PRODUCT / PROCESS CHANGE NOTIFICATION

ALTERNATIVE METHODOLOGY FOR BIAS & LINEARITY STUDIES IN SEMICONDUCTOR INDUSTRY

What is the change?

Current condition:

To conduct bias & linearity studies, AIAG MSA manual rely on a statistical approach based on t_{test} statistical value, which provides a criteria to judge if the difference in bias or linearity response is statistically different from zero compared to the repeatability of the metrology system.
Bias & Linearity studies based on T_{test} statistics approach conducted at several ST Front-End manufacturing plants, involving either identical or different metrology techniques tested over their operating range, all exhibit some bias error and nonlinear behavior.
A clear picture on the consequences of this established situation versus the accuracy requirement has been highlighted by Sematech consortium few years ago and is summarized in the Sematech internal document in:
http://sematech.org/docubase/document/Semiconductor_Industry_MSA_Practices.pdf

New condition:

An alternative methodology to outdoing classical statistical approach as described in the AIAG MSA Manual - which appears to be no more suitable to the semiconductor industries - is provided by rather focusing the statistical studies on:

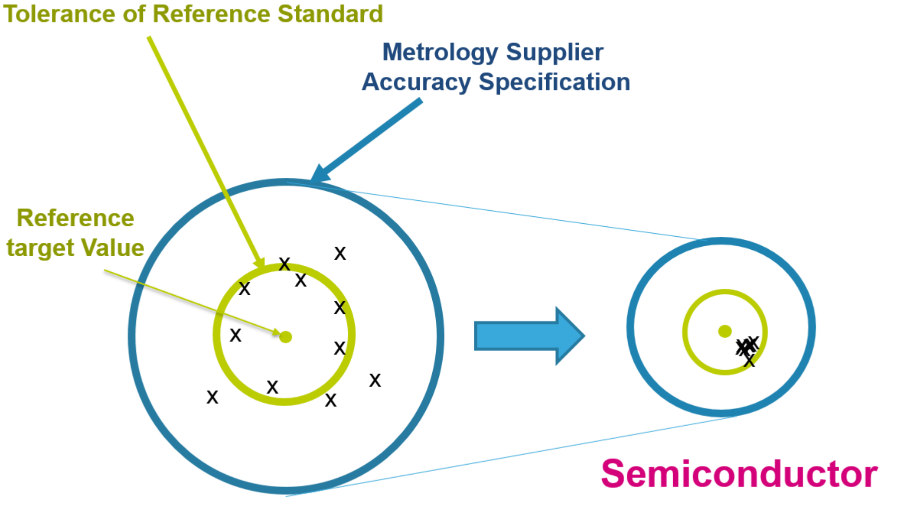
- The compliance of the bias to the metrology supplier accuracy
- The stability of the linearity response of the system over time
- The consistency of the linearity response within equipment fleet

The method which is described in the ST Company Specification “MEASURING SYSTEM ANALYSIS (M.S.A.)”, DMS #0151977 is based on a statistical analysis to verify the good correlation (R2) between the values given by the metrology systems over their operation range. The method also allow to verify that the level of misalignment between metrology systems does not impact the quality decision judgment.

Why?

Modern wafer fab’s requirements have now even surpassed the expectations in the AIAG MSA manual. To fulfill the aggressive requirement of semiconductor product specifications, the metrology repeatability and stability improved very drastically. Two main aspects can be highlighted:

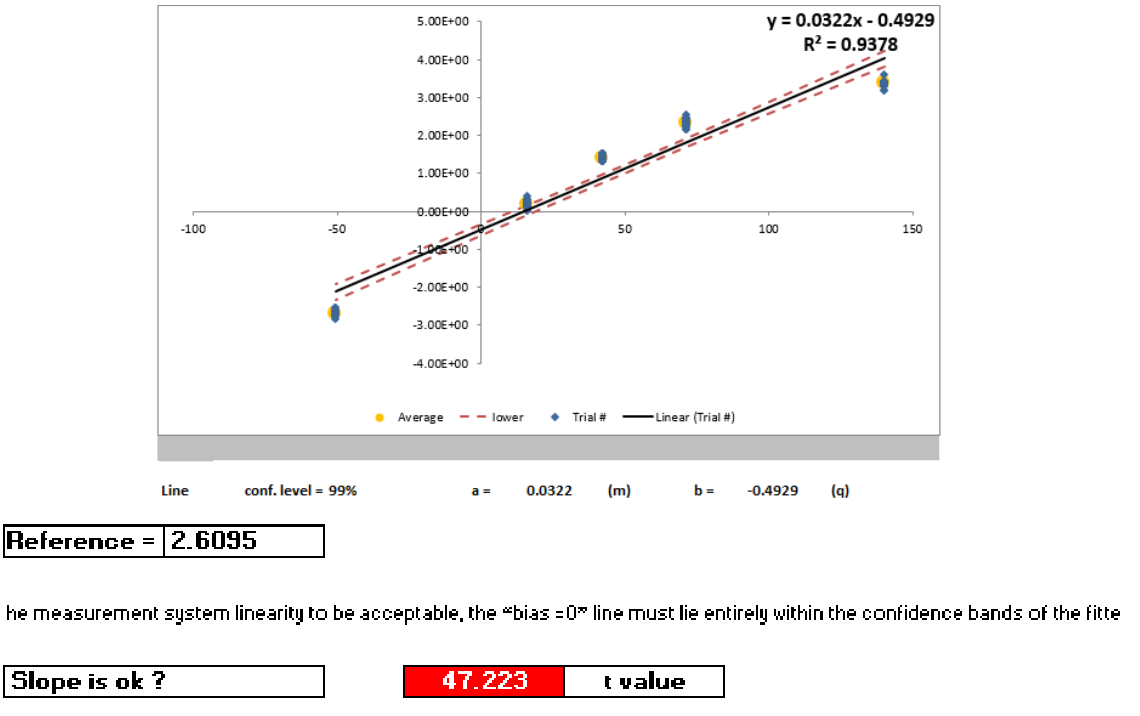
- In many cases, tolerance of reference standards are now much larger than the precision of the semiconductor metrology equipment themselves. This inevitably leads to the conclusion that **statistically** it exists a significant Bias even if this Bias is included in the tolerance provided by the best in-class worldwide certified instrument. Being this bias within the potential values, it is fully acceptable.
  This is illustrated in the figure below in a very schematic way.



Bias becomes statistically significant compare to precision for semiconductor industries

- In the field of semiconductor metrology, metrology systems are used indifferently to measure all parameters in the manufacturing line coming from multiple products and equipment monitoring. They have to cover a very wide measurement range not only one product specifications. Linearity as well as uniformity (change in repeatability over operating range) or consistency (change in repeatability over time) actually varies significantly over the operating range of our metrology equipment. This is totally in compliance with process control requirements over the operating range (ex: use of ellipsometry module for thin films with tinny specifications and use of reflectometry for thicker films with larger process tolerance).
  Still, due to the excellent repeatability of our metrology system, which is inherent to our industry requirements, this inevitably leads to the conclusion that the linearity error of our measurement systems is statistically significantly different from zero when compared to their repeatability.
  It appeared that the statistical approach for Bias and linearity studies as described in AIAG is not adapted to FE metrology semiconductor equipment due to their excellent repeatability.

This is illustrated below with the linearity test for overlay optical microscope metrology system.



Linearity test of an overlay metrology system.
Reference values are defined from NIST traceable standards.

When?
The improved methodology is ready to be applied on all ST manufacturing Front End plants.

How has the change been qualified?
Bias and linearity are unavoidable criteria to be controlled as part of a metrology system management and, in the semiconductor fabs, those characteristics are actually effectively controlled but in a different method than the one proposed by the AIAG. Indeed what is known to be more important for most internal semiconductor metrology needs is the stability and consistency/matching of the results given by the metrology systems over their operating range.

The change consists in establishing an engineering approach for Bias and linearity study leaning on the wide-spread monitoring of matching and stability critical metrology characteristics in order to provide an effective way to control bias and linearity.

- Consistency/Matching: The difference in readings between equipment used to measure the same characteristics in the semiconductor fab is of critical importance. This is controlled through measurement of same samples over the entire fleet. The verification sample set generally also contains several samples covering the operating range. The consistency of the linearity response and the mismatching (Bias) from multiple metrology systems within the fleet can then be followed and compared against established (supplier) and/or process required specifications.

- Stability: This characteristic is controlled very closely through regular measurement of the same monitoring check samples on the metrology equipment and through SPC control charts management. The check samples used to monitor the metrology equipment stability generally include several samples covering the operating range so that the linearity signature of the metrology equipment can be verified and maintain constant over time.

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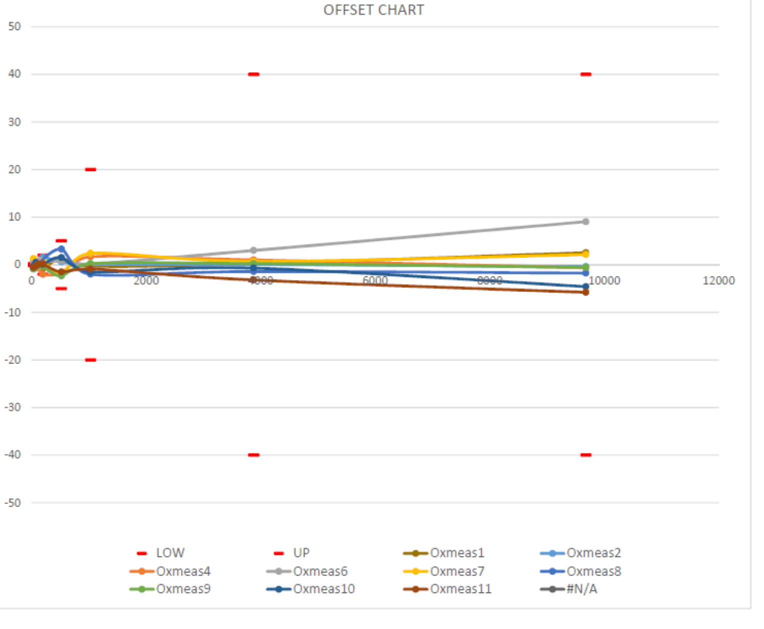
Linearity report

Criteria:

Within Metrology Fleet	Good	Acceptable	Not Acceptable
R^2	> 0.95	Between	< 0.90
Offset (Δ Value)	< 10% of Tolerance	Between	> 30% of Tolerance

Tightest Event	Target	Tolerance	+/-10% of Tolerance	+/- 30% of Tolerance	Offset (Δ Value)	Criteria
GATOX125	72.69	7	0.7	2.1	1.441	ACCEPTABLE
RTSAC1	125.75	20	2	6	1.214	GOOD
RTSACCZ2	197.00	40	4	12	3.556	GOOD
ANBOX500	519.32	100	10	30	5.623	GOOD
TEOS08	1029.16	400	40	120	4.390	GOOD
TEOS01	3876.80	800	80	240	6.196	GOOD
FLDOX80	9679.38	800	80	240	14.859	GOOD

Metrology Tool	Oxmeas1	Oxmeas2	Oxmeas4	Oxmeas6	Oxmeas7	Oxmeas8	Oxmeas9	Oxmeas10	Oxmeas11	
R^2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Criteria	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	



What is the impact of the change?

- **Form:** No change on product
- **Fit:** No change on product
- **Function:** No change on product
- **Reliability, or Processability:** NA (Not applicable).

How can the change be seen? No change on product

Risk assessment

The new method developed by our Company adapts to the semiconductor environment the requirements included into the AIAG MSA core tool for specific cases where classical statistical approach is not fulfilled, even in front of state-of-the-art measurement methodologies.

No risks associated have identified, instead, we are proposing an improving methodology to assess bias and linearity otherwise not possible (based on classical statistical approach), proven by the assessment described in the document.