

# Cost Modeling of “MEMS Systems”

Scotten W. Jones, President

**IC***KNOWLEDGE LLC*

# Introduction

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- In this talk I will describe
  - Why MEMS Cost Modeling is important
  - What is a “MEMS System”
  - What some of the challenges of MEMS Cost Modeling are
- I will then present a commercially available MEMS Cost Modeling product that meets the requirements described above

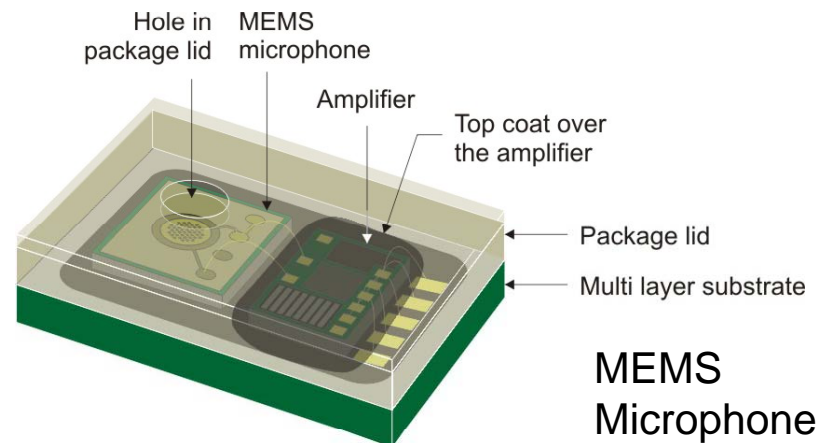
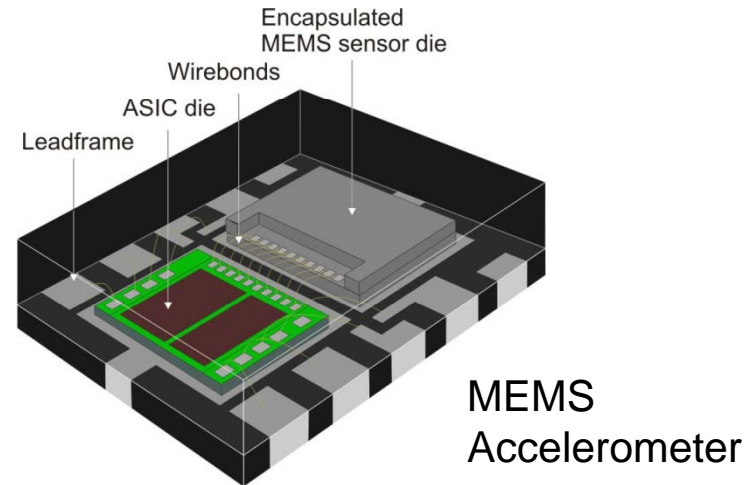
# Why Cost Model

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- Cost is a critical driver of the success of any product
- Cost modeling can provide insight into
  - What a product being developed will cost to produce
  - How various process options compare for cost
  - What competing products cost to produce
  - What a product being purchased costs the supplier to produce and therefore what kind of margins are the supplier charging
  - What the largest cost categories are to address for cost reduction efforts

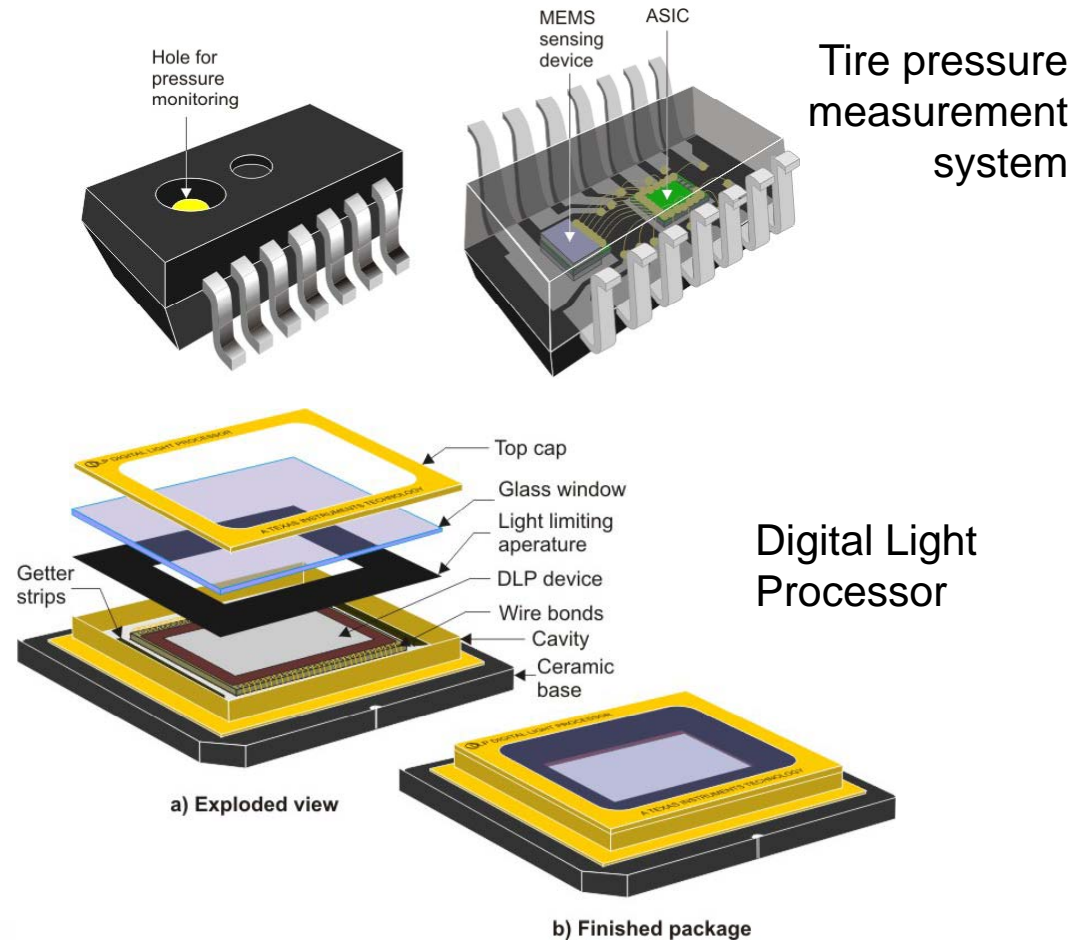
# What is a “MEMS System”

- Many of today's MEMS products are complete systems and incorporate:
- MEMS sensors
- Integrated Circuit signal conditioning
- May provide digital output
- Custom packaging



# MEMS Cost Modeling Challenges 1

- Products may include multiple MEMS and/or IC Die
- Many/most MEMS processes are custom
- Many/most MEMS packages are custom
- Non standard test requirements



# MEMS Cost Modeling Challenges 2

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- Cost Modeling users have different needs and levels of technical knowledge:
  - Fund raising – 3<sup>rd</sup> party modeling to prove to investors that the product can meet cost targets – knowledge varies - needs customization
  - Purchasing – want to cost suppliers product – may have limited information and/or technical knowledge – wants standard selections
  - Marketing – want to cost their own or competitors product – knowledge varies – may want standard selections or customization
  - Development engineer – wants to cost products or processes during development – deep technical knowledge – wants customization
  - Managers – benchmarking, product costing, competitive analysis – want to cost products or processes – knowledge varies – customization varies
  - Others
- To meet all these needs a model must be flexible and comprehensive

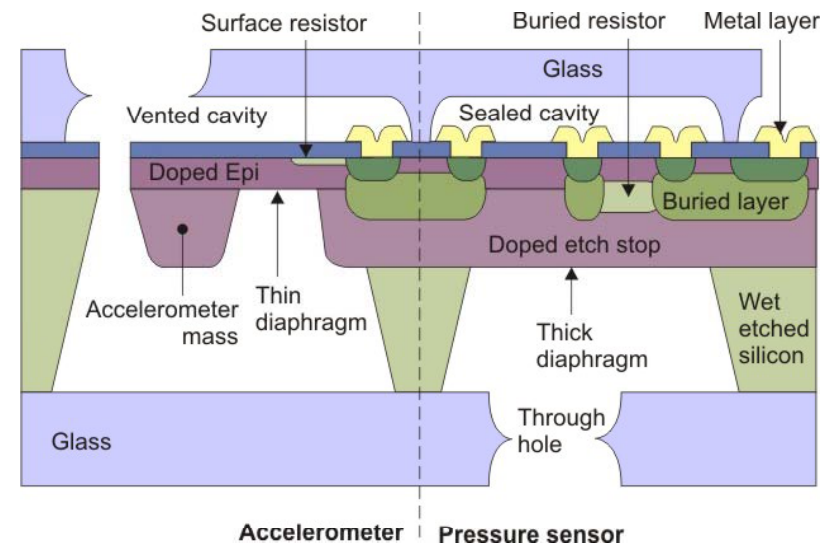
# IC Knowledge – MEMS Cost Model

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- Includes 4 complete die costing engines – 2 IC and 2 MEMS cost engines
  - The IC cost engines analyze IC die and IC/MEMS integrated die where the IC processing is dominant
  - The MEMS cost engines analyze MEMS die and MEMS die with some electronics where MEMS processing is dominant
  - The 4 engines may be used simultaneously in any combination
- Packaging and test are supported

# Multiple ways to build a model

- Product driven
  - Select a product and throughout the model input selection help is provided
- Custom
  - Select existing MEMS processes or define your own MEMS process
  - Select existing MEMS Fabs or define your own fab
  - Up to four substrates per process may be selected
  - Select IC processes
  - Select package and tests



Tire pressure measurement system with three substrates



# Product Selection

**1 Select the product to model** Robert Bosch - SMB200 - Accelerometer

MEMS Process 1	Robert Bosch - Accelerometer
MEMS Fab 1	Robert Bosch 150mm or 200mm
MEMS die size 1	2.5 L (mm) 2.2 W (mm)
Foundry margin 1	0%
MEMS Process 2	None
MEMS Fab 2	NA
MEMS die size 2	NA L (mm) NA W (mm)
Foundry margin 2	NA
Integrated Circuit (IC) Process 1	150nm - 800nm - Bosch - CMOS - 1 layer poly - 3 layer aluminum
IC die size 1	Unknown L (mm) Unknown W (mm)
Foundry or supplier margin 1	0%
Integrated Circuit (IC) Process 2	NA
IC die size 2	NA L (mm) NA W (mm)
Foundry or supplier margin 2	NA
Package	SOIC 16 pin package with 2 die (1 MEMS + 1 IC)
MEMS wafer sort 1	Accelerometer
MEMS wafer sort 2	None
IC or Integrated MEMS sort 1	Signal Conditioning IC
IC or Integrated MEMS sort 2	None
Product test	Accelerometer

# Custom Process Definition

- A set of process steps are presented
- For predefined processes the number of times each step is used is displayed
- For custom processes the user enters how many times each process is used
- Certain etch and deposition steps are thickness based

Step Entry is for MEMS die 1 Step Entry Disabled

Process step	Steps entered	Number of steps	Steps used
Band - Anodic	1	Number of steps	1
Band - Temporary	1	Number of steps	1
Band - Thermal	1	Number of steps	0
Clean - RCA	1	Number of steps	4
Clean - SC1	1	Number of steps	1
CMP	1	Number of steps	0
Deposition - Epitaxial	1	Number of steps	1
Deposition - thick Silicon Nitride	1	Number of steps	0
Deposition - thick Oxide	1	Number of steps	1
Deposition - thick Polysilicon	1	Number of steps	0
Deposition - thin Silicon Nitride	1	Number of steps	1
Deposition - thin Oxide	1	Number of steps	0
Deposition - thin Polysilicon	1	Number of steps	1
Etch - DRIE	1	Number of steps	1.2
Etch - KOH	1	Number of steps	1
Etch - lang Wet	1	Number of steps	1
Etch - zhart Wet	1	Number of steps	0
Etch - lang Dry	1	Number of steps	3
Etch - zhart Dry	1	Number of steps	4
Furnace - lang cycle	1	Number of steps	1
Furnace - zhart cycle	1	Number of steps	0
Grind	1	Number of steps	0
Tape	1	Number of steps	0
De Tape	1	Number of steps	0
Lift-off	1	Number of steps	0
Metal Deep - non precious	1	Number of steps	1
Metal Deep - precious	1	Number of steps	0
Metrology - Inspect	1	Number of steps	9
Metrology - Particle	1	Number of steps	2
Metrology - CD	1	Number of steps	2.97
Metrology - Film Thickness	1	Number of steps	4
Photo - Stopper	1	Number of steps	0
Photo - Contact	1	Number of steps	9
Plating	1	Number of steps	0
Saw	1	Number of steps	0
Special	1	Number of steps	0
Spin-on	1	Number of steps	0
Strip photoresist - Acid	1	Number of steps	2
Strip photoresist - Ashing	1	Number of steps	3
Strip photoresist - Solvent	1	Number of steps	4

# Wafer Cost Output 1

Robert Bosch - SMB200 - Accelerometer				
	MEMS Part 1	MEMS Part 2	IC Part 1	IC Part 2
Wafer fab capacity (wafs/mth)	26,000	NA	137,000	NA
Utilization (%)	90%	NA	90%	90%
Wafer size	200mm	NA	150mm	150mm
	(\$/waf)	(\$/waf)	(\$/waf)	(\$/waf)
Starting wafers	\$92.75	\$0.00	\$17.00	\$0.00
Direct labor	\$56.17	\$0.00	\$48.29	\$0.00
Depreciation	\$6.96	\$0.00	\$11.42	\$0.00
Tool maintenance	\$18.93	\$0.00	\$13.31	\$0.00
Indirect labor	\$9.12	\$0.00	\$25.54	\$0.00
Monitor wafers	\$3.28	\$0.00	\$8.85	\$0.00
Facilities	\$62.98	\$0.00	\$39.22	\$0.00
Consumables	\$38.34	\$0.00	\$64.25	\$0.00
Total	\$288.52	\$0.00	\$227.88	\$0.00
Wafer yield (%)	91.0%	0.0%	97.2%	97.2%
Yielded wafer cost	\$317.21	\$0.00	\$234.45	\$0.00
Suggested margins	0%	NA	0%	NA

# Wafer cost output 2

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These are consumables costs for MEMS die 1 only

	\$/year	\$/waf
Reticles	\$5,054,400	\$18.00
Photochemicals	\$1,333,900	\$4.75
Cleaning and etching chemicals	\$1,298,458	\$4.62
Spin-on	\$0	\$0.00
Bulk gases	\$690,151	\$2.46
Specialty gases	\$342,576	\$1.22
CMP	\$0	\$0.00
Quartzware	\$1,284,855	\$4.58
Cleanroom and safety supplies	\$762,000	\$2.71
Precious metals	\$0	\$0.00
User entered consumables	\$0	\$0.00
Total cost	\$10,766,340	\$38.34

# Product cost

	(\$/die)	(\$/die)	(\$/die)	(\$/die)
Gross die (n/waf)	2,109	0	1,043	0
Die yield (%)	85.0%	NA	94.2%	NA
Net die (n/waf)	1,792	0	983	0
Yielded die cost (\$/die)	\$0.189	\$0.000	\$0.25	\$0.00
				(\$/part)
Packaging yield				97%
Package cost				\$0.064
Packaged unit cost				\$0.519
Class test yield				98%
Class test cost				\$0.044
Product cost				\$0.574

# Conclusion

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- Cost modeling is a critical capability for product design and analysis
- MEMS cost modeling has diverse requirements
- The IC Knowledge – MEMS Cost Model is:
  - Commercially available since 2004
  - Well vetted with a wide user base
  - Flexible enough to meet the needs of a diverse user base
  - Flexible enough to provide pre defined and custom cost capabilities

**Thank you!**