Collaboration in the European R&D ecosystem to enable a global supply chain

- Jon Greenwood
- Sr. Director Packaging R&D
- GLOBALFOUNDRIES
Agenda

- GLOBALFOUNDRIES – A Truly Global Partner
  - GLOBALFOUNDRIES Overview
  - GLOBALFOUNDRIES European Presence - Dresden Fab and Bumping Capabilities

- Partner Collaboration and Value Creation
  - Collaboration Viewpoints and Drivers

- Successful collaboration and the New Product Introduction
  - NPI Process and Key Partners
  - R&D collaboration in Europe and enabling the global supply chain

- The New Supply Chain
  - Transition from development to global supply chain

- Summary
GLOBALFOUNDRIES – A Truly Global Partner

- GLOBALFOUNDRIES Overview
- GLOBALFOUNDRIES European Presence - Dresden Fab and Bumping Capabilities
GLOBALFOUNDRIES at a Glance

- **Global Operations**
  - Over 12,000 employees, 12 locations, three continents
  - Administrative offices in Silicon Valley
  - 300mm Fabs in Singapore, Germany, New York
  - 200mm Fabs in Singapore

- **One of the World’s Largest Foundries**
  - 160 customers including many of the world’s largest IC companies

- **Leadership in Foundry Technology and Service**
  - Substantial time-to-volume advantage for advanced technologies
  - Driving the global standard for new technologies
  - Full foundry offering from mainstream to leading edge with value-added Solutions
  - Committed to best-in-class customer service
The First Truly Global Foundry

Global Manufacturing and Support Footprint

- Silicon Valley, CA
- Austin, TX
- Saratoga, NY (East Fishkill, NY)
- London, UK
- Munich, Germany
- Dresden, Germany
- Yokohama, Japan
- Shanghai, China
- Hsinchu, Taiwan
- Singapore

Manufacturing Centers
Sales and Support Offices

300mm
200mm
# State-of-the-Art 300mm Fabs

<table>
<thead>
<tr>
<th>Fab 1 in Germany</th>
<th>Fab 7 in Singapore</th>
<th>Fab 8 in New York</th>
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<tbody>
<tr>
<td><strong>Technology</strong></td>
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<td>45nm and below</td>
<td>130nm to 40nm</td>
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<td><strong>Capacity</strong></td>
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<td>Production ramping 2012</td>
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Global foundry capacity expansion minimizes geographic risk
**Fab 1 – Dresden, Germany**

- Europe’s largest 300mm Fab
- Output expanding to ~1M wafers/ year

- Construction of 110,000 sq. ft. of new clean room space
- Brings total capability to 80,000 wafers per month
- Focused on 45/40nm and 32/28nm technology
- Leading the foundry industry ramp in 32/28nm HKMG technology

- Increasing supply chain value to meet customers expectations → Bumping/Test Facility (BTF)
Fab 1: Bumping Line & Advanced Interconnect
Dresden BTF Value Proposition

- Pb-free Bump, PI Passivation
- Cu Pillar, fine pitch
- 24/7 Bump Engineering
- Fab Quality Systems and Control
- World Class Yield
- 24/7 Quality Engineering
- Large platform offering
- Soft Error Rate (SER), HTOL Ovens
- 24/7 Test Engineering

BTF Manufacturing

24/7 Operations w/ 24h Quality and Engineering coverage

World Class CT for rapid Prototyping,
Dresden BTF Capabilities

Bump Offering:
- PI passivation Capacity: 60 k Wafer/months
- Bump Capacity: 45 k Wafer/month
- Bump capability: 45/32/28nm Lead Free
- 28/20nm Product Qual: Cu Pillar
- Dev: uBump and advanced interconnect
- Proven large scale and manufacturing excellence

Sort Offerings:
- SORT floor space can accommodate ~200 testers
- Wide array of tester platform available
  - LTX Sapphire (Credence), Teradyne J973, J750, Advantest T2000, Verigy 93k-PS400 + Teradyne Ultra-flex (Engineering)
- Fully automated data transaction and handling
  - Test cell concept, Data handling concept, Inkless map generation, Probe card tracking (life, performance, status)
- In-house Probe card maintenance and repair
Dresden BTF Value Proposition/Summary

- Rapid Time to Market with continued focus on key metrics

Product Device

Production Line

Capability

Cycle Time

Quality

Cost

Rapid Time to Market with continued focus on key metrics
Partner Collaboration and Value Creation

- Collaboration Viewpoints and Drivers
Collaboration Viewpoints/Definitions

From Merriam Webster

1) to work jointly with others or together especially in an intellectual endeavor
2) to cooperate with or willingly assist an enemy of one's country and especially an occupying force
3) to cooperate with an agency or instrumentality with which one is not immediately connected

From Wikipedia (condensed)

Collaboration is working together to achieve a goal.[1] It is a recursive[2] process where two or more people or organizations work together to realize shared goals, (this is more than the intersection of common goals seen in co-operative ventures, but a deep, collective, determination to reach an identical objective
Collaboration Viewpoints/Definitions

Our View....

- Partners working jointly in a shared risk/reward environment to develop/qualify/productize leading edge technology solutions that enables a flexible and open supply chain for respective customers.
  - Customers collaborate closely with foundry to develop supply chain of choice
  - Foundry collaborates with partners from early module development (consortia, materials & equipment suppliers) through final productization (OSAT’s, materials & equipment suppliers)
Collaboration Drivers – Cost & TTM

- Industry consolidation and evolving landscape
  - Time, cost and complexity has drastically shifted the IDM landscape
  - Of those remaining, they have adjusted their strategy to a more collaborative/open model

### Transition of Logic Production to IC Foundries

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<tr>
<th>130nm IDM</th>
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- A New York based consortium.
- Built on the base program started under ISMI’s R450 Program.
- Funded to collaboratively work with suppliers to develop 450mm equipment.
- Using wafers, equipment, people and cleanroom space to develop and test equipment to meet industry needs.

Source: G450C website
The cost trend for advanced node scaling will continue to increase
- With lithography being a key component of increasing cost
- Is apparent this is a key collaboration driver at the fab/foundry level
  - Will it become a stronger driver for the FBEOL industry?

Source: IMEC INSITE program in collaboration with partners
Key components enable partners to develop solutions faster and create alignment → Opportunity value

- Advanced Si and test chips create early module development at partners
- Aligned and strategic definition/inputs to equipment and material suppliers.

- Product-like test chips
- Tool standardization
- TSV metrics
- Redundant vias for yield
- Probe at fine pitch
- Test chips for TSV and thinning impacts on transistors
- Process Window Characterization

Customer/Foundry
Foundry/OSAT/Tool Suppliers
Metrology with OSATs/Customers
Foundry/Customer/EDA suppliers
Foundry/Customer/Tool suppliers
Foundry/OSATs
Foundry/ OSATs/ Customer
Collaboration Drivers – Diversity and Multi-Channel Sourcing for HVM

- Geographic and regional advantage by collaborating with leading providers of wafer level, assembly and test services
- Customers participate in strategy and definition of supply chain partners

* Snapshot of supply chain options
Collaboration Drivers – Capability and Flexibility

- Customer engagement/involvement is flexible → Customer decides engagement level and supply chain of choice
  - GLOBALFOUNDRIES offers full Turnkey solutions as one option
Successful collaboration and the New Product Introduction

- NPI Process and Key Partners
- R&D collaboration in Europe and enabling the global supply chain
Successful collaboration and NPI

- Different parts of the supply chain are at different levels of maturity
- IDM (or IDM like) model for 3D/2.5D is risky and solutions developed in collaborative model are more likely to succeed
- **Success is dependent on a system that clearly defines milestones/objectives and drives stakeholder participation/accountability**
  - NPI systems for concept through HVM are key for successful product introduction and supply chain creation

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Ref: Gregg Bartlett   Keynote ECTC 2012
Collaboration Opportunities – High Level
NPI Process

- New Product Introduction (NPI) and steps for engagement
  - A step by step and gate driven process
- Systems for collaboration and execution are critical to the successful launch of products and meeting customer expectations
- System needs to overlap entire supply chain
  - Comprehensive understanding by all stakeholders of entire supply chain

- **Research & Discovery**
  - Consortia Collaboration
  - Multi stakeholder input/collaboration for baseline definition and project definition
- **Build Business Case**
  - Customer Collaboration
  - Define business case and supply chain options
- **Development & Supply Chain Creation**
  - Partner Collaboration
  - 2 way collaboration (SOW)
  - Multi party collaboration (SOW) with customers and partners
- **Qualification & HVM**
  - Supply Chain Qualification
  - Can be Customer driven
  - Turnkey available
Collaboration – Development & Supply Chain Enablement

- Statements of Work are the foundation to successful collaboration
  - SOW’s define program deliverables, requirements, ownership and supply chain partners
    - Program definition and transparency
  - Can be 2 way baseline technology qualification or multi-party way with customers and partners
  - Used at all levels of engagement
    - Research
    - Development
    - Qualification & HVM

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**Alignment**
- Customer requirements
- Milestones/Schedules
- Shared Market
- Systems

**Investment**
- Development & NPI
- HVM Strategy
- Roadmaps
- Core Business
- Shared Risk/Reward

**Ownership**
- Commitment
- Resourcing
- Prioritization
- Infrastructure

**Supply Chain**
- Partner selection
- Customer preference
- Technology leaders
- Investment strategy

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Statements of Work are the foundation to successful collaboration. SOW’s define program deliverables, requirements, ownership and supply chain partners. Program definition and transparency can be a 2-way baseline technology qualification or multi-party way with customers and partners. Used at all levels of engagement, including research, development, qualification & HVM.

Program definition and transparency can be a 2-way baseline technology qualification or multi-party way with customers and partners. Used at all levels of engagement, including research, development, qualification & HVM.
Consortia/University partners are key for early module development

Global participation with key research partners

European partnerships are a strong pillar in the model
Collaboration - GLOBALFOUNDRIES & Fraunhofer ASSID

- Close collaboration for rapid execution
- Partner (Fraunhofer ASSID)
  - GLOBALFOUNDRIES and Fraunhofer IZM-ASSID have established a collaboration model that enables rapid technology and broad supplier participation
  - The flexibility of the model and co-location of the site ensures real time responses to the evolving needs of customers and foundries.
  - A long term commitment by both parties ensures stability for customers and supply chain partners

Fraunhofer's leading edge technology development facility IZM-ASSID co-located next to GLOBALFOUNDRIES FAB1 in Dresden, Germany
Alignment of roadmaps, leading into requirements & investment

- Partner
  (Fraunhofer IZM, ASSID)

### 3D Heterogeneous System Integration @ Fraunhofer IZM

Fraunhofer IZM- ASSID operates a **Leading Edge 200/300 mm Process Line for Wafer Level System Integration** for process development, prototyping and manufacturing under industry-compatible conditions.

#### Facility & Infrastructure
- **Clean Room:** 970 m²

#### Equipment:
- Cu-TSV Formation
- Pres-Assembly
  - Wafer Thinning, Handling, Dicing
  - 3D Stacking and Assembly

All tool specifications are aligned to the requirements for specific applications and customer requests to 3D technology for TSV formation, silicon interposer and multifunctional device integration. Tools are leading edge developments of selected supplier and aligned to process development, prototyping and low volume manufacturing under industrial manufacturing conditions.

© Fraunhofer IZM

M.J. Wolf

Courtesy: M. Juergen Wolf, Semicon Europe 2012
Complimentary capabilities and resources

Partner
(Fraunhofer IZM, ASSID)

3D Wafer Level System Integration (Examples)

3D TPM (ASIC+TX+MEMS)
WL Camera
TSV Interposer (MPU+MEM)

MEMS/ASIC Integration
ARM Sensor
Image Sensor

Image Sensor (Sensor+IP+SP)

Courtesy: M. Juergen Wolf, Semicon Europe 2012
GLOBALFOUNDRIES & Fraunhofer IZM-ASSID jointly develop TSV integration into 28 nm HKMG device wafers to enable 3D chip stacking solutions.

- **FEOL & MOL**
  - @GLOBALFOUNDRIES FAB1
  - 28nm HKMG

- **TSV preparation**
  - @GLOBALFOUNDRIES FAB1
  - CMP stop layer
  - TSV lithography

- **TSV processing**
  - @IZM-ASSID
  - TSV etch
  - Liner and barrier/seed dep
  - TSV Cu fill

- **BEOL**
  - @GLOBALFOUNDRIES FAB1
  - 28nm BEOL flow

TSV etch | Liner and barrier/seed dep | TSV Cu fill | TSV CMP
Notable results of the GLOBALFOUNDRIES/Fraunhofer IZM-ASSID TSV project include:

- Excellent TSV depth uniformity across the wafer without dependency on TSV pattern density.
- Minimum influence of post-TSV polishing on wafer surface planarity.
- Conformal dielectric liner and barrier deposition.
- Robust processes with repeatable results.

The close proximity of foundry and research facility ensure not only minimum response times and fast feedback, but also facilitate an intensive and frequent knowledge exchange at the engineering level.
GLOBALFOUNDRIES and Fraunhofer IZM-ASSID will leverage the achieved results of the 28 nm 3D/TSV project to expand their collaboration into other areas of 3D chip stacking technology, research & development.

- **TSV process & flow optimization**
- **TSV backside reveal**
- **Thin die impact on device performance**
- **Backside metallization**

Q1/2013 → Q4/2013 and beyond
GLOBALFOUNDRIES and Fraunhofer IZM-ASSID have also expanded their collaborative engagement to advanced interconnect development

- Fine, very fine pitch CuP for 3D, 2.5D and advanced nodes

- High Aspect Ratio Lithography
- Fast Pillar Plating
- Etch and Clean
- Fine Pitch
Collaboration - GLOBALFOUNDRIES & imec

- GLOBALFOUNDRIES is a core partner of imec
- Collaboration for early module development on key packaging technologies
- Added value of multi stakeholder input/collaboration for project definition
Prioritize focus on areas that meet multi partner inputs/requirements and align to GLOBALFOUNDRIES roadmaps.

- imec 3D Program
- GLOBALFOUNDRIES has dedicated resource/assignee for these technologies

- Active participation and support of core programs and strong collaboration on custom programs

Collaboration - GLOBALFOUNDRIES & imec

- Mobile
- Memory
- High Performance computing
- Heterogeneous integration

- 3D Design
- Path finding
- 3D Design
- Authoring
- 3D Test
- strategy
- Impact 3D on device
- performance
- Signal and Power
- integrity
- Cost effective processes

Demonstration: design and fabrication
- With advanced CMOS nodes on 300mm,
- CPI, CMOS 3D logic-on-logic, DRAM-on-logic, interposer stacking
Collaboration - GLOBALFOUNDRIES & imec

- 2.5D design and TV collaboration
  - Silicon interposer with 1 large + 2 small dice, assembled onto organic HDI BGA substrate

- Interposer (GLOBALFOUNDRIES design with imec features)
  - 32 x 26 mm² die size, ~100µm thick
  - 10 x 100µm TSVs (~28k)
  - Cu dual damascene FS RDL (4ML + Al), 1ML BS RDL, C4 solder bumps

- Large top die (GLOBALFOUNDRIES design)
  - 18 x 22 mm² die size
  - Micro pillar interconnects, min. pitch 40/50µm

- Small top die (65nm test vehicle, imec design)
  - 8 x 8 mm² die size, ~600µm thick
  - Functional chip design with test features for die-to-die communication
  - Micro pillar interconnects, min. pitch 40µm
The New Supply Chain

- Transition from research to global supply chain
Collaboration—Development & Supply Chain Enablement

- System level enablement, product qualification and supply chain creation through technology and industry leaders
- Open and multi source supply chain
- Customers participate in strategy and definition of supply chain partners

GLOBALFOUNDRIES
Manufacturing & Test
Supply Chain Partners

Tools
- BEOL and TSV
- BSI or MEOL
- Assembly
- Test
- Metrology & Analysis

Components
- Substrates
- Interposers
- Device
- Memory

Materials
- Device
- Packaging
- Processing
- MEOL

OSAT’s
**Collaboration – 2.5D and 3D Supply Chain Enablement**

- Key to enabling the supply chain is clearly defining the ownership and systems to support integration
- Partners must operate in a transparent and open model that allows for sufficient planning and investment to meet customer demands

**Supply Chain Model for 2.5D and 3D Systems**

- **Via-First** (2.5D TSV Interposer)
  - TSV Photo
  - TSV ETCH
  - TSV CVD
  - TSV PVD
  - TSV ECP
  - TSV CMP
  - BEOL

- **Via-Middle** (3D Logic, Memory)
  - TSV Photo
  - TSV ETCH
  - TSV CVD
  - TSV PVD
  - TSV ECP
  - TSV CMP
  - FEOL

- **Post Foundry** (Bumping, OSAT)
  - RDL & BUMP
  - BOND & THIN
  - BS VIA REVEAL
  - BS RDL/BUMP
  - CHIP STACK
  - PKG ASSY & TEST
Collaboration – 2.5D and 3D Supply Chain Enablement

- Module development at consortia partners
- Integration in Foundry
- Collaboration between consortia, foundry, tool manufacturers, material suppliers and customers

GLOBALFOUNDRIES Fab 7, Singapore
2.5 D Solutions

GLOBALFOUNDRIES Fab 8, New York
3D Solutions

GLOBALFOUNDRIES TSV Wafer
Collaboration – 2.5D and 3D Supply Chain Enablement

Wafer Bump and Backside Integration (MEOL)

Courtesy: Ron Huemoeller, Amkor Technology October 2012
Collaboration – 2.5D and 3D Supply Chain Enablement

TSV Production Intercepts

- Gaming, Tablet, HDTV (28 - 20nm)
- Smart Phone, Tablet (28 - 20nm)
- Server, Custom Mem. (45 & 32nm)
- FPGA (28nm)
- Mobile (RFPA) (28nm)

MCM SiP (2.5D); Logic + DDR\(^T\) all mounted to Si Interposer

Logic\(^T\) + SDR or DDR3\(^T\)

SIP (2.5D) required some platforms

Stacked DDR\(^T\)

Logic on Si Interposer

Production Since Nov ’11

Production Since ’10

Die with TSV indicated by = T

Value Market

Performance & Enthusiasts

Volumes

Courtesy: Ron Huemoeller, Amkor Technology October 2012
Collaboration – 2.5D and 3D Supply Chain Validation

- 2.5D interposer process development, characterization and qualification
- Collaboration between foundry, customers, consortia and manufacturing partners
- Target Outputs:
  - Qualified interposer, assembly, supply chain
  - RLC based parameters in PDK/DM, representing full product and supply chain
Customers collaborate closely with foundry to develop supply chain of choice

Open supply chain – where customers can participate in the ecosystem, the definition of the supply chain model and the overall strategy

Foundry collaborates with partners from early module development through final productization (consortia → OSAT)

Collaboration model takes full advantage of key regional strategies & strengths

- Key research and development at European consortia partners
- Development and qualification of supply chain at HVM partners

Enablement of supply chain model that delivers industry wide leadership

Successful collaboration can only be realized through effective NPI systems and an “open” communication/ecosystem

Collaborative supply chain for 2.5D/3D has been enabled