A ROUND ROBIN EXPERIMENT TO PROVIDE PRECISION AND BIAS FOR SEMI MS5: TEST METHOD FOR WAFER BOND STRENGTH MEASUREMENTS USING MICRO-CHEVRON TEST STRUCTURES

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Abstract

An international round robin was organized to update SEMI Standard MS5: *Test Method for Wafer Bond Strength Measurements using Micro-Chevron Test Structures*. The results of the round robin are added to MS5 as a new section: **12. Precision and Bias**. The round robin identified a between-laboratory reproducibility **R** as 152% and a within laboratory repeatability **r** of 111%. Since no Reference Materials exist for this method, no bias statement can be made at this time. In addition, the test procedure was re-written for clarity and the analysis procedure was updated to allow for a wider range of geometries.

Background

In 2006, the Wafer Bond Task Force (TF) of the SEMI MEMS Committee undertook the development of a standard method to measure wafer bond strength. From the various methods of measuring this parameter described in the literature, the TF chose the Micro-Chevron technique [1] to serve as the first standard method. This method has the advantages of 1) being based on a well-characterized, standard technique (ASTM C1421-01b) [2] and 2) providing a more quantifiable measurement procedure than that of the other techniques considered.[1] MS5-1107 was published in 2007 without precision and bias data.

To validate the standard, a round robin was organized by the TF [3]. The round robin began once enough laboratories were identified to fulfill the minimum statistical requirements [4] were identified. One laboratory was chosen to follow and verify the procedure. The materials consisted of 25 bonded chip pairs, a description of the round robin protocol, a data-reporting sheet, and a copy of MS5-1107. The researcher was asked to follow the procedure specified in MS5-1107 as exactly as possible and report to the round robin coordinator any concerns and challenges faced while performing the test. From this researcher's feedback, changes to the test procedure and experiment protocol were developed that clarified a number of steps in the test procedure described in MS5-1107. For all remaining laboratories, the test package included an updated test procedure to replace the test procedure section of MS5-1107.

[1] Although the second of these considerations directed the choice of this technique for the first versions of the wafer bond strength standard, the standards process allows for future extension of this standard to include other test methods.

Material	G_{cwb}	SG_{cwb}	S_r	S_R	r	R
W14	0.3784	0.1581	0.1143	0.1836	0.3202	0.5140
W15	0.4761	0.1734	0.1818	0.2282	0.5090	0.6390
W12	0.5827	0.3380	0.3785	0.4580	1.0599	1.2823
W13	0.5919	0.2139	0.1452	0.2445	0.4065	0.6847
Cell Pooled Average, % G_{cwb}		43.1%	39.5%	54.1%	110.53%	151.45%

Data from seven participating laboratories was included in the analysis, using ASTM E691-05, for the updated MS5. Six laboratories provided data that met E691-05's consistency criteria; one laboratory's data was excluded and the remaining participating laboratories did not return their results in time for inclusion in the analysis. The updated MS5 includes measured precision, updated test procedure, and a modification to the analysis procedure to incorporate recent work to extend the technique to a wider range of geometries [5]. This update was successfully balloted in Summer 2009 and is now in final pre-publication review by SEMI.

Conclusions

A new MS5 is expected to be published in early 2010 including key intra- and inter-laboratory comparisons. Highlights of the round robin are shown in the table in order of increasing critical wafer toughness G_{cwb}; the remaining columns in the table are the statistical parameters defined in E691-05. The key results are the within-laboratory repeatability **r** and between-laboratory reproducibility **R** shown as percentages in the lower right cells of the table. These parameters define the maximum expected range between experiments of nominally identical chevron structures from laboratories implementing MS5.

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References

[1] J. Bagdahn, A. Plößl, M. Wiemer, and M. Petzold, "Measurement of the local strength distribution of directly bonded silicon wafers using the micro-chevron-test," Proc. 5th International Symposium on Semiconductor Wafer Bonding, *Electrochem. Soc.* PV 99-35, pp. 218-223, 2001.

[2] ASTM C1421-01b(2007) Standard Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperature. Available from www.astm.org.

[3] R. A. Allen, J. C. Marshall, W. A. Baylies, D. T. Read, F. DelRio, K. T. Turner, M. Bernasch and J. Bagdahn, "A Standard Method for Measuring Wafer Bond Strength for MEMS Applications," ECS Transactions, 16 (8) 449-455 (2008) 10.1149/1.2982899.

[4] ASTM E691-05 (2005) Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method. Available from www.astm.org.

[5] R. Tadepalli and K.T. Turner, "A Chevron Specimen for the Measurement of Mixed-Mode Interface Toughness of Wafer Bonds," Engineering Fracture Mechanics 75 (2008) 1310-1319.