**3D-PEIM Symposium** 

#### Heterogeneous Integration for IoT Cloud and Smart Things A Roadmap for the future

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IEEE COMPONENTS, PACKAGING AND MANUFACTURING TECHNOLOGY SOCIETY





### Outline

- Visions 1965 to 2016
- IoT, Smart Things & Cloud
- SiP & Heterogeneous Integration
- Roadmapping to the Future
- Heterogeneous Integration Roadmap for Semiconductors
- Summary

### Vision 1965: Gordon Moore Paper

"Cramming More Components onto Integrated Circuits," Gordon E. Moore, *Electronics*, pp. 114–117, April 19, 1965.

#### Key Messages in Moore's 1965 Paper on Integration



Market

51 years later Transistor Production has reached astronomical scale, while transistor price droped many billionth Source: Dan Hutcheson- April 3<sup>rd</sup> 2015



Moore's Law Scaling cannot maintain the pace of Progress for the Electronics Industry

#### Density has maintained the rate of improvement

- Other key parameters have not and, in some cases, they are heading in wrong direction
  - Cost
  - Power efficiency
  - Performance



#### Scaling to the next node increases cost per transistor.



2014

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The International Technololgy Roadmap for Semiconductors (ITRS) will published Its Final Edition this month

- The semiconductor industry has enjoyed a 50 + year period of unprecedented progress. CMOS scaling was the key enabler.
- The driving force has always been market & economics and technology the enabler. With end market inflection points, CMOS scaling alone cannot enable the future.
- The world is more complex today and we are seeing infexion points in the end markets, but economics remains the driver and technologies will be the enablers.
- For much of the 50+ years ITRS has guided the industry & research ecosystems for roadblocks, difficult challenges for CMOS scaling.

The question is which Technologies and Roadmaps will best guide us for the future of IoT, Smart Things & Migration to the Cloud

### Vision 2016 – IoT, Smart Phone & Cloud

"The future of integrated electronics is the future of electronics itself. The advantages of SiP through **heterogeneous integration** will bring about a proliferation of electronics, pushing this science into many new market application areas, Internet of Things, Smart Phones, Cloud Infrastructure, and many other smart things", ......"

Revisiting Dr Moore's 1965 Vision – 2016 (edited words in blue & red with acknowledgement to Dr. Moore)



# IoT, Consumer & Cloud Driving Forces



#### SiP & Heterogeneous Integration: Markets Heterogeneous Components & Package Innovations :



Electrical Design

Innovation and challenge exist across diverse specific applications, heterogeneous components,

**Reinvent Wirebond** 

and packaging technologies tool box.

Automotive

# **Connected World**



Wearables Smart Homes Intelligent Factory Health Agriculture Smart Cities

Data Centers Networks Computers Connected vehicles



Prismark September 2015

# Connected World: Electronic Systems Hardware Revenue

2014 = \$1,715 Bn

2019 = \$2,033 Bn







Source: Prismark 2015

Everything Will & Must Change

#### Including Roadmaps



IoT, Smart Things & Cloud present requirements we cannot satisfy through scaling CMOS

The end market inflexion point and their system level requirements present major roadblocks & challenges

These challenges can only be overcome by Heterogeneous Integration in System in Package (SiP) technologies

We must bring all electronics ecosystem together to work in collaboration



# **Changing Roadmaps**

#### The ITRS Dominated But Multiple Successors Will Contribute In The Future

International Electronics Manufacturing Ditiative (INEMI) Roadmap

- 10 year horizon
- Available free to members and for purchase to non-members
- Focus on market segments and manufacturing technologies

"An important tool for defining the "state of the art" in the electronics industry as well as identifying emerging and disruptive technologies"

International Roadmap for Devices and Systems (IRDS)

- 15 year horizon for some parts
- Sponsored by IEEE Standards Association
- Available Free to all

"The new effort aims to take a broad view of the needs of computing generally. It will address road map issues that include computer systems, architectures and software as well as the chips and other components used in them"

# The ITRS Dominated And Multiple Successors Will Contribute In The Future

Photonic Systems Manufacturing Poadmap (PSMR)

- 15 year horizon
- Available free to all
- Focused on manufacturing of Photonic Systems
- Sponsored by NIST and AIM Photonics, Managed jointly by MIT Microphotonics Center and INEMI

"A strategic Roadmap that i) identifies critical technical requirements for nextgeneration systems integration and packaging, ii) details potential solutions to meet those requirements economically, and iii) identifies the technology supply chain limitations"

Heterogeneous Integration Technology Roadmap for Semiconductors (HITRS)

- 15 year horizon for most topics; 25 year horizon for emerging research areas
- Available free to all
- Sponsored by IEEE CPMT Society, SEMI with participation by IEEE EDS

# The ITRS Dominated And Multiple Successors Will Contribute In The Future

International Technology Roadmap for Wide Band Gap Semiconductors

- Available free to all
- Sponsored by IEEE Power Electronics Society

#### DEFINITION ITRS 2.0 Heterogeneous Integration December 2014

Heterogeneous Integration is defined as the integration of separately manufactured components into a higher level assembly (SiP) that in the aggregate provides enhanced functionality and improved operating characteristics.

### SiP through Heterogeneous Integration



- 1. The best nodes for the application
- 2. Heterogeneous Components
- 3. Market specific applications

The Whole is greater than the sum of the parts

Aristotle – Greek Philosopher

### Heterogeneous Integration Technology Roadmap For Semiconductors (HITRS)

The IEEE CPMT Society, the IEEE Electron Devices Society and SEMI have sponsored a new Roadmap focused on the critical technologies that can maintain the pace of progress, at least until a replacement for the CMOS switch is found.

> http://cpmt.ieee.org/technology/heterogeneous-integration-roadmap.html http://www.semi.org/en/heterogeneous-integration-roadmap

The HITRS is committed to collaboration with other Roadmaps where ever possible

# **HITRS** Purpose

- The Roadmap serves as <u>a guideline for the global electronics industry of</u> <u>projected technology needs</u> and opportunities for innovation.
- The Roadmap is devised and <u>intended for technology assessment only</u> and is without regard to any commercial considerations pertaining to individual products or equipment.
- <u>Serving the Profession, Industry, Academia and Research Institutes</u>, the Roadmap provides:
- A forecast of <u>industry requirements to maintain the pace of progress</u> for the industry and user community over the next 15 years, and the next 25 years for the heterogeneous integration of emerging devices and materials which require a longer research development horizon.
- <u>Identification of difficult challenges</u> that must be addressed to meet these industry requirements.
- Where possible the Roadmap will <u>identify research requirements and</u> <u>potential technical solutions.</u>

#### Heterogeneous Integration Components

- Single-Chip & Multi-Chip Packaging (including substrates)
- Integrated Photonics
- Integrated Power Devices
- MEMS & Sensors
- RF & Analog Mixed Signal
- Plasmonics

All these components exist today but they will change dramatically over the 15 year life of the HITRS Roadmap

### SiP through Heterogeneous Integration



#### **Cross Cutting Topics**

- Emerging Research Materials
- Emerging Research Devices
- Interconnect (system package and chip level)
- Test

New materials and devices will be required for high performance interconnect.

Test approaches must change dramatically to support test access and transistor wear out with Complex 3D SiP.

#### **Integration Processes**

- System in Package
- 2.5D and 3D
- Integrated Power SiPs
- Wafer Level Packaging (Fan-in, fan-out and panel processing)

These processes exist today but have been slow to move to volume production Cost is the limiting factor today. Cost reduction <u>at system level</u> will be the driving force for wide spread adoption

#### **Co-Design and Simulation**

- Design at the device, package, subsystem and system level
- Modeling and Simulation tools to move optimization from the factory to the computer
- Continuous test while running, intelligent redundancy, dynamic self-repair and graceful degradation to ensure reliability
- Security at every level (hardware and software)
- Automotive

Each of these elements are necessary to meet cost, reliability, security and time to market requirements

### Packaging for Specialized Functions

- Mobile
- IoT and Wearables
- Medical
- Automotive
- Data Centers
- Mission Critical Applications

Each of these functions have unique requirements that will drive specialized packaging technology.

### HITRS Calendar Of 2016 Activity As Of Today

Face to Face Workshops

- 1. ECTC + ITHERM Las Vegas, NV USA 05/31- 06/04
- 2. Palo Alto Workshop before SEMICON WEST (3101 Alexis Drive, Palo Alto. CA ) 07/10
- 3. <u>SEMICON WEST</u> San Francisco, CA USA 07/11
- 4. Taiwan (at ITRI 08/12)
- 5. China (associated with ICEPT in Wuhan, China 08/16-19) <u>http://www.icept.org/en/</u>
- 6. Japan August 9, 2016 at SEMI office in Tokyo
- 7. ESTC Grenoble, France 09/13-16
- 8. ELECTRONICS PACKAGING SYMPOSIUM Binghamton, NY USA 10/5-8
- 9. IMPACT Taipei, Taiwan 10/26-28
- 10. ICSJ Kyoto, Japan 11/7-9
- 11. **EPTC** Singapore 11/30 12/03

### Summary

- Smart Electronics , IoE connected devices , Smart Things, and Cloud constitute over 50% of Global Electronic System Revenue.
- Progress for IoT, Smart Devices & the Cloud will require deep collaboration and partnership internally and externally across ecosystems and the whole technical community.
- Heterogeneous Integration Roadmap for Semiconductor (HITRS) will continue the role of ITRS providing guidance to industry, academia and research community in the era of IoE, Smart Things and Cloud Infrastructure.

# Thank You for your Attention