Understanding the costs of MEMS products

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Introduction

There are many situations that require an understanding of the manufacturing costs for MEMS products. For example: Engineers designing new products need to hit cost targets for a successful product launch. Purchasing managers responsible for negotiating pricing need to evaluate the quality of the deal they are getting in order to negotiate with confidence. Managers running fabrication facilities need to benchmark their cost structure to insure they are running a competitive operation, and many other applications. Until recently there hasn't been a comprehensive and easy to use solution for modeling the cost of complete MEMS products. In the balance of this paper we will describe the IC Knowledge – 2009 MEMS Cost Model that provides that capability.

Cost Model Overview

Since 2001 IC Knowledge has been offering an Integrated Circuit cost model that has grown to become the industry standard in IC cost modeling. In 2004 we introduced a MEMS Cost Model based on the same bottoms-up fab simulation and costing methodology modified for MEMS. Frankly the product did not sell as well as we expected and we believe this was due to the limitations of the original product, specifically that it only modeled the wafer fab costs and provided no testing or packaging costing functionality unlike it's more successful IC Cost Model sibling. Successful MEMS products also now routinely incorporate Integrated Circuits along with MEMS devices into multi chip hybrids to provide complete product functionality, see figure 1. In order to address the original MEMS cost model shortcomings, we completely redesigned the MEMS Cost model at the end of 2008 to provide for costing of up to two MEMS die and up to two IC die in the same package with packaging and test costs. The end result is the ability to model the complete manufacturing cost of most MEMS products.

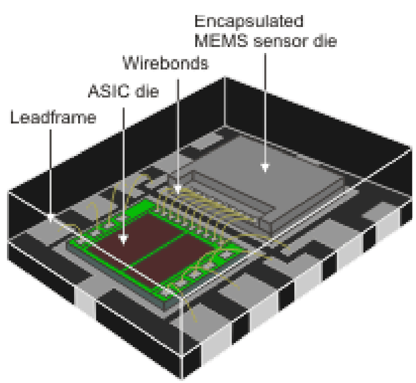

Figure 1. Bosch Accelerometer Cut Away View.

Methodology

The heart of the model is the wafer fabrication cost methodology. For IC processes the model relies primarily on predefined processes built into the model. For MEMS there is far less process standardization and so both predefined and user defined processes are supported. The wafer costing begins with a table that contains the number of times each of a set of standard process steps occurs in each process. For a MEMS process – process steps would include DRIE, KOH etch, lithography and many others. Since MEMS involves a wide variety of thicknesses, certain steps have thickness range options and other such as DRIE are entered in multiples of 100 micron etches (fractions are allowed) or KOH that is entered in multiples of 500 microns (once again fractions are allowed). There are additional tables with throughput, cost and footprint values for each unit step. The combination of these tables along with a selected throughput allows the wafer fab equipment set cost and footprint to be determined. Up to four substrates per process are supported and background tables in the model provide cost for a variety of substrate types and sizes. Labor costs and productivity by country, utility rates by country and usage and many other factors are includes and utilized to complete a detailed bottoms-up simulation and cost calculation for each process.

To create a model the user begins at the product page. Many products are pre-defined in the model and may be selected from a drop-down list. For predefined products the user is guided through the settings throughout the rest of the model. For products that aren't predefined the user will need to have knowledge of the required settings. The user then goes through a sequence of steps to complete the model.

After the product selection in step 1, step 2 is used to define the MEMS 1 and MEMS 2 processes. The processes may be selected from predefined processes listed in drop-down lists or for the MEMS 1 process the user may build their own process. Step 3 is to then select a fab to run the process in, a wide variety of MEMS fabs from around the world are already predefined and available for selection in a drop-down list. In step 4, up to 4 substrates per MEMS die are selected from drop-down lists for each MEMS process.

Step 5 is the definition of IC die if required. This step provides a variety of predefined IC processes as well as IC and MEMS integrated processes to choose from. Step 6 and step 7 provide for the definition of the package and testing required. Both are selected from drop-down lists and the model then does the calculations.

Recently we have also added the ability to view and modify all of the key parameters around the equipment set such as throughout and cost for each piece of equipment. General fab parameters such as year the fab was built, capacity and country the fab is located in may also be modified in the most recent release. These capabilities allow a high degree of model customization.

These are consumables costs for MEMS die 1 only

	$/year	$/waf
Reticles	$2,721,600	$12.00
Photochemicals	$751,566	$3.31
Cleaning and etching chemicals	$3,072,410	$13.55
Spin-on	$0	$0.00
Bulk gases	$440,582	$1.94
Specialty gases	$153,090	$0.68
CMP	$300,000	$1.32
Quartzware	$47,440	$0.21
Cleanroom and safety supplies	$546,000	$2.41
Precious metals	$907,200	$4.00
User entered consumables	$0	$0.00
Total cost	$8,939,888	$39.42

Figure 2. MEMS process consumable costs.

The cost sheet provides a detailed breakdown of the costs for each of the 4 die being used (2 MEMS and 2 IC). The product can have a single MEMS die or a single IC die or any combination up to 2 die of each type. Test costs at the wafer and product type and package costs are also presented. Several additional output sheets provide a detailed look into the MEMS 1 die fabrication costs, see figures 2 and 3.

Approximate Average Cost per step costs for MEMS die 1 only

	Steps	Cost/step	Cost/waf
Bond	0.0	$0.00	$0.00
Clean	10.0	$1.32	$13.19
CMP	1.0	$2.85	$2.85
CVD Dep	9.0	$1.75	$15.78
DRIE	0.0	$0.00	$0.00
Dry Etch (excluding DRIE)	3.0	$2.23	$6.70
Wet Etch	4.0	$1.44	$5.77
Furnace	1.0	$1.79	$1.79
Grind	0.0	$0.00	$0.00
Lift-off	1.0	$9.49	$9.49
Metal Dep	7.0	$2.80	$19.58
Metrology	19.6	$1.17	$22.89
Lithography	8.0	$4.07	$32.58
Plating	0.0	$0.00	$0.00
Saw	1.0	$1.76	$1.76
Special	0.0	$0.00	$0.00
Spin-on	0.0	$0.00	$0.00
Strip (Photo)	7.0	$2.44	$17.05
Totals	**71.6**		**$149.43**

Figure 3. MEMS process step costs.

Examples of the model usage

Now that the model methodology has been described some examples of the model usage may be presented. In the simplest example a purchasing manager wants to understand the production costs for a MEMS product they are purchasing. For the sake of discussion assume the purchasing manager is buying an Analog Devices - ADXL278 – Dual axis high G accelerometer. By selecting that product from the product type drop-down list the values required to create a model are displayed throughout the model and the purchasing manager simply makes the suggested selections for each step. The net result is a calculated product cost that can then be used to compare to the price being paid to determine the gross margin being charged.

As another example let's assume you are an engineer responsible for making a Robert Bosch – SMG060 – angular rate sensor and you want to evaluate the cost saving from eliminating certain process steps. You would begin by selecting the product and then filling in all of the steps as suggested by the model. This initial calculation would provide the baseline cost. You could then use the user entered MEME1 process capability to enter in the new abbreviated process. By comparing the initial cost of the product to the new abbreviated process cost you could determine the potential cost savings.

There are many other potential uses for the model from calculating the impact of different material costs on a product to determining the cost of single process steps. The aforementioned model is currently in use at equipment companies, MEMS suppliers and customers, financial analysts and many other companies.

Conclusion

The 2009 MEMS cost model enables user to easily calculate the manufacturing costs of most MEMS products by making selections from drop-down lists. Anyone purchasing the model gets free upgrades and support for 12 months. To learn more about the model or download the model manual with screen shots of an actual calculation please visit our MEMS Cost Model page here: http://www.icknowledge.com/our_products/MEMSmodel.html or email us at info@icknowledge.com