

# SEMI M48-1101 (Withdrawn 1110) GUIDE FOR EVALUATING CHEMICAL-MECHANICAL POLISHING PROCESSES OF FILMS ON UNPATTERNED SILICON SUBSTRATES

This standard was technically approved by the global Silicon Wafer Committee. This edition was approved for publication by the global Audits & Reviews Subcommittee on August 27, 2010. Initially available at [www.semi.org](http://www.semi.org) in October 2010. Originally published November 2001.

**NOTICE:** This document was balloted and approved for withdrawal in 2010.

## 1 Purpose

- 1.1 The purpose of this document is to provide a guide for evaluation of chemical-mechanical polishing (CMP) processes of thin films on unpatterned silicon substrates. This includes recommended procedures for process testing and reporting formats.
- 1.2 This guide is intended for use by both suppliers and end users.

## 2 Scope

- 2.1 This document provides a guide for evaluating a CMP process for films deposited or grown on an unpatterned silicon substrate. These evaluations could include tests with fixed polishing time, fixed removal rate, fixed ending thickness, time-dependent material removal, and others.
- 2.2 Recommended procedures for characterizing a CMP process are discussed in this guide.
- 2.3 This guide suggests selected parameters and values of the properties of the starting monitor wafer.

**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 The guide does not address evaluation of CMP processes for films on patterned substrates.
- 3.2 Evaluation of surface quality or surface contamination is not addressed in this document. Surface quality and surface contamination are important aspects of the CMP process evaluation but they are beyond the scope of this guide.
- 3.3 This guide employs sample standard deviation to estimate variation.
- 3.4 Wafer positioning precision on a metrology tool can affect the precision of the polishing evaluation. This issue is not addressed in this standard.
- 3.5 The values derived from the calculations in this guide are sample-dependent. They are affected by measurement location and number of observations.

## 4 Referenced Standards and Documents

### 4.1 SEMI Standards

- SEMI E89 — Guide for Measurement System Analysis (MSA)
- SEMI M1 — Specifications for Polished Single Crystal Silicon Wafers
- SEMI M20 — Specification for Establishing a Wafer Coordinate System
- SEMI M62 — Specifications for Silicon Epitaxial Wafers

#### 4.2 ASTM Standards<sup>1</sup>

ASTM F534 — Test Method for Bow of Silicon Slices

ASTM F1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

ASTM F1530 — Test Method for Measuring Flatness, Thickness and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

ASTM F1618 — Standard Practice for Determination of Uniformity of Thin Films on Silicon Wafers

#### 4.3 DIN Standards<sup>2</sup>

DIN 50441/4 — Measurement Determination of the Geometric Dimensions of Semiconductors Slices [including] Diameter and Flat Depth

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

### 5 Terminology

5.1 *blanket polish* — polishing of material deposited on an unpatterned silicon substrate.

5.2 *diameter scan* — measurements of material on a wafer taken along a specified diameter. The diameter scan is useful in determining the thickness profile of the material on the wafer surface.

5.3 *edge scan* — measurements of material taken along a specified radial segment in the edge region of the wafer. A series of edge scans can be employed to determine circumferential thickness profile.

5.3.1 *Discussion* — The data density for edge scan measurements is generally higher than for other measurements. Combining a low-density diameter scan in the central region of the wafer with a higher-density edge scan, taken along the same scan line, can improve throughput with appropriate local measurement data density.

5.4 *film total thickness variation (film TTV)* — the total thickness variation ( $Thk_{max} - Thk_{min}$ ) of film material among a set of measurement points.

5.4.1 *Discussion* — The variation may pertain to a region within a wafer, a complete wafer or multiple wafers with a single polish head, or multiple wafers with multiple polish heads. These wafer and head combinations must be considered in planning and comparing measurements. If one assumes that a given wafer is polished by a subset of the tool heads (typically one), a hierarchical relationship exists such that wafers must be associated with the (tool head) subsets used to polish them. Another way to look at this is, if *head* is considered an experimental treatment, then a wafer polished by one head will be assumed to be treated differently than a wafer polished by a different head. This relationship leads to what is known as a hierarchic or nested model. (In this case, one says that wafer is nested within *head*). A more complete model would also treat *head* as a fixed effect, *wafer* random and nested within *head*, and error as nested with *head* and *wafer*. A random effect indicates that the observation comes from a random sample of a larger population. *Head* is a fixed effect because the entire population of heads (i.e., all the heads on the tools) constitutes the entire population of interest. Given this model, variance components would be used to estimate the different sources of variation. In this case, the sample standard deviation underestimates the population standard deviation. Historically, the expected value of the variance components is equal to the population standard deviation. This is not the case for the sample standard deviation.

5.5 *head to head removal rate non-uniformity (HTHNU)* — this metric is useful when evaluating polishing processes on a multi-head tool configuration. It is the standard deviation ( $1\sigma$ ) of the removal rate variation from polish head (HTH) to polish head for a fixed number of wafers where the number of wafers run for each head must be equal. It is expressed as follows:

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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; <http://www.astm.org>

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

$$HTHNU = \sqrt{\frac{\sum_{k=1}^p (\overline{RR_k} - \overline{RR_{HTH}})^2}{p-1}} \quad (1)$$

where  $k$  is the head indexer and  $p$  is the total number of heads.  $\overline{RR_k}$  is the average within wafer removal rate of head  $k$ .  $\overline{RR_{HTH}}$  is the head to head wafer removal rate averaged across all wafers and all heads. The measurement site locations on each wafer must be identical for all wafers sampled.

It may also be expressed as a percentage of the average head to head removal rate:

$$\% HTHNU = \frac{\sqrt{\frac{\sum_{k=1}^p (\overline{RR_k} - \overline{RR_{HTH}})^2}{p-1}}}{\overline{RR_{HTH}}} \times 100 \quad (2)$$

5.6 *removal rate (RR)* — the amount of material removed per unit time during the polish process. At any given point  $i$  on the wafer, the removal rate is expressed by:

$$RR_i = \frac{Thk_{prei} - Thk_{posti}}{\text{Polish time}} \quad (3)$$

5.7 *thickness, prepolish ( $Thk_{pre}$ )* — the thickness of material on an incoming blanket film wafer prior to polish.

5.8 *thickness, post-polish ( $Thk_{post}$ )* — the thickness of material remaining at a measurement site on a silicon substrate after completion of the polish process.

5.9 *wafer to wafer (WTW) variation* — the variation across multiple wafers at site locations where the locations on each wafer are identical for all wafers sampled.

5.10 *wafer to wafer removal rate nonuniformity (WTWNU)* — a measure of the wafer to wafer removal rate variation. It is the standard deviation ( $1\sigma$ ) of the removal rate variation wafer to wafer over a polish run that employs a single polishing head. The average removal rate for such a group of wafers is expressed as:

$$\text{Average WTW RR} \Rightarrow \overline{RR_{WTW}} = \sum_{j=1}^m \frac{\overline{RR_j}}{m} \quad (4)$$

where  $j$  is the wafer indexer and  $m$  is the total number of wafers within the group. A typical number for  $m$  is  $\geq 25$ .

The measurement site locations on each wafer must be identical for all wafers sampled. The wafer-to-wafer removal non-uniformity is expressed as follows:

$$WTWNU = \sqrt{\frac{\sum_{j=1}^m (\overline{RR_{wiw}} - \overline{RR_{wtw}})^2}{m-1}} \quad (5)$$

It may also be expressed as a percentage of the average wafer to wafer removal rate:

$$\% \text{ WTWNU} = \frac{\sqrt{\frac{\sum_{j=1}^m (\overline{RR}_{j\text{WTW}} - \overline{RR}_{\text{WTW}})^2}{m-1}}}{\overline{RR}_{\text{WTW}}} \times 100 \quad (6)$$

5.11 *within wafer average removal rate* — the average removal rate within a wafer. It is given as:

$$\text{Average WIW RR} \Rightarrow \overline{RR}_{\text{WIW}} = \sum_{i=1}^n \frac{RR_i}{n} \quad (7)$$

where  $i$  is the site indexer and  $n$  is the total number of measurement sites within the wafer, and  $RR_i$  is within wafer removal rate.

5.12 *within wafer removal rate nonuniformity (WIWNU)* — a measure of removal rate variation. It is the standard deviation ( $1\sigma$ ) of the removal rate within the wafer and is expressed as follows:

$$\text{WIWNU} = \sqrt{\frac{\sum_{i=1}^n (RR_i - \overline{RR}_{\text{WIW}})^2}{n-1}} \quad (8)$$

where  $i$  is the site indexer,  $n$  is the total number of measurement sites on the wafer and  $\overline{RR}_{\text{WIW}}$  is the average within wafer removal rate. It may also be expressed as a percentage of the average removal rate:

$$\% \text{ WIWNU} = \frac{\sqrt{\frac{\sum_{i=1}^n (RR_i - \overline{RR}_{\text{WIW}})^2}{n-1}}}{\overline{RR}_{\text{WIW}}} \times 100 \quad (9)$$

5.13 *within wafer (WIW) variation* — the variation in measurement values obtained at defined locations within a single wafer.

## 6 CMP Process Test

### 6.1 Introduction

6.1.1 The CMP process test should be performed with attention to the quality of both the substrate and the incoming film material, and the relative condition of the consumables and polishing system being utilized.

6.1.2 The number of wafers within the group should be specified.

### 6.2 Monitor Wafer

6.2.1 Monitor wafer specifications should be per SEMI M1 for incoming bow, warp, total thickness variation (TTV), and edge profile.

6.2.2 The geometry of the wafer may influence the CMP process results. Tables R-1 and R-2 in Related Information 1 recommend specifications for wafer geometry that can minimize the effects of such geometry on the CMP process test.

6.2.3 Record bow, warp and other wafer geometry characteristics.

6.2.4 Wafers can be laser-marked for ease of tracking. Data taken in this mark area should be excluded from the process analysis. It is desirable that all wafers in an evaluation lot contain marks at the same nominal locations.