Cost of Misclassification

for Non-Contact Sheet Resistance and Film Thickness Mapping

The cost of misclassified product is often overlooked in the determination of total cost of ownership for measurement systems. In some cases the cost of misclassified product can be several times the total of all other costs for operating and owning a metrology tool.

In order to illustrate this analysis consider a single step manufacturing process such as an epitaxial deposition on a semi-insulating substrate wafer. Following the deposition the product is tested on Lehighton Electronics 1510-RS sheet resistance measurement system. Following this test a decision is made to either pass the wafer or fail it. Misclassification results when a defective wafer is passed or when a good wafer is failed.

If….

P_1 =		P_2 =		C_1 =		C_2 =
the probability that a good wafer will be failed	AND	the probability that a defective wafer will be passed	AND	the cost of failing a good wafer	AND	the cost of passing a defective wafer

Then ….

Total Cost of Misclassification = Total Wafers Measured x $(C_1P_1 + C_2P_2)$

We can use the definition of process capability (C_P)

Where ….

C_P =	USL =	LSL =	STD DEV=
(USL-LSL) / 6 STD DEV	Upper Specification Limit	Lower Specification Limit	the Standard Deviation of the sheet resistance for the epitaxial deposition process

Define tool accuracy as ….

The average difference between the measured value of sheet resistance and the accurate value as a percentage of USL-LSL.

Also define the (p/T) ratio as ….

(p/T) = (STD DEV of Measuring Tool) / (STD DEV Process)

Example 1: For marginal process capability and marginal (p/T) ratio

C_P	=	1.00
(p/T)	=	0.3
Tool Accuracy as % of USL ö LSL	=	0%
C_1	=	$1,000
C_2	=	$1,000
Total Wafers Measured	=	106

For Example 1, using the tabulated results from Table 1, we find:

P_1 =	**P_2 =**		**Total Cost of Misclassification =**
0.002015	0.00065	THEN	106 x 103 x (0.002015 + 0.00065) =
			$2,665,000

Example 2: For improvements in process capability and (p/T) ratio

C_P	=	1.33
(p/T)	=	0.1
Tool Accuracy as % of USL ö LSL	=	0%
C_1	=	$1,000
C_2	=	$1,000
Tool A Total Wafers Measured	=	10^6

For Example 2, using the tabulated results from Table 1, we find:

P_1 =	**P_2 =**		**Total Cost of Misclassification =**
0.000038	0.000014	THEN	10^6 x 10^3 x (0.000038 + 0.000014)
			$52,000

These examples show how changes in the measuring tool performance and any associated improvement in process capability can have a major impact on the cost structure of the manufactured product.

Consider the Lehighton Electronics sheet resistance measurement system to determine the Cost of Misclassification of your process as follows:

1. Determine the precision of a 1510 system using the LEI brochure or an error of measurement study for your process using your 151 0 system on your process. Compute the (p/T) ratio.

2. Use your 1510 system to compute the process capability of your process.

3. Evaluate the cost for C_1 and C_2 for your product.

4. Use the calibration standards furnished with your 1510 from LEI to keep the average of your measured values near the standard values. You can estimate the cost penalty for a significant calibration error by using the 25% values in Table 1.

5. Use the foregoing information to select appropriate values of P_1 and P_2.

6. Use the values of P_1 and P_2 and total number of wafers measured in combination with your sampling plan to estimate your Total Cost of Misclassification.

7. Explore the effect on product cost of additional improvements in process capability, measurement precision, measurement accuracy, and sampling plan.

8. Use your Cost of Misclassification results to justify the purchase of a new LEI system or an upgrade to a higher performance system form LEI.

The basic results are summarized in Table 1.

Table 1: Input Parameters for Cost of Misclassification Results

Process Capability (C_P)	Tool Accuracy (% of Spec Window)	(p/T) ratio, %	P_1	P_2	Cost ($) of Misclassification
0.67	0	60	0.028724	0.019490	48,214,000.00
		30	0.011114	0.006797	17,911,000.00
		10	0.004870	0.003831	8,701,000.00
	25	60	0.049291	0.029798	79,089,000.00
		30	0.022331	0.017060	39,391,000.00
		10	0.010112	0.009554	19,666,000.00
1.00	0	60	0.008309	0.000906	9,215,000.00
		30	0.002015	0.000649	2,664,000.00
		10	0.000720	0.000405	1,125,000.00

Process Capability (C_P)	Tool Accuracy (% of Spec Window)	(p/T) ratio, %	P_1	P_2	Cost ($) of Misclassification
	25	60	0.050717	0.018252	68,969,000.00
		30	0.020359	0.011726	32,085,000.00
		10	0.008931	0.006715	15,646,000.00
1.33	0	60	0.001749	0.000025	1,774,000.00
		30	0.000161	0.000020	181,000.00
		10	0.000038	0.000014	52,000.00
	25	60	0.044081	0.007676	51,757,000.00
		30	0.014362	0.005475	19,837,000.00
		10	0.005557	0.003399	8,956,000.00

Conclusions

For Process Capability less than 1 it is normally very important to use a high performance metrology tool. This can often be the case for new product development and the early stages of production manufacturing. In this situation good metrology systems can prevent the shipment of defective product and provide information needed to improve process capability.

A precise and accurate metrology system from Lehighton Electronics is an important factor in minimizing the cost of misclassification associated with tool ownership and use.

Improvements in process capability reduce the cost of misclassified product.

As process capability improves the sampling rates for metrology can be reduced. This will also help to facilitate the growth of production as new products are accepted by the market. Monitor rates for sampling are still advisable to verify that production stays in control while yields are high and quality standards are met.

Please contact us if you have any questions. We will be pleased to show you how to minimize your Total Cost of Ownership including the Cost of Misclassified Product. We will help you to use your process and product specifications to determine your Cost of Misclassified Product and Total Cost of Ownership. Typical Total Cost of Ownership results for Lehighton Electronics sheet resistance mapping systems are estimated at $.06 per measured wafer for an average manufacturing operation.

Reference

Copies of the following paper are available on request.

Sudhakar M. Kudva and Randall W. Potter – SEMATECH, 2704 Montopolis Drive, Austin, Texas 78741