

SEMI M43-0301

GUIDE FOR REPORTING WAFER NANOTOPOGRAPHY

This guide was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org December 2000; to be published March 2001.

1 Purpose

1.1 This guide provides a framework for reporting of nanotopography surface features on silicon wafers.

2 Scope

2.1 This guide addresses reporting the characterization of nanotopography surface features found on wafer surfaces. Nanotopography is the non-planar deviation of the whole front wafer surface within a spatial wavelength range of approximately 0.2 to 20 mm and within the fixed quality area (FQA). Typical examples include dips, bumps or waves on the wafer surface that vary in peak to valley height from a few nanometers to a several hundred nanometers.

2.2 This guide provides a framework for communicating specific values limiting feature levels and/or densities as agreed upon between suppliers and users.

2.2.1 *Discussion* — Nanotopography measurements have not been needed for 0.25 μm generation devices, but are expected to be required for smaller feature sizes to meet CMP requirements. Nanotopography on a wafer surface prior to CMP processes can result in variations in post-CMP dielectric thickness with potential negative consequences for circuit performance and yield; features as small as 20 nm (peak to valley) can result in post CMP discoloration of dielectrics as a result of local thickness variation of the remaining dielectric¹. Height variations over specified distances (determined by CMP issues and/or lithography systems) need to be properly controlled to assure that wafers are acceptable for selected process steps. In the case of CMP, the issue is control of film thickness variation introduced by nanotopography. The metrology industry is building tools that will measure and map surface features at nanotopography amplitudes and spatial wavelengths. Nanotopography features are characterized by their height variation within an area, and are discriminated from other features of similar height by their spatial wavelength range.

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 Limitations

3.1 The reported surface features will be influenced by limitations and parameters of the measurement tool. These include:

3.1.1 The finite surface spatial bandwidth of the tool and the applied filtering will prevent surface variations outside the bandwidth of operation from being measured. Also, the finite bandwidth of filtering produces non-physical artifacts that may be apparent in regions where the power in the rejected bands is high.

3.1.2 Bandwidth edges are not always well defined. Measurement results do not always agree well between systems, because different tool designs employ different geometries and operate them over different spatial bandwidths.

3.1.3 All surface profiling measurement systems have a minimum height variation sensitivity that will distort signals near the noise floor.

3.1.4 The reported shape of some features may also depend on the pixel grid orientation employed by the instrument.

3.1.5 The pixel size and sampled area will affect the bandwidth limits.

3.2 Reported profiles also vary with interactions between wafer and tool. These limitations include:

3.2.1 Measurements made near the wafer edge may result in false readings. Under certain conditions, this may cause incorrect height measurement within the FQA.

3.2.2 Closely spaced features may be counted as a single feature, or as no feature, if the pixel size is larger than the feature, or is larger than the spacing between features. Reported features may result from the combination of the actual surface features, the manner in which the wafer is chucked, or be caused by particles trapped between the wafer back surface and the chuck.

3.2.3 High-pass (spatial frequency) filtering is typically used with these measurements to remove the (long-spatial wavelength) effects of wafer shape (such

¹ K. V. Ravi, "Wafer Flatness Requirements for Future Technologies," Future Fab International, July 1999.

as bow, warp and sori). This filtering may affect the reported results.

3.3 Nanotopography characterization does not include microroughness, which applies to a shorter spatial wavelength range.

3.4 The location of defective areas as calculated in section 6 may not coincide with the location of the surface features that lead to those values. This may cause lack of spatial correlation between reported defective areas and device process defect areas.

3.5 The height map used to create nanotopography reports may be affected by wafer shape and measurement chuck effects.

4 Referenced Standards

4.1 SEMI Standards

SEMI M1 — Specification for Monocrystalline Polished Silicon Wafers

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *fixed quality area (FQA)* [SEMI M1] — the central area of a wafer surface, defined by a nominal edge exclusion, X over which the specified values of a parameter apply.

Discussion: The boundary of the FQA is at all points the distance X away from the periphery of a wafer of nominal dimensions. (See Figure 1). The size of the FQA is independent of the wafer diameter and flat length tolerances. For the purpose of defining the FQA, the wafer periphery at locations with notch fiducials is assumed to follow the circumference of a circle with diameter equal to the nominal wafer diameter.

5.2 *nanotopography, of a wafer surface* — the non-planar deviation of a surface within a spatial wavelength range of approximately 0.2 to 20 μm .

5.3 *nanotopology, of a wafer surface* — see *nanotopography*.

5.4 *roughness* [SEMI M1] — the more narrowly spaced components of surface texture.

Discussion: These components are considered within defined limits of spatial wavelength (or frequency).

5.5 *spatial wavelength* — the spacing between adjacent peaks of a purely sinusoidal profile.

6 Measurements

6.1 The height map is obtained from a front-surface

measurement. An explicit reference plane is not used for calculating and assigning values.

NOTE 2: Other methods of analyzing nanotopography may require the use of an explicit reference plane.

6.2 The high-pass filter removes long spatial wavelength wafer tilt and topography effects, effectively creating a global reference surface.

6.3 *Calculation* — The calculation determines the peak to valley height (P-V) variation among the pixels included in the analysis area, and assigns that variation in nanometers to the center of the analysis area. The calculation is performed for every analysis area within the FQA of the wafer. These calculations may be repeated for analysis areas of different dimension D .

NOTE 3: This calculation describes the “full-analysis area” method. There is another calculation, the “partial analysis area” method, where the calculation is performed for every analysis area whose center pixel is within the FQA of the wafer. The partial analysis area method, not defined in this document, is being addressed by SEMI for inclusion in a standard.

6.4 The following measurement elements should be reported:

6.4.1 Filtering

- Spatial cutoff of high pass filter
- Type of Filter
- Pixel spacing

Filtering is used to remove long wavelength shape components from the raw height data.

6.4.2 *Analysis Area* — Specify this analysis area's:

- Shape, e.g., square, circle, and
- Dimension D of the analysis area

An analysis area contains a pixel at its center (Figure 1). The pixels within the surrounding analysis area of dimension D , and within the FQA, are used to determine the value assigned to the center pixel location.

6.4.3 *Data Report* — Report one or more of the following:

6.4.3.1 *Statistical Representation by Threshold Curve* — Plot, for each D , % area vs. threshold T , in nanometers, where % area is the ratio of

- the number of analysis areas whose assigned value (calculated per Section 6.3) exceeds the threshold T , to
- the number of pixels within the FQA.

The ratio is expressed as a percentage.