

SEMI C100-1120

GUIDE FOR REPORTING CHEMICAL MECHANICAL PLANARIZATION (CMP) POLISHING PADS HARDNESS USED IN SEMICONDUCTOR MANUFACTURING

This Standard was technically approved by the Liquid Chemicals Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on October 21, 2020. Available at www.semiviews.org and www.semi.org in November 2020.

1 Purpose

- 1.1 This Document will provide a guide for the measurements of and reporting of more accurate parameters of hardness of chemical mechanical planarization (CMP) pads, than current industry standards.
- 1.2 This Document will provide a guide for the measurement of and reporting of effect of the temperature on the pad hardness.
- 1.3 Reference to this Guide can be used in the corresponding certificate of acceptance (CoA) from a CMP supplier to its customers.
- 1.4 Reference to this Guide can be used for generating roadmaps for the development of new semiconductor technologies.

2 Scope

- 2.1 This Document provides guidance on how hardness of CMP pads should be reported, for example, on a CoA.
- 2.2 Related Information 1 provides extensive background information on the following topics:
 - Details of the test conditions to be reported on, for example, CoA for measurement of the hardness of CMP pads.
 - The fundamentals for measuring pad hardness using more accurate metrologies, than the current industry process of record (POR) shore hardness (SH), or compressibility.
 - The fundamentals and justification for measurements and reporting on, for example, CoA hardness at different ambient temperatures.
 - List of deformation modes appropriate for the pads of different range of hardness and manufacturing styles.

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

3 Limitations

- 3.1 Due to the proprietary nature of CMP pads, this Guide will not address any specifics regarding the pad manufacturing process.
- 3.2 Due to the proprietary nature of CMP pads, this Guide will not address any composition or ingredient-related aspects of CMP pads.
- 3.3 This Guide does not define which measurement technique, test conditions and recipes, or selection of the test coupons should be used for pad hardness measurements; it only determines that these techniques, conditions and coupons should be reported on, for example, a CoA.

4 Referenced Standards and Documents

4.1 *ASTM Standards*¹

ASTM D2240 — Standard Test Method for Rubber Property—Durometer Hardness

ASTM D4065 — Standard Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures

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

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CMP* — chemical mechanical planarization

5.1.2 *CoA* — certificate of acceptance

5.1.3 *CTE* — coefficient of thermal expansion

5.1.4 *DMA* — dynamic mechanical analysis

5.1.5 *DSC* — differential scanning calorimetry

5.1.6 *GTT* — glass transition temperature

5.1.7 *POR* — process of record

5.1.8 *SH* — shore hardness

5.1.9 *SM* — storage modulus

5.1.10 *TGA* — thermal gravimetric analysis

5.1.11 *TMA* — thermal mechanical analysis

5.2 *Definitions*

5.2.1 *glass transition temperature, T_g* — a temperature, at which certain structural changes in a polymer occur, such as transition from glassy state to viscoelastic state.

5.2.2 *loss modulus, G''* — a parameter that measures pad ability to adsorb mechanical energy in dynamic oscillation mode of applied stress, or applied strain, indicates viscous component of viscoelastic deformation.

5.2.3 *polymeric pads* — relatively hard one or two-layered polymer-based pad with usually grooved surface.

5.2.4 *poromeric pad* — relatively soft two multilayered polymer-based pad with embossed surface.

5.2.5 *storage modulus, G'* — a parameter that measures pad hardness in dynamic oscillation mode of applied stress, or applied strain, indicates elastic component of viscoelastic deformation.

5.2.6 *sub-pad* — a polymer-based ‘pad’ used as a cushion for the main pad; sub-pad is not used for polishing.

5.2.7 *tan delta* — is determined as ratio of G''/G' , and measured in dynamic oscillation mode of applied stress, or applied strain.

5.2.8 *top-pad* — the main pad that can be used individually or in combination with a sub-pad.

6 Background to Data Reporting of CMP Pad Hardness

6.1 Pad hardness metrologies are based on various measurement principles, direct and indirect.

6.1.1 Direct principles include such metrologies, as SH, compressibility, dynamic mechanical analysis (DMA), and nano DMA (nDMA). These examples are not a comprehensive list of all available metrologies. Examples of DMA data for CMP pads is shown in Related Information 1.

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, <http://www.astm.org>

6.1.2 Non-direct principles include such metrologies as differential scanning calorimetry (DSC); modulated differential scanning calorimetry (mDSC), which measures crosslinking in the pads; thermal mechanical analysis (TMA) and modulated thermal mechanical analysis (mTMA), which measures coefficient of thermal expansion (CTE); and thermal gravimetric analysis (TGA), which measures pad decomposition at higher temperatures. These examples are not a comprehensive list of all available metrologies. Examples of DSC, TMA, and TGA data for CMP pads are shown in Related Information 1.

6.2 Traditional industry POR pad hardness measurements are reported using SH (see ASTM D2240) and compressibility metrologies, which are not normally conducted at specified temperature conditions.

6.2.1 Traditional industry POR SH and compressibility can still be used to differentiate between pads that were manufactured to have wider ranges of hardness, but these parameters alone may not meet the industry requirements to allow for differentiation of pads of the same type or within the same lot/batch.

6.2.2 Compressibility of the top pad may also depend on the sublayer substrates.

6.3 Pad hardness variations, not detected on the suppliers' CoA due to insufficient metrology accuracy, may be a root cause for quality issue in fab planarization processes.

6.4 Using DMA, pad hardness is measured as storage modulus (SM) G' (see ASTM D4065 and ASTM D2240).

6.4.1 SM can be measured at either a specific temperature of interest or an entire range of temperatures, depending on the mode utilized.

6.4.2 Other parameters that can be measured include loss modulus G'' , loss modulus peak location, $\tan \delta$ G''/G' , G''/G' peak location and G''/G' peak height.

6.4.2.1 Reporting some of these parameters may not be possible or would not have direct correlation with any physical property of the pads when measured at a single fixed temperature.

6.5 DMA parameters interpretation (see Effect of Cure on the Mechanical and Thermoanalytical Properties of Phenolic Resins and Composites²):

6.5.1 G' is a measure of pad hardness at a specific temperature.

6.5.2 Location of the peak of G'' temperature (T) curve defines the glass transition temperature (GTT), whereas GTT indicates structural changes in the rubber polymers, such as the transition from glassy to rubbery states.

6.5.3 Height of the $\tan \delta$ T peaks indicate the degree of polymer crosslinking.

6.5.4 Location of the peak of $\tan \delta$ T is sometimes approximately interpreted as GTT.

6.6 Parameters obtained during DMA tests depend on the test conditions and coupon deformation modes.

6.7 DMA tests can be conducted in different deformation modes.

6.8 DMA deformation modes include tensile deformation, three-point bending, dual or single cantilever, and compression.

6.8.1 Selection of deformation modes depends on pad hardness, number of layers in the pad, reproducibility of the measurements, etc.

6.8.2 Frequency of oscillation of the coupon deformation will determine values of DMA parameters; for example, higher frequency will result in higher G' .

6.8.3 Amplitude of oscillations should be selected for each type of the tested pads; it should not be too high to exceed linear deformation range, but it should be high enough to optimize signal/noise ratio.

² Tregub, A., *et al.* "Effect of Cure on the Mechanical and Thermoanalytical Properties of Phenolic Resins and Composites." Proceedings of SAMPE Technical Conference, Orlando, November 1997.