SEMI 3D1-0912 (Reapproved 0418)
TERMINOLOGY FOR THROUGH SILICON VIA GEOMETRICAL METROLOGY

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1 Purpose

1.1 Clear and commonly accepted definitions are needed for efficient communication and to prevent misunderstanding between buyers and vendors of metrology equipment and manufacturing services. The purpose of this Document is to provide a consistent terminology for the understanding and discussion of metrology issues important to through silicon vias (TSV).

2 Scope

2.1 The scope of this Document is limited to the definitions of terms used to specify measured quantities that characterize TSV. This Document does not describe measurement procedures, but rather attempts to define the measurands clearly, usefully, and unambiguously.

2.2 The focus of this Document is on geometry-related metrology and measurands important for definition and control of fabrication and inspection operations on structures that include openings for TSV.

2.3 This Document is intended for TSVs in silicon.

2.4 This Document does not attempt to discuss statistical considerations, which are covered in SEMI E89 and elsewhere.

2.5 This Document adapts structure and wording from other SEMI Documents, particularly SEMI P35.

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

3 Referenced Standards and Documents

3.1 *SEMI Standards and Safety Guidelines*

SEMI E89 — Guide for Measurement System Analysis (MSA)

SEMI P35 — Terminology for Microlithography Metrology

3.2 *Other Documents*

SEMI International Standards: Compilation of Terms[1]

International Technology Roadmap for Semiconductors, 2009 Edition, Chapter on Interconnect

NBSIR 79-1758 — The Calibration of a Roundness Standard (http://emtoolbox.nist.gov/Publications/NBSIR79-1758.pdf)

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

4 TSV Metrology Issues

4.1 *Geometrical Measurements* — Any measurement of length or position contains an unknown error, the influence of which on subsequent application of the measurement data is best described by numerical measurement uncertainty. The problem of measuring geometric dimensions on TSV is complicated by the fact that the TSV is a three-

[1] SEMI International Standards: Compilation of Terms available at http://www.semi.org/en/Standards/StandardsPublications

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dimensional object with (usually) an irregular and complex shape. The metrology problem is further complicated because TSV are microscopic, and only magnified images can be measured.

4.2 In efficient practice, TSV opening geometry is specified using only a few selected parameters, because the additional data needed to fully describe the complex TSV shape can be considered immaterial to the subsequent applications of the measurement data, and are seldom available.

4.3 The first rule of metrology is to define exactly what is to be measured. The approach used here, in light of the previous paragraphs, is to define specific applications of widely used terms such as depth and diameter for TSV. These definitions will rely on standard geometrical constructions such as straight lines, circles, ellipses, etc. as needed for clarity. The differences between the ideal and the actual shape of a TSV opening may contribute to the overall measurement variability or uncertainty of some dimension of the TSV being characterized.

4.4 *Challenges from the International Technology Roadmap for Semiconductors (ITRS) Roadmap* — The ITRS, 2010 Update, anticipates minimum TSV diameters ranging from 8 µm to 0.8 µm in global and intermediate interconnect levels in 3D-SICs from 2009 to 2015. Among the five most critical challenges beyond the 16 nm node is a practical approach for 3D chip stacking; Table INTC5 states that engineering manufacturable solutions that meet cost targets for this technology is key. Addressing this challenge will require advances in metrology. This Document is part of the groundwork for that metrology.

5 Definitions

5.1 *through silicon via opening (TSV)* — a hole or recess in a silicon wafer that begins at the wafer top surface and may or may not: a) extend fully through the wafer from one surface to the other; b) contain a conductor; c) contain additional layers such as an insulator between the conductor and the silicon, a diffusion barrier on the silicon surface within the hole, or others.

5.1.1 *Discussion* — The ITRS defines a through-silicon-via as an electrical conductor. Here we are defining specifically terms for the metrology of the TSV opening, within which the complete electrical conducting TSV will be constructed.

5.2 *wafer top surface* — the wafer surface where the TSV opening is initially created and where the excavation of the TSV begins. This surface is defined to be horizontal; its perpendicular is defined to be vertical. Figure 1 shows a sketch of a TSV at the wafer top surface.

5.3 *wafer bottom surface* — the wafer surface opposite the *wafer top surface*.

5.4 *area* — geometrical area of the TSV opening in a particular horizontal plane. In Figure 1, the area of the TSV opening is the area covered by the light upward diagonal line pattern.

5.4.1 *top area* — area of the TSV opening at the top surface of the wafer.

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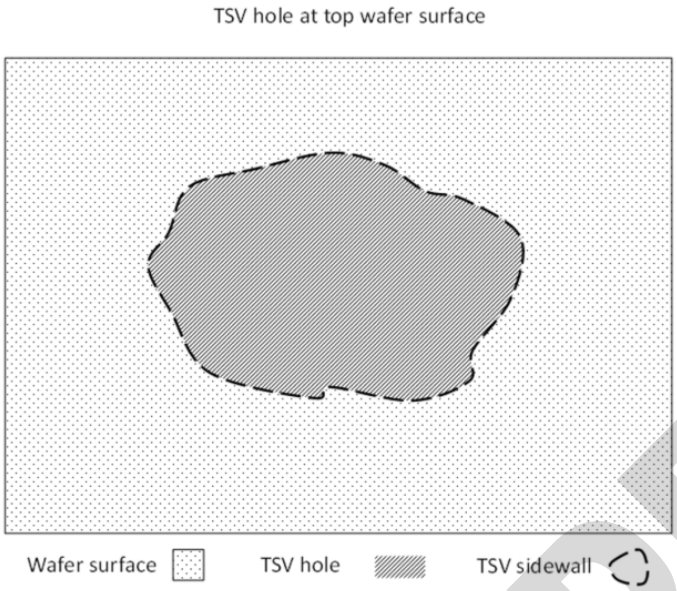

Figure 1
TSV with Sidewall at Top Wafer Surface

5.5 *depth* — the distance, measured from the wafer top surface vertically toward the wafer bottom surface, between the top surface and the deepest point of the TSV opening.

5.5.1 *intermediate depth* — the distance measured from the wafer top surface to a selected level less than the full depth of the TSV opening. For example, the TSV opening area at an intermediate depth of 50% of the wafer thickness might be of interest.

5.5.2 *full depth TSV* — a TSV opening that extends from the top surface to the bottom surface of the wafer.

5.6 *reported horizontal dimensions* — the scheme and numerical values used to specify the breadth of a TSV. The breadth of a TSV may be specified in a variety of ways depending on circumstances such as the fabrication method and the measurement tools that are available. This Standard adopts the major and minor diameters, as defined below, as the reference geometrical construction for the horizontal dimensions of the TSV opening. Other possible examples of reference dimensions, not defined in this standard, include the diameter of a circle in a horizontal plane that can be inscribed in the TSV opening, the side of a square that can be inscribed in the TSV opening, etc. The geometrical terms and definitions herein are intended to be consistent, to the extent feasible, with their standard usage in the literature on geometry, in order to promote the use of existing mathematical methods and software and to minimize confusion.

5.6.1 *center* — the center of a TSV opening in any horizontal plane is the centroid ('center of gravity') of the area of the TSV.

5.6.2 *chord* — a straight line that extends from one point on the sidewall of the TSV opening in a specific horizontal plane to another such point in the same plane.

5.6.3 *major diameter* — the length of the longest chord of the TSV opening in any particular horizontal plane. There is no requirement that this diameter pass through any geometrical center or centroid of the TSV opening. There is no relationship implied between the length of the major diameter and the area of the TSV opening. Figure 2 indicates the major and minor diameters of a TSV opening. The unit for this dimension shall be the micrometer.

5.6.3.1 *Discussion* — This definition implies that all diameters of the TSV are observable within the field of view of the measurement instrument. If only a subset of the TSV diameters is within the field of view, for instance, by use of a vertical cross section, the reported diameter value will be affected by the geometrical relationship between the measurement plane and the TSV.

5.6.3.2 *center point of the major diameter* — the point on the major diameter equidistant from its ends.

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