified for.

Table 2 Transmission for Broadband Exposure Systems

Type	*Average*	*Minimum*
AR-Coated	≥ 98 %	96%
Non-AR-Coated	≥ 91 %	82%

Table 3 Transmission for Monochromatic Exposure Systems

Type	*Minimum*
AR Coated	99%
Non AR Coated	98%

4.1.2.4 *Thickness* — This is determined by agreement between user and supplier. The default thickness tolerance is ± 0.1 µm maximum for Broadband Exposure Systems and ± 0.05 µm maximum in all other cases.

4.1.2.5 *Mechanical Strength* — The pellicle film must withstand air blow within ranges shown below:

Air pressure: ≤ 2.1 kgf/cm^2 (at input of the air blow gun).

Nozzle diameter of the air blow gun: ≤ 2 mm.

Distance between the nozzle tip and the film: ≥ 25 mm.

4.1.2.6 *Defect Limits* — Maximum defect limits are determined by agreement between the user and the supplier. These are based on the pellicle standoff, the numerical aperture and exposure wavelength of the given type of exposure system, and a typical specification is given in Table 4. For broadband exposure systems a typical value of size would be 45 µm, and for monochromatic exposure systems the size will be significantly smaller.

Table 4 Maximum Defect Limits

Characteristics	*Max. No. Allowable*	*Size Counted for Max. No. Allowable*
Non-removable		
Particles	None	> ***size*** µm
Pinholes	None	>limit of detection
Scratches	None	Width > ***size*** µm
Dirt	None	>limit of detection

4.2 In addition, the following items may also be specified:

4.2.1 Frame Material or Type

4.2.2 Frame Finishing or Coating

4.2.3 Frame Shape, Size and Height

4.2.4 Frame Adhesive Material or Type.

4.2.5 Frame Adhesive Thickness and Width.

4.2.6 Film Adhesive Material or Type

4.2.7 Film Adhesive Thickness and Width.

4.2.8 Film Thickness Uniformity.

4.2.9 Pellicle Vent Mechanism, e.g. vent hole.

4.2.10 Frame inner-wall adhesive.

4.3 If two pellicles will be attached to a photomask then each pellicle should be independently specified. For thicker photomask substrates a pellicle is only attached to the patterned side of the photomask. For thinner photomask substrates a pellicle is normally attached to both the patterned and glass sides of the photomask.

5 Requirements

5.1 *Film Adhesive* — Film must be sealed on the entire top of the frame. Seal with a minimum of 50% of the frame width at any location.

5.2 *Frame Adhesive* — Frame adhesive must be continuous and allow no gaps larger than the Defect Size Limit between pellicle frame and adhesive, and between adhesive and photomask after attachment. No part of the frame adhesive may extend beyond the frame wall, and its edges must be free of visually detectable stringers (and particles). Adhesive should form a complete seal between the frame and the mask over a minimum of 60% of the width of the frame.

5.3 *Frame* — Pellicle frame must have no visually detectable machining burrs, discontinuities in anodization, or particles.

5.4 *Light Resistance*

5.4.1 For Broadband Exposure Systems this is expressed by total exposure energy value (mj/cm^2 or j/cm^2) on pellicle film until dropping 1% of optical transmission of one of the peak wavelengths between 360 nm–440 nm. The test conditions (special characteristics of exposure wavelength, exposure energy between 360 nm–440 nm, exposure conditions, and others) must be stated. Under these conditions, the pellicle shall release no material, which could contaminate the photomask or the pellicle itself.

5.4.2 For Monochromatic Exposure Systems this is expressed by total exposure energy value (mj/cm^2 or j/cm^2) of specified wavelength on pellicle's film until dropping 0.5% of optical transmission at specified wavelength. Also, the test conditions (half bandwidth of exposure specified wavelength, energy of exposure specified wavelength, exposure conditions, and others) must be stated. Under these conditions, the pellicle shall release no material, which could contaminate the photomask or the pellicle itself.

5.5 *Other Characteristics* — Other characteristics of pellicles are to be determined between the supplier and the user. The transmission of light for mask alignment is such a characteristic.

6 Measurement Methods

6.1 Measurement methods are to be determined between the user and supplier. General and example methods are as follows:

Optical Transmission: by spectrophotometer

Optical Film Thickness: by spectrophotometer

Thickness Uniformity: by monochromatic (e.g., green) light

Width of Film Adhesive: Visual check by minimum defect sample

Defects: Visual check by maximum sample or particle detector

7 Sampling

7.1 Inspection levels shall be agreed upon between the user and supplier.

8 Handling

8.1 Pellicles are to be handled by the frame only.

9 Certification

9.1 Certification is to be determined between the user and supplier.

SEMI P6-88
SPECIFICATION FOR REGISTRATION MARKS FOR PHOTOMASKS

1 General Specification

1.1 *Scope*

1.1.1 This specification defines the shape, range of sizes, and general placement of a registration mark for use on all photomasks. Methods of use will be stated in accompanying application notes (to be furnished at a later date).

1.2 *Applicable Documents* — None.

2 Detail Specifications

2.1 *Introduction*

2.1.1 The complete specification for this registration mark is to be agreed upon by the circuit designer, mask maker, and the mask user.

2.2 *Requirements*

2.2.1 This specification covers a defined mark placed photolithographically on photomasks for the express purpose of determining the registration accuracy of one imaged photomask to another imaged photomask within the same set of photomasks.

2.3 *Other*

2.3.1 This mark is not intended to be used for the determination of overlay accuracy of an imaged layer of a photomask onto a maker to any subsequent imaged layers on the same wafer.

3 Guidelines for Shape and Sizes of Registration Mark

3.1 The shape of the mark shall be in the form of a cross (see Figure 1).

3.2 The area of intersection of the horizontal and vertical lines shall be "user-defined." The designer, mask maker, or user may define any shape of geometry within this area. The "user-defined" geometry used shall not exceed the width or height of the area of intersection (see Figure 2).

3.3 The width of both the horizontal and vertical lines shall be equal.

3.4 The length of both the horizontal and vertical lines shall be equal.

3.5 The width and length of the horizontal and vertical lines may vary due to design rules, scaling, process bias, etc. Table 1 lists the design dimensions for each type of photomask. Sections 3.3 and 3.4 are not superceded by this statement.

3.6 Any of the four quadrants created to the outside of the cross shall be defined as "No-Man's Land" and shall not have any geometry or marks placed within them (see Figure 3).

3.7 A field or registration mark (i.e., dark or clear) is user-definable.

3.8 The mark shall be placed as per attached application notes (to be furnished at a later date).

Table 1 Dimensions of Registration Mark For All Mask Types (all dimensions are in micrometers (μm))

Type of Photomask	*Width*	*Length*	*User Defined Area*	*Total Pattern Window*
1× Masters	4 – 8	10 – 15	min. 4 × 4 max. 8 × 8	min. 24 × 24 max. 38 × 38
1× Stepper Reticles	4 – 8	10 – 15	min. 4 × 4 max. 8 × 8	min. 24 × 24 max. 38 × 38
5× Stepper Reticles	8 – 40	20 – 75	min. 8 × 8 max. 40 × 40	min. 48 × 48 max. 190 × 190
10× Stepper Reticles	16 – 80	40 – 150	min. 16 × 16 max. 80 × 80	min. 96 × 96 max. 380 × 380

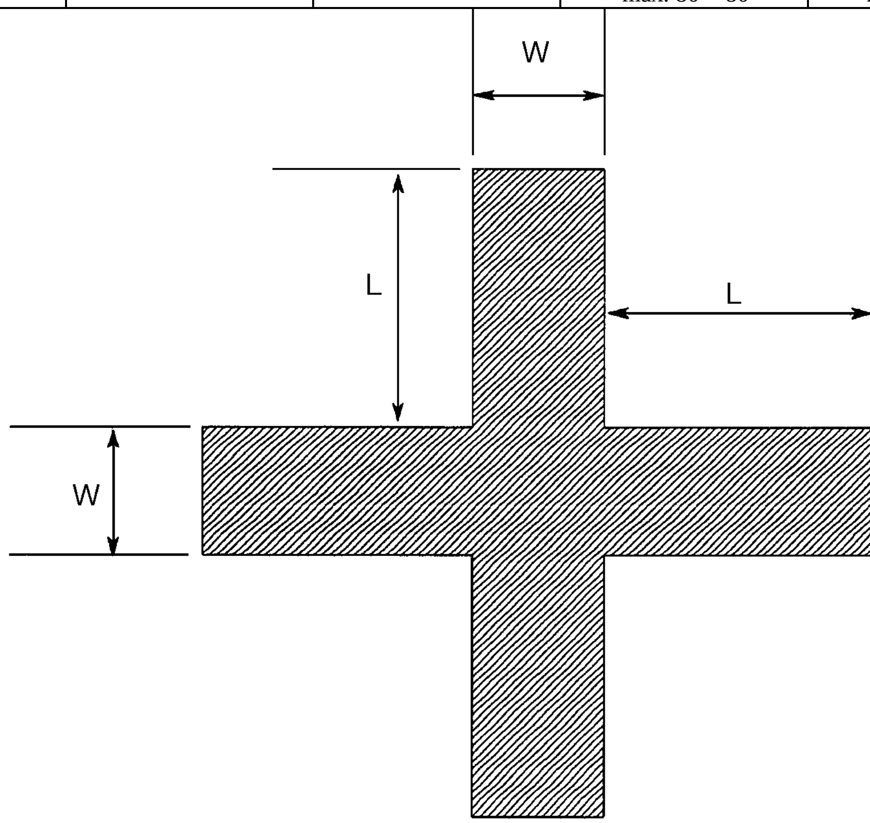

Figure 1
Shape of Registration Mark

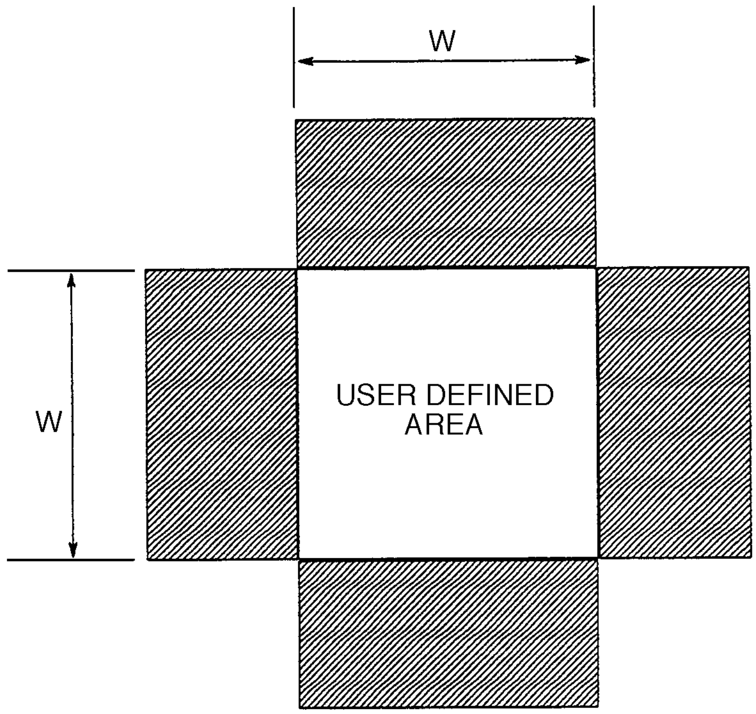

Figure 2
User-Defined Area

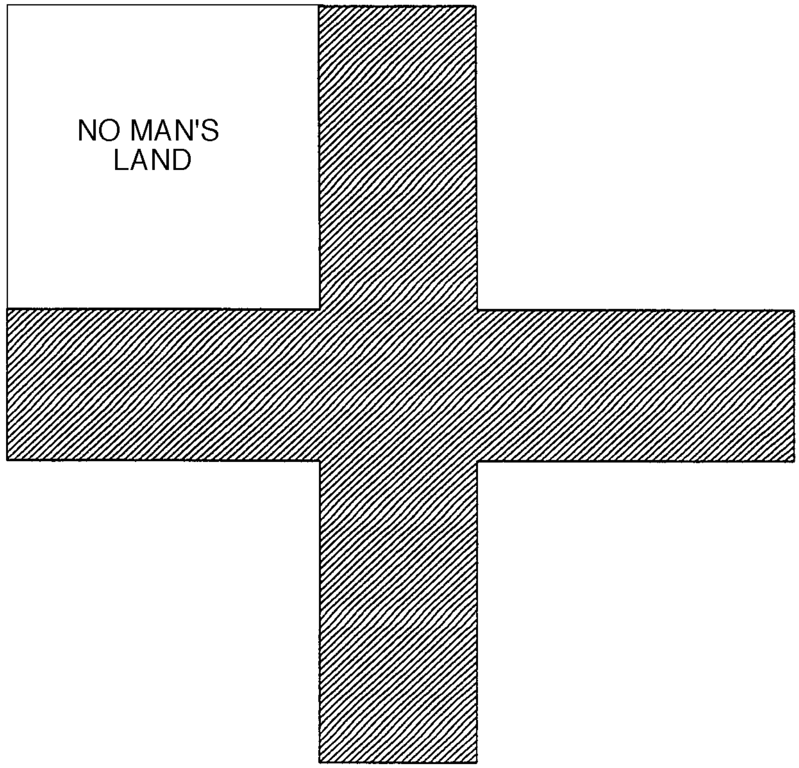

Figure 3
No Man's Land

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SEMI P7-0997 (Reapproved 1103)
METHOD OF VISCOSITY DETERMINATION, METHOD A — KINEMATIC VISCOSITY

This method was technically reapproved by the Global Micropatterning Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee on July 27, 2003. Initially available on www.semi.org October 2003; to be published November 2003. Originally published in 1982; previously published in September 1997.

1 Scope

1.1 This method, a simplified version of ASTM D 445 and ASTM F 66 is intended for determining the kinematic viscosity of photoresists by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary at a fixed temperature. Efflux time is measured in seconds and multiplied by the calibration constant of the viscometer to obtain kinematic viscosity in units of centistokes (cSt). Optionally, kinematic viscosity may be multiplied by the density of the photoresist to obtain dynamic viscosity in units of centipoise (cP). Refer to ASTM D 445 and F 66 for additional information and definitions.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

2 Referenced Standards

2.1 *ASTM Standard*[1]

D 445 — Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)

F 66 — Photoresist Used in Microelectronic Fabrications

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

3 Apparatus

3.1 *Calibrated Viscometer* — Of the glass capillary type. (A listing of such viscometers is given in Table 1, ASTM D 445.)

3.2 *Constant Temperature Bath* — Equilibrated to 25.0 ± 0.1° C.

3.3 *Viscometer Clamp* — Adjustable to achieve vertical alignment.

3.4 *Thermometer* — Graduated in 0.1° C intervals and calibrated (see ASTM D 445 and ASTM F 66).

3.5 *Stopwatch* — Readable in 0.2 second intervals or better.

3.6 *Chemicals* — Acetone, chromic acid, methyl ethyl ketone, xylene.

4 Procedure

4.1 Confirm that the constant temperature bath is equilibrated to 25.0 ± 0.1° C.

4.2 Select a clean dry viscometer of appropriate viscosity range. Choose the proper tube size for the given viscosity so that the efflux time is greater than or equal to 200 seconds.

4.3 Charge the viscometer with photoresist in the manner dictated by the design of the viscometer and wipe clean.

4.4 Insert the viscometer into the clamp holder in the constant temperature bath. Vertical alignment of the viscometer is essential for proper flow measurement.

4.5 Allow 15 minutes for the sample temperature to equilibrate.

4.6 Use suction or pressure to adjust the level of the test sample to a position in the capillary arm about 5 mm ahead of the first timing mark.

4.7 With the sample flowing freely, measure the time for the meniscus to pass from the first timing mark to the second. Record the time in seconds.

4.8 Repeat the steps in Sections 4.6 and 4.7. (For reverse flow viscometers, use the same or another viscometer and begin with the step in Section 4.3 for the second measurement.)

4.9 The two measurements must agree within 0.5 seconds. If they do not agree, then reject the measurement results.

4.10 After the measurement, the viscometer should be flushed several times with a suitable solvent (methyl

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555, Website: www.astm.org

ethyl ketone or acetone for typical novolac positive resists or equivalent and xylene for rubber based negative resists or equivalent).

4.11 Dry the tube by blowing dry, filtered air through the viscometer for a few minutes.

4.12 The viscometer should periodically be cleaned with chromic acid to remove trace organic deposits.

5 Calculation

5.1 Average the flow measurements.

5.2 Kinematic viscosity in cTs = Viscometer constant × efflux time in seconds.

5.3 Dynamic viscosity in cP = Photoresist density at 25.0° C in g/mL × kinematic viscosity in cSt.

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SEMI P8-0997
METHOD FOR THE DETERMINATION OF WATER IN PHOTORESIST

1 Scope

1.1 This method is intended for the application of the Karl Fischer titration to the determination of water in photoresists. An electrometric method is used for determining the endpoint. The procedure is applicable to most resists that have polymer and solvent systems fully compatible with Karl Fischer reagent and diluent. The resist manufacturer should be consulted to determine if this procedure can be used with the resist in question.

2 Referenced Documents

2.1 *ASTM Standard*[1]

E 203 — Water by the Karl Fischer Method

2.2 *Reagent Chemicals* — Sixth Edition, American Chemical Society Specifications

3 Apparatus

3.1 Automatic titrator, equipped for Karl Fischer titrations. The titrator should be equipped with a titration vessel with a port for sample entry, desiccated vent tube, and a platinum versus platinum electrode. Mechanical stirring of the titration solvent should be provided for. The manufacturer's suggested operating procedure should be followed, and the endpoint timer set for 20 seconds.

3.2 Hypodermic syringes with lock tip, 0.25 mL and 10 mL.

3.3 Syringe needles, 5 to 8 cm length, 20 and 22 gauge.

3.4 Lint-free tissue.

3.5 Analytical balance, capable of weighing to 0.1 mg.

3.6 *Reagents*

3.6.1 Distilled water.

3.6.2 Methanol, ACS Reagent Grade.

3.6.3 Karl Fischer reagent with a titer of 3.0 (± 5.0) mg of water per ml of titrant. Typical preparation involves a one-to-one dilution of stabilized Karl Fischer reagent with Karl Fischer diluent from the same supplier.

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4 Procedure

4.1 *Standardization of Karl Fischer Reagent* — The Karl Fischer reagent should be standardized immediately before its use in water determinations.

4.1.1 Install Karl Fischer reagent in the titrator and flush all lines of the titration equipment at least three times.

4.1.2 Fill the titration vessel with enough methanol to cover the electrodes, and seal.

4.1.3 Titrate the methanol automatically with the Karl Fischer reagent to the endpoint (blank).

4.1.4 Draw 0.1 mL of distilled water into a 0.25 mL syringe equipped with a 22 gauge needle. Draw the water from the needle into the syringe by inverting the syringe (needle up) and drawing the plunger downward an additional 1 to 2 cm.

4.1.5 Wipe the needle with lint-free tissue.

4.1.6 Weigh the syringe assembly to the nearest 0.1 mg (W_1).

4.1.7 Inject the water into the titration vessel.

4.1.8 Titrate to the same endpoint used for the methanol blank.

4.1.9 Reweigh the syringe assembly to the nearest 0.1 mg (W_2).

4.1.10 Record the number of milliliters of titrant consumed (V_1).

4.1.11 Calculate the Karl Fischer factor (F):

$$F = \frac{\text{mg water injected}}{\text{mL KF titrant}} = \frac{W_1 - W_2}{V_1}$$

4.1.12 Repeat the standardizing titration twice and calculate the mean value for F from the three values (which should fall within a range of 0.02).

4.2 *Determination of Water*

4.2.1 Fill the titration vessel with enough methanol to cover the electrodes, and seal.

4.2.2 Titrate the methanol automatically with the Karl Fischer reagent to the endpoint (blank).

4.2.3 Flush a dry 10 mL syringe fitted with a 20 gauge needle several times with the sample to be tested. Fill the syringe with 3–5 mL of photoresist sample.

4.2.4 Wipe the needle with lint-free tissue.

4.2.5 Weigh the syringe assembly to the nearest 0.1 mg (W_3).

4.2.6 Inject the sample into the titration vessel.

4.2.7 Titrate to the same endpoint used for the methanol blank.

4.2.8 Reweigh the syringe assembly to the nearest 0.1 mg (W_4).

4.2.9 Record the number of milliliters of titrant used (V_2).

4.2.10 Calculate the water content of the sample.

$$\text{Weight \% } H_2O = \frac{\text{mL KF titrant} \times \text{F}}{\text{sample weight in mg}} \times 100$$
$$= \frac{V_2 \times F}{W_3 - W_4} \times 100$$

4.3 *Remarks* — Photoresists which contain interfering compounds (such as aldehydes and ketones) may require modification of the solvent or titration conditions. For further information, see Section 3.4 of ASTM Standard E 203. For some negative (polyisoprene) photoresists, solubility can be improved by substituting ethylene glycol as the solvent for methanol.