32. Chemnitzer Seminar
»MEMS Technologies and Applications«

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From sampling to ramping:

Technology and Business Model Challenges for a MEMS Foundry to Address WLP Applications

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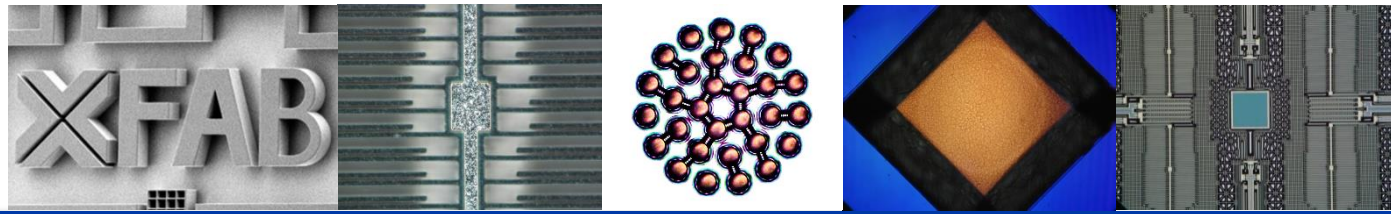
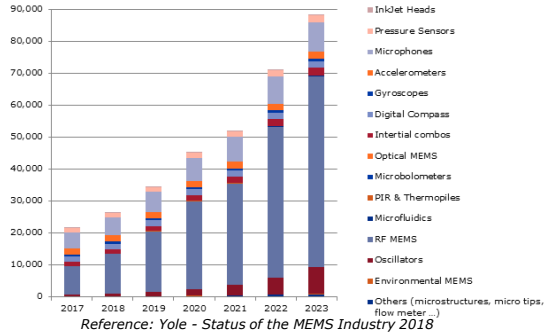
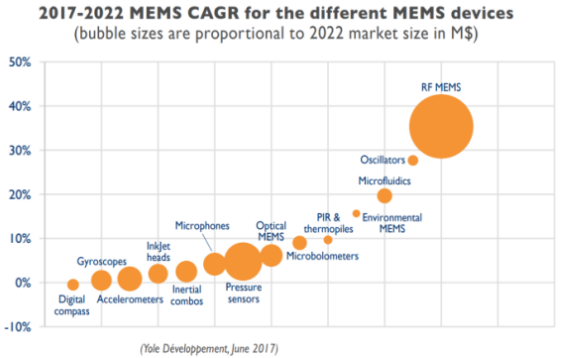


Kontext

- Yole 2017 “The MEMS and Sensor market is growing and new applications are arriving. However, MEMS companies and MEMS foundries are struggling to grow”
- “Everything looks good - so where is the problem”
- Voice from trenches: “MEMS high volume manufacturing is super complex”



Reference: Yole - Status of the MEMS Industry 2018



About X-FAB

Corbeil-Essonnes

- CMOS, SOI, RF
- Wafer size: 200mm
- Capacity: 35k 200mm equiv. WSPM
- Capacity upside in 9k sqm unused fab space

Erfurt

- CMOS, SOI, MEMS
- Wafer size: 150mm, partly 200mm (MEMS)
- Capacity: 12k 200mm equiv. WSPM

Lubbock

- CMOS, SiC
- Wafer size: 150mm
- Capacity: 15k 200mm equiv. WSPM

Itzehoe

- MEMS
- Wafer size: 200mm
- Wide portfolio of materials, technologies & capabilities

Dresden

- CMOS
- Wafer size: 200mm
- Capacity: 8k 200mm WSPM
- Capacity upside up to 10k WSPM

Sarawak

- CMOS, SOI
- Wafer size: 200mm
- Capacity: 24k WSPM
- Capacity upside above 30k WSPM

Legend:

WSPM = Wafer Starts Per Month

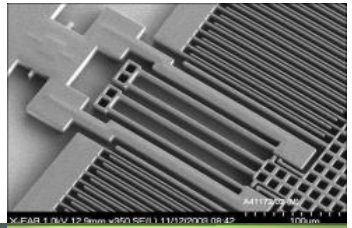
X-FAB MEMS Foundry

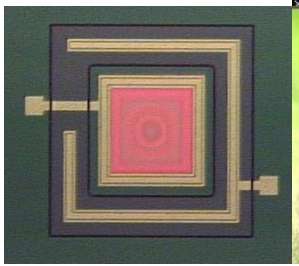
Overview

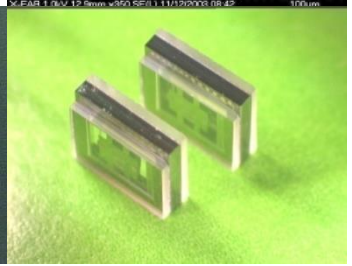
- High-volume MEMS production operation embedded in CMOS environment
- 200 mm & 150 mm MEMS operations in 4 clean rooms
- Wide range of processes and materials – CMOS and non-CMOS compatible
- MEMS & CMOS integration
- Automotive quality system

Application examples

- Automotive
  - Pressure sensors, Inertial sensors
- Medical / µFludic
  - DNA sequencing, Drug & allergy screening
- Mobile Communication
  - Microphones
- Industrial
  - Gas Sensor

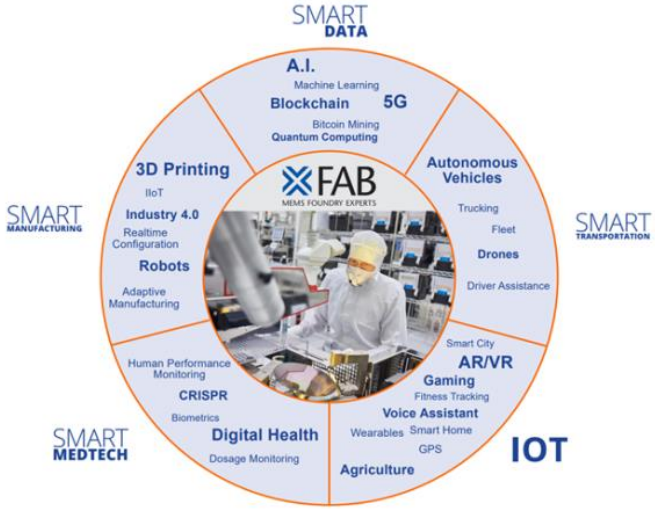






Business Profile

- 90% of MEMS projects at X-FAB are addressing customer specific technology solutions
  - Typically 3-5 RFQ’s per month from all regions
  - 30+ ongoing development programs
  - Concurrent dev’t of process and product
  - 30%+ of all programs don’t succeed in getting to SOP
- 10% of new MEMS projects are using X-FAB MEMS open platform technologies
  - Readily qualified technologies,
  - DR, Specs, PDKs
  - Pressure Sensor
  - Inertial Sensor



MEMS Foundry Challenge

Fragmented and diverse MEMS market

- One Product
- One Process
- One Package
- One Calibration

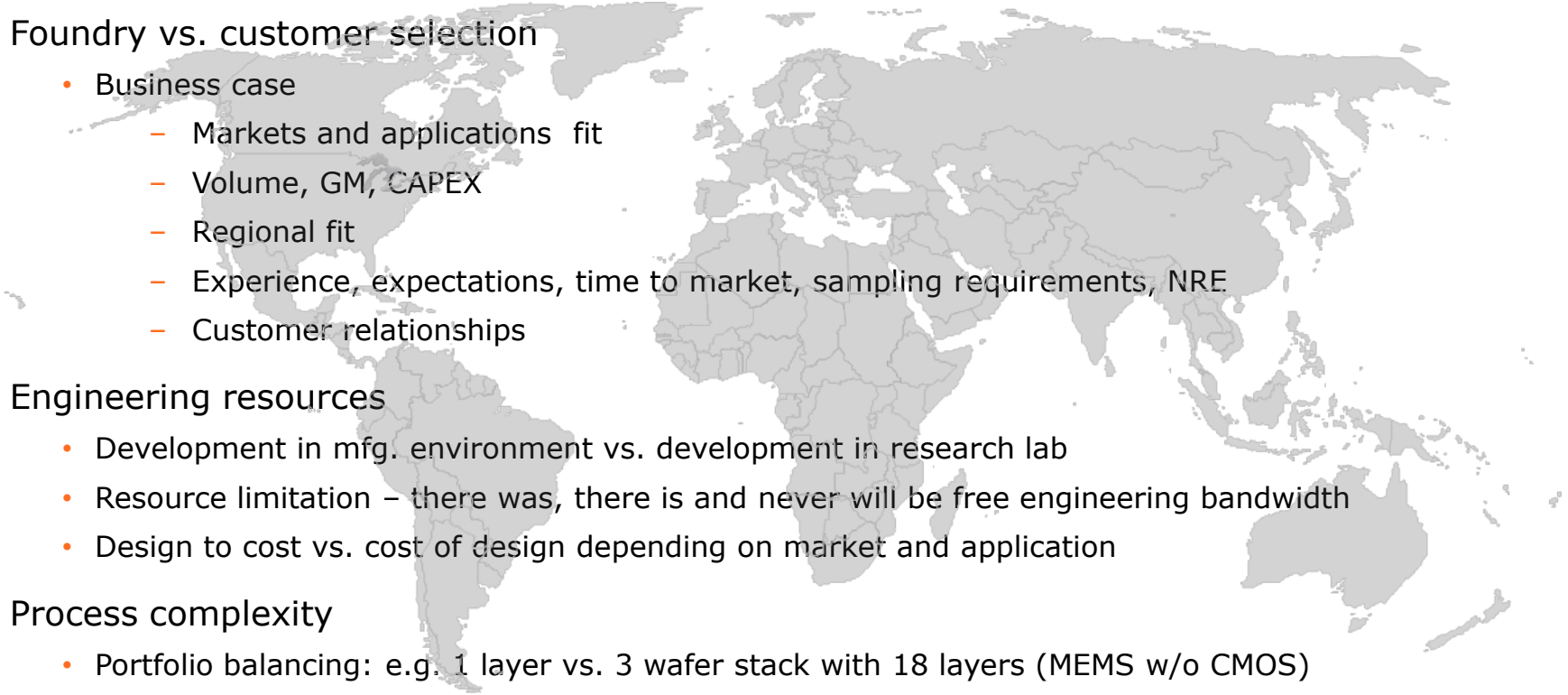
Small CUSP Business cases

- Opportunity risks
- Large CAPEX
- Utilizing existing tools at and beyond the tool limits
- Concurrent design and technology development
- Diverse technologies
- Long learning cycles

strategic vectors for X-FAB

- Business
- Customer
- Technology
- Tools
- Experience
- Methodology

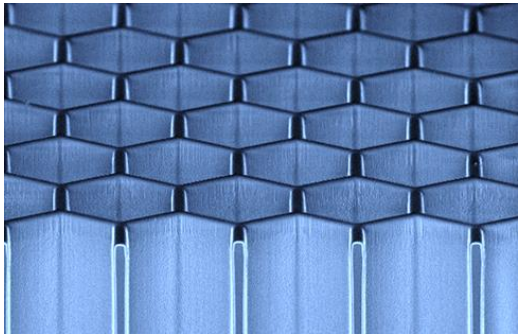
Customer



- Foundry vs. customer selection
  - Business case
    - Markets and applications fit
    - Volume, GM, CAPEX
    - Regional fit
    - Experience, expectations, time to market, sampling requirements, NRE
    - Customer relationships
- Engineering resources
  - Development in mfg. environment vs. development in research lab
  - Resource limitation – there was, there is and never will be free engineering bandwidth
  - Design to cost vs. cost of design depending on market and application
- Process complexity
  - Portfolio balancing: e.g. 1 layer vs. 3 wafer stack with 18 layers (MEMS w/o CMOS)

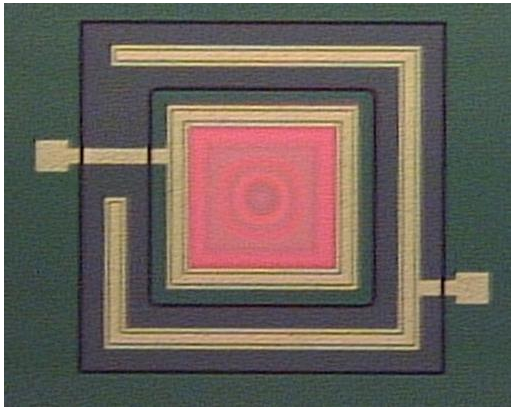
Methodology

- No differences compared with CMOS development methodology
  - FMEA's, PCM concept, patent research, early phase reliability investigations, ….
  - Alignment with customer on development methodology
    - Frozen process spec vs. fluid spec due to concurrent process and device development
  - Sample production in non-frozen process
- Program management
  - Management of CMOS / MEMS interface
  - Supply chain optimization & management
- Problem solving methodology
  - Fishbone, 8D, 5Why, specific FA
  - Lessons learned



Technology

- Concurrent tool, process, design and packaging developments
  - Long development cycles
  - Learning cycles through supply chains are very long
- Technical differences MEMS vs. CMOS
  - MEMS control philosophy
  - CMOS equipment used for MEMS processing
    - Additional parameter control needed such as mechanical stress, topology
    - Tool operations at critical conditions – very thick process layer
    - High requirements on tolerance and homogeneities (typical tolerances for layer thickness 3%-5% MEMS vs. 10% CMOS [analog]

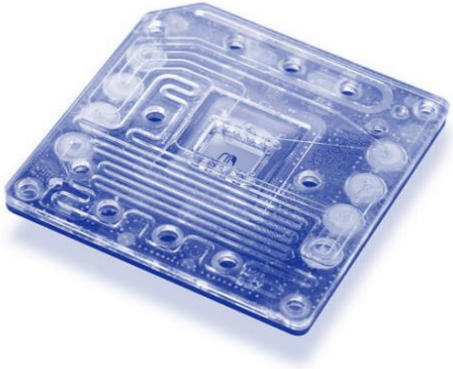


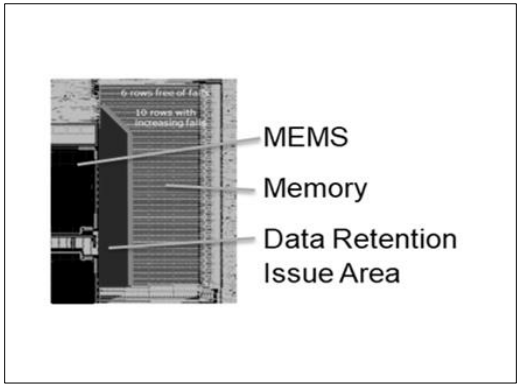
CMOS + MEMS @ X-FAB

- CMOS-MEMS integration is an area of focus for X-FAB.
  - realization of very complex technologies and advanced customer products allow different ion and customer retention
- Opportunity to capture more value in supply chain for foundry
  - MEMS silicon value in value in final product is less compared with IC business
- Required technologies
  - Wafer bonding
    - Capping sensitive sensor and actuator structures
    - Manufacturing worthy integration concept, up to the assembly and packaging of the final device required
  - Through Silicon Vias
    - Manufacturing worthy integration concept, up to the assembly and packaging of the final device , required

CMOS + MEMS WLP technology challenges

- Mechanical, electrical, chemical, physical properties have to be matched with CMOS, MEMS, Package and calibration requirements
- Fully holistic view required from project start onwards
- Examples
  1. TSV: wafer bow compensation
  2. TSV: cross contamination concerns with open passivation
  3. NVM Data retention issues caused by release etch – 100% hermitic seal requited
  4. Anodic Bond for TGV: glass electrode wafer
  5. Flat passivation for bond surface preparing
  6. Fluidic optimization of polymer bond system





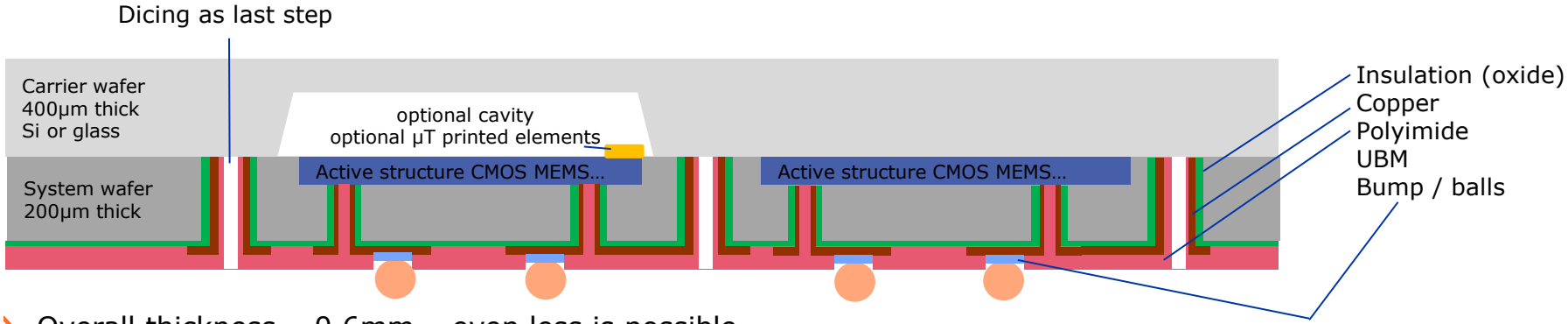
WLP technology use @ X-FAB

WLP	Production	Development	Comment
Anodic bonding	Pressure Sensor	Inertial Sensor µFludic	High volume
Glass frit bonding	Inertial Sensor, Optical Sensor		
AlGe		Optical Sensor	
Polymer Bond	µFludics		
Fusion Bond	Pressure Sensor Inertial Sensor		High volume
TSV		Optical Senor µFluidic	

X-FAB WLP Definition & Vision

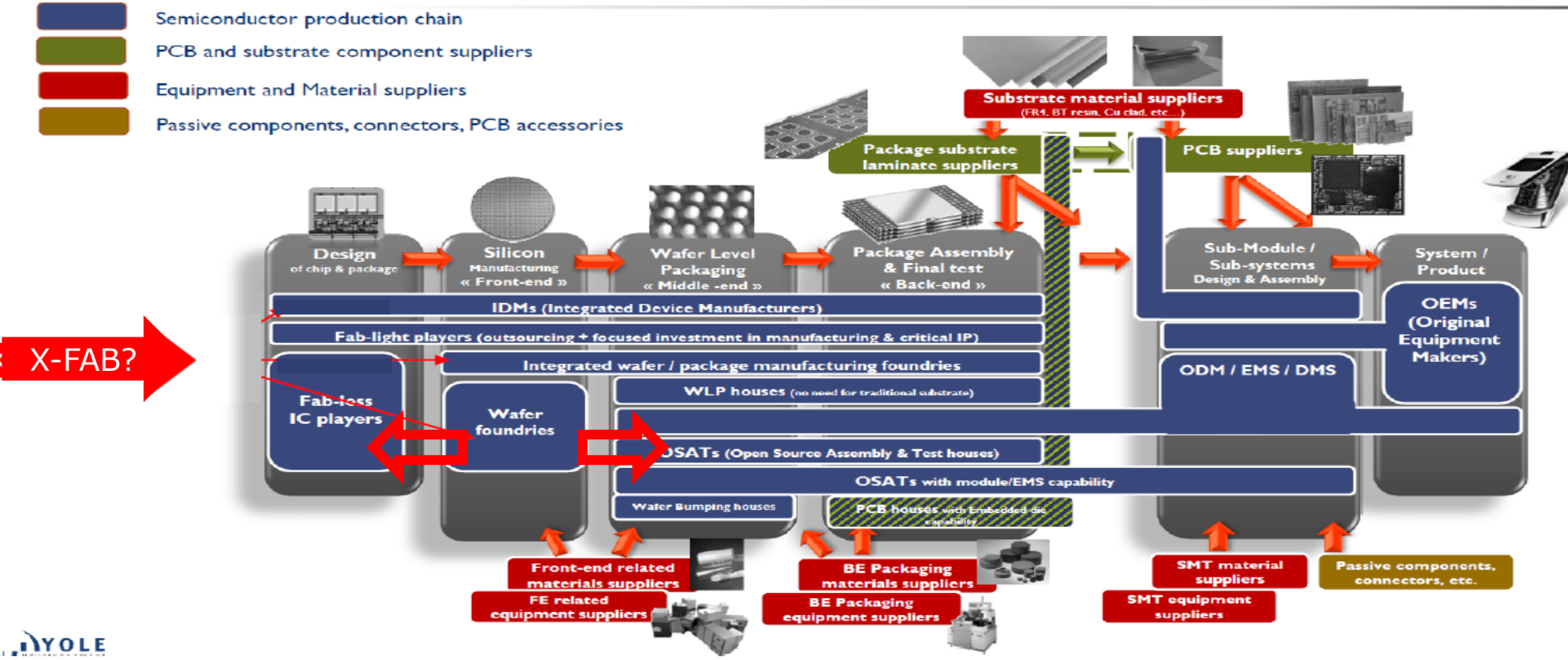
Vision

- Enable wafer level (sensor) integration and packaging up to direct mounting on PCB

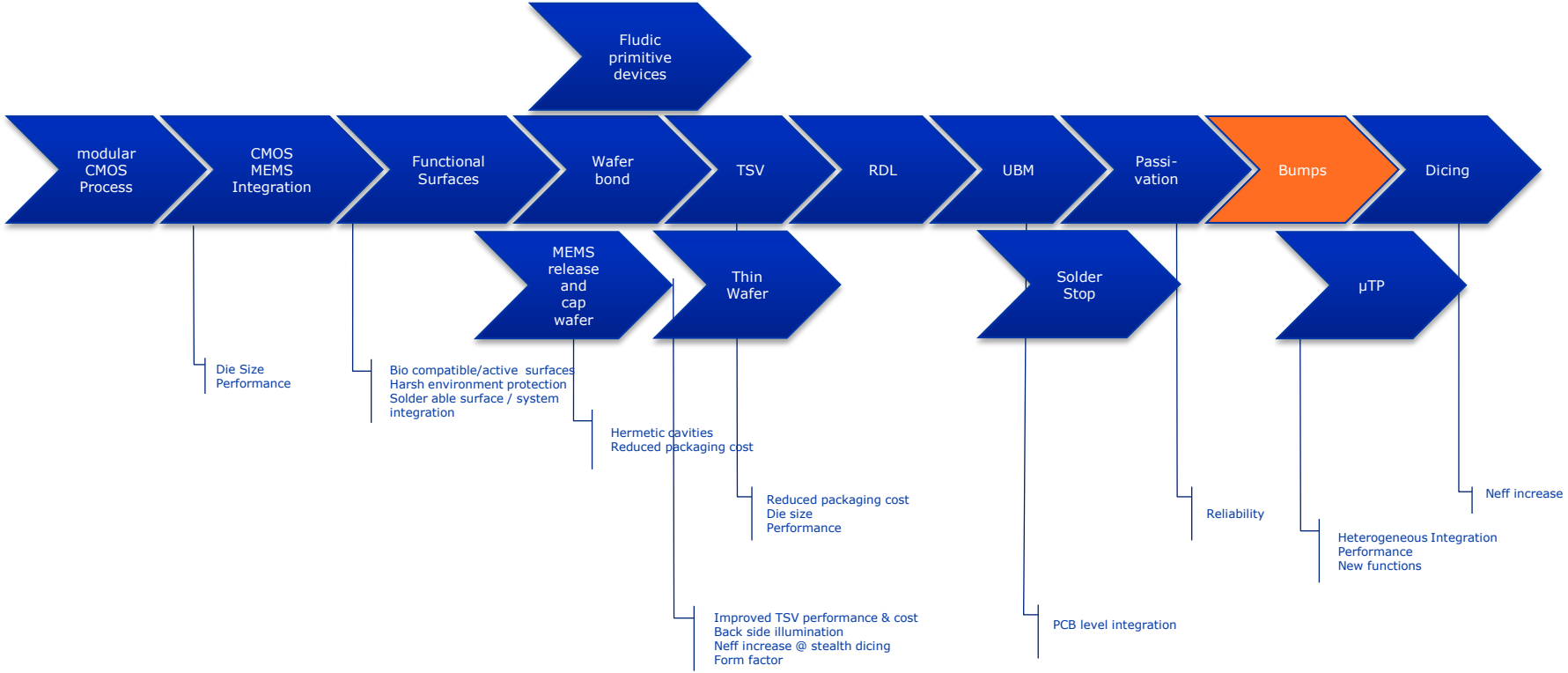


- Overall thickness – 0.6mm – even less is possible
- AlGe or Glass ftit Bonding with hermetic sealing
- Grinding of system wafer after bonding – no thin wafer handling needed
- X-FAB TSV process
- Device sidewall passivation (Oxide Cu Polyimide) for all around protection of active structures
- Dicing only through the carrier wafer at end of process

Semiconductor Supply Chain 2020 (Yole view)

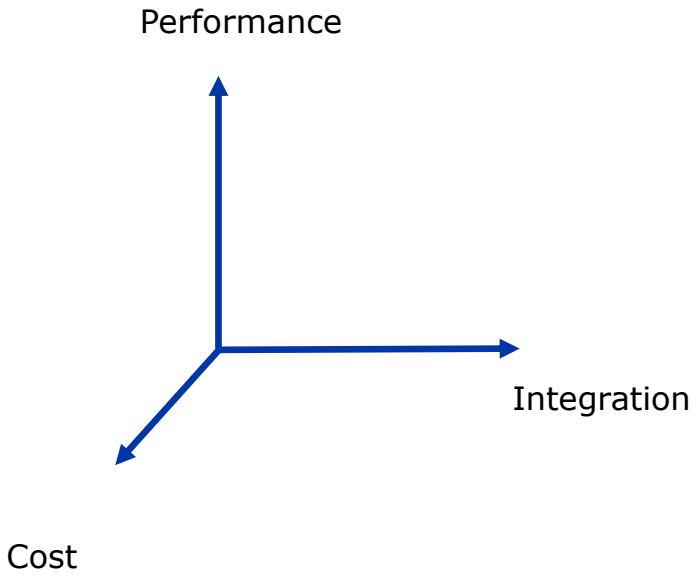


WLP Modular Process Concept



Trade Off's

- Performance
  - Hermitic seal, yield, Bond Strength, Drift, reliability
- Process Integration
  - Wafer bow, release etch, open passivation , pad quality , NVM integration, temperature budget, out gassing, alignment tolerances, wafer thickness, bond frames, noble metal
- Cost
  - Process complexity
  - Capex
    - Tools
    - Metrology, Monitoring
    - Cross contamination
  - Opex



Reuse

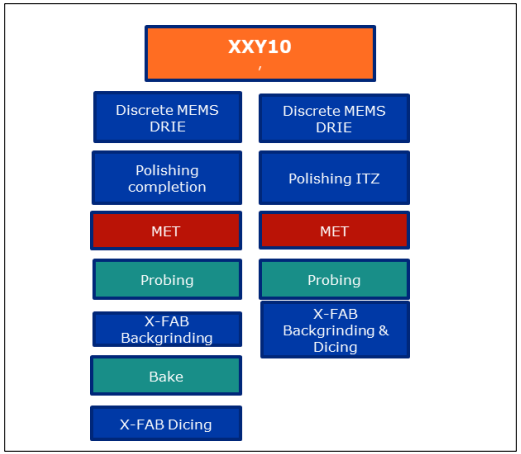
- Leverage of high volume mfg. experience:
  - Bond pad protection schemes in MEMS processing
    - Dicing over pads
  - Outgassing in cavities
  - Front side protection vs. edge grip handling capabilities
  - ….
- Requirements:
  - Standard Process Blocks and process module reuse
  - Gap development vs. full flow development

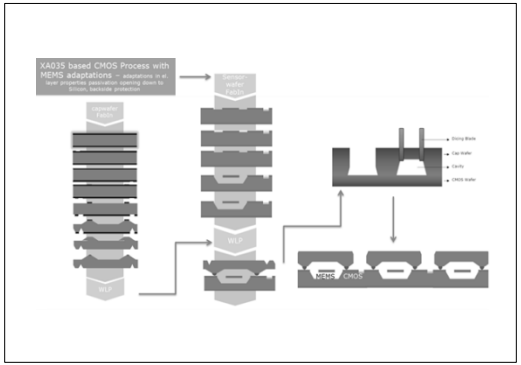
Cross Contamination

- Leverage of CMOS high volume manufacturing infrastructure requires managing the risks involved
  - Objective is zero risk for CMOS WIP
- Methodology requirements
  - Developing and sustaining of specific mindset
  - Controlled material flow and related logistics
  - Additional in line tests - MEMS and CMOS specific (detailed GOX monitoring)
- Tools and infrastructure
  - Separation by clean room, main frame or chamber required
  - Dedicated tools and handling systems (supported by tool automation)

WLP Supply Chain

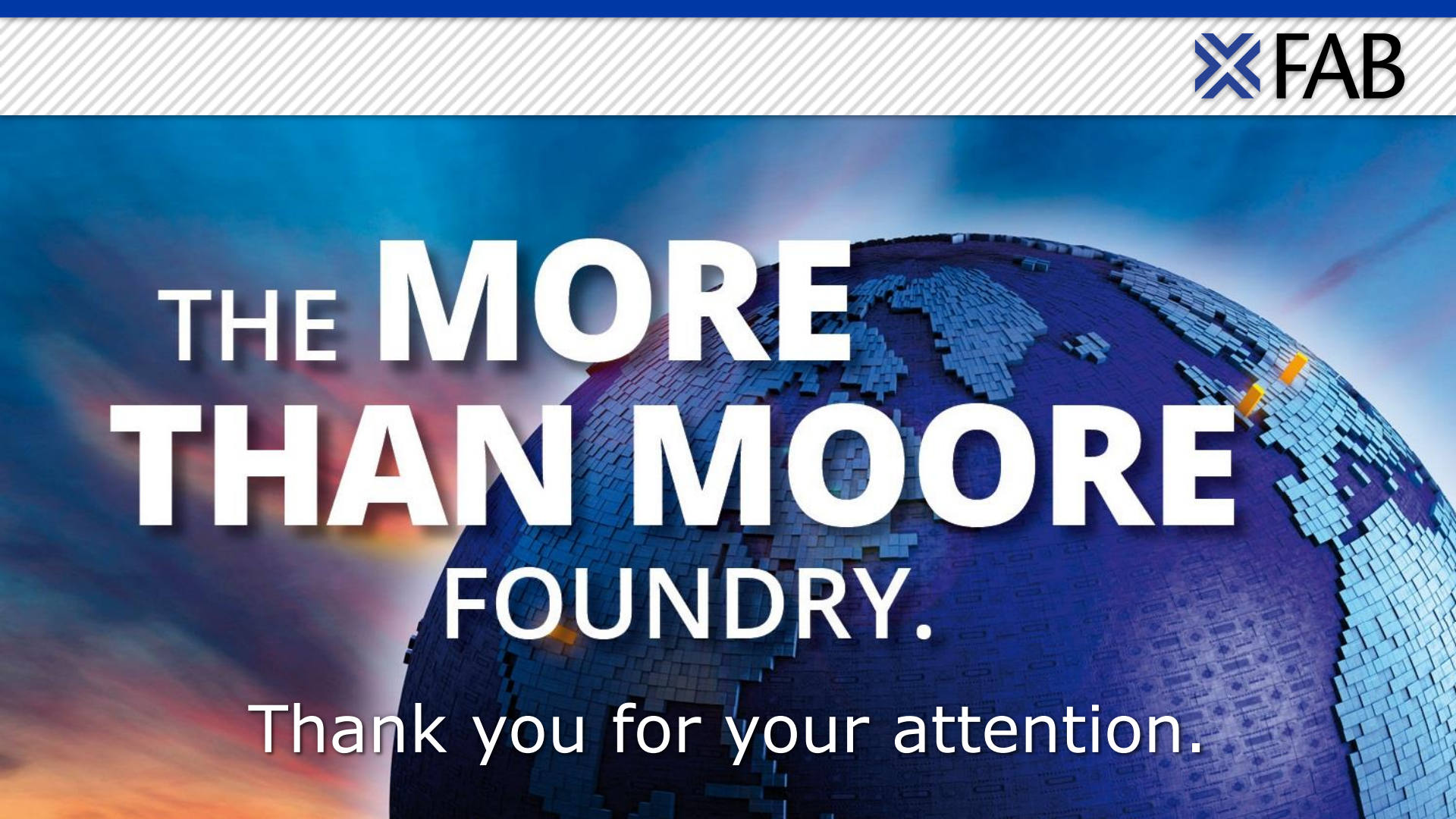
- Complex supply chains
  - Up to three internal fabs and external processing / or probing
- Issues to manage
  - SOP prior process freeze
  - Quality gates are cost drivers (AVI)
  - ERP system
  - Lead time
  - Yield management
  - Foreign material handling
  - Loading swings by consumer business





Key Messages

- We do not expect MEMS WLP high volume manufacturing to become a commodity in the next years
- We believe managing the business model risk (large capex, small projects) is key
- We see specs for tools and process constantly being pushed to the limits and above
- We experience complex supply chain issues
- We recognize standardization and process module re-use is key


FAB
THE MORE THAN MOORE
FOUNDRY.
Thank you for your attention.