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FF02: iNEMI Technology Roadmap

Session Chair:
Bob Pfahl
APEX
March 31, 2009

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Presentations

- Keynote: 2009 iNEMI Roadmap — Jim McElroy, iNEMI
- Environmentally Conscious Electronics — Scott O'Connell, Dell
- Board Assembly — Chuck Richardson, iNEMI
- New Technology — Bob Pfahl, iNEMI
- Summary & Conclusions

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The 2009 iNEMI Roadmap

Jim McElroy

Apex

April 1, 2009

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Agenda

- Introduction
- Roadmap Overview
- Business Issues
- Technology Issues and Needs
- Systems Packaging Evolution
- Evolution of Organic Substrate Technology
  - Alternative Component Technologies
- Board Assembly and Test
- Sustainable Electronics
- Emerging Energy Efficient Technologies
  - Solid State Illumination
  - Photovoltaics
- Summary & Conclusions

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Introduction

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Who Are We?

- **iNEMI organization:**
  - Corporate membership
  - Not-for-profit, R&D consortium
  - Collaboration defined by organization by-laws, intellectual property policy, and project agreements.
- **Member companies/organizations:**
  - Leadership OEM, EMS, and Supplier companies
  - Government labs
  - Academic Institutions.
- **Small staff provides services to facilitate global collaboration (USA, Asia & Europe):**
  - Support to help organize & manage projects
  - Communication services for collaboration
  - Manage Relationships with other Organizations.

Global Operations

- iNEMI is headquartered in Herndon, Virginia, USA.
- Started iNEMI China Collaboration in 2003.
- Opened an office in Shanghai and added a team member in Europe in 2007.
- Dr. Haley Fu is leading operations in Asia, based in Shanghai, China.
- Grace O'Malley is representing iNEMI in Europe from her base in Ireland.

OEM/EMS Members

Agilent Technologies

Alcatel·Lucent

Boston Scientific

Delivering what's next.™

CISCO

Celestica™

DELL

DELPHI

FOXCONN

FLEXTRONICS

hp invent

HUAWEI

intel

MICRO SYSTEMS ENGINEERING

PLEXUS

SANMINA-SCI

Sun microsystems

MED-EL MEDICAL ELECTRONICS

Supplier Members

3M

ALBEMARLE®

Cookson Electronics
A Division of Cookson Group plc

iST INTEGRATED SERVICE TECHNOLOGY

HOVER-DAVIS

ASSET
Driving Embedded Instrumentation

DOOSAN Doosan Corporation
Electro-Materials

Universal Instruments

Vitronics Soltec

DYCONEX
ADVANCED CIRCUIT TECHNOLOGY

kester®
CONNECTING INNOVATION™

IHS®

Endicott Interconnect®
Technologies, Inc.

TRI Test Research, Inc.

INDIUM CORPORATION OF AMERICA®

NAN YA

生益科技
SHENGYI SCI. TECH

nanodynamics

CORELIS
An EWA Company

EMC
ELITE MATERIAL CO., LTD.

NIHON SUPERIOR CO., LTD.

Speedline technologies

ITEQ
INNOVATION • TEAMWORK • EXCELLENCE • QUALITY

STATSChipPAC®

Senju Comtek

ROHM AND HAAS

TERADYNE

TEXAS INSTRUMENTS

Tyco Electronics

iNEMI®

Association/Consortium, Government, Consultant & University Members

AeA
Advancing the Business of Technology®

AMR Research

EIA

PURDUE

IEEC

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES®

ITRI
Industrial Technology Research Institute

Georgia Institute of Technology

ncms
National Center for Manufacturing Sciences

CIT
CENTER FOR INNOVATIVE TECHNOLOGY

NIST
National Institute of Standards and Technology

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Deliverables

"Advancing Manufacturing Technology"

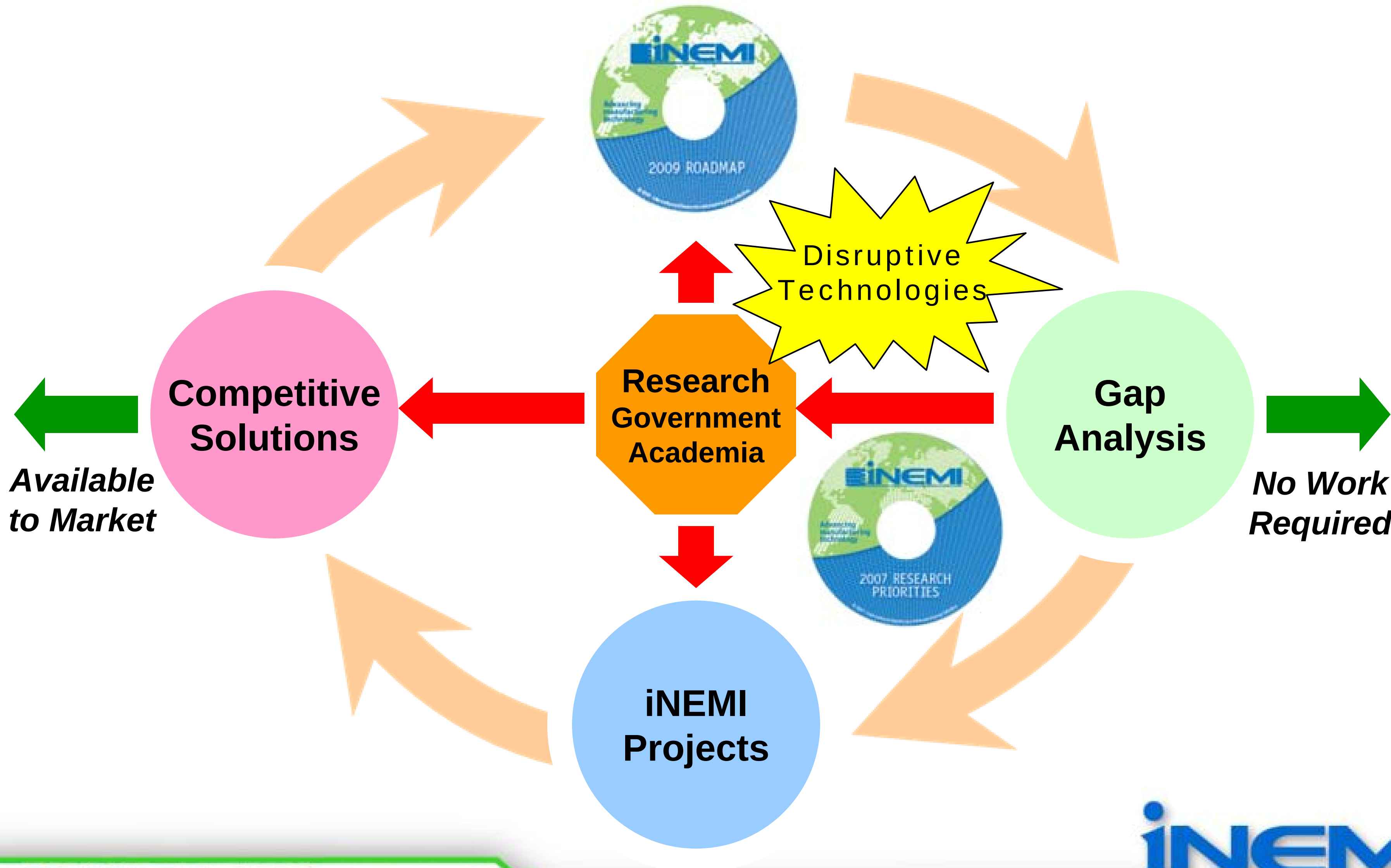
iNEMI provides five important deliverables:

1. Technology roadmaps
2. Technology deployment projects
3. Research priorities
4. Forums on key industry issues
5. Position papers to focus industry direction

Leadership through Innovation

- **A proven approach for identifying the technology needs and gaps of the industry through our roadmapping process**
- **A strong track record of developing supply chains to introduce new materials, processes, and technologies into production**
- **A research vision with three major thrusts:**
  - **Energy & the environment**
  - **Miniaturization**
  - **Medical electronics**

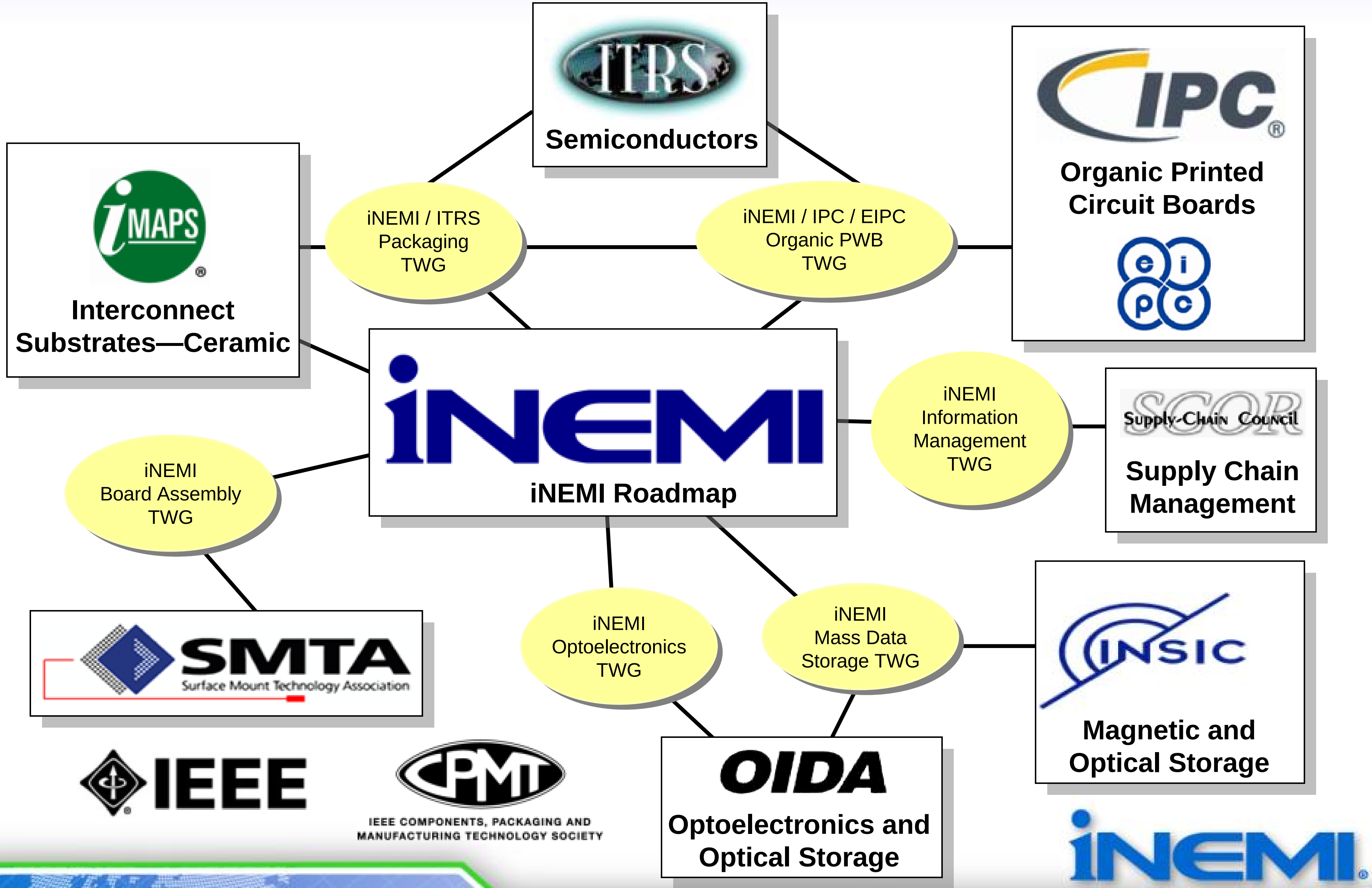
iNEMI Methodology



Statistics for the 2009 Roadmap

- > 550 participants
- > 250 companies/organizations
- 18 countries from 4 continents
- 20 Technology Working Groups (TWGs)
  - New roadmaps on Solid State Illumination, Photovoltaics and RFID Item-Level Tag
- 5 Product Emulator Groups (PEGs)
- > 1400 pages of information
- Roadmaps the needs for 2009-2019

Nine Contributing Organizations



2008-9 iNEMI Roadmap Process Highlights

- Maintained/expanded strong linkages with other technology roadmaps
- Strengthen Product Emulator value:
  - Utilized TWG Chair input on Key Attribute Spreadsheet formats & improve
  - Expanded PEG participation utilizing T.C. input
  - Initiated PEG Kickoff at SMTAI in October with 5 PEG Chairs
  - Presented Updated Emulator Spreadsheets by N.A. TWG kickoff
- Strengthened linkages with European and Asian organizations
- Expanded emphasis on prioritizing technical gaps, market gaps, and needs throughout roadmap
- New Roadmap on Solid State Illumination
- New Roadmap on Photovoltaics
- New RFID Item Level Tag (ILT) Roadmap

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2009 iNEMI Roadmap

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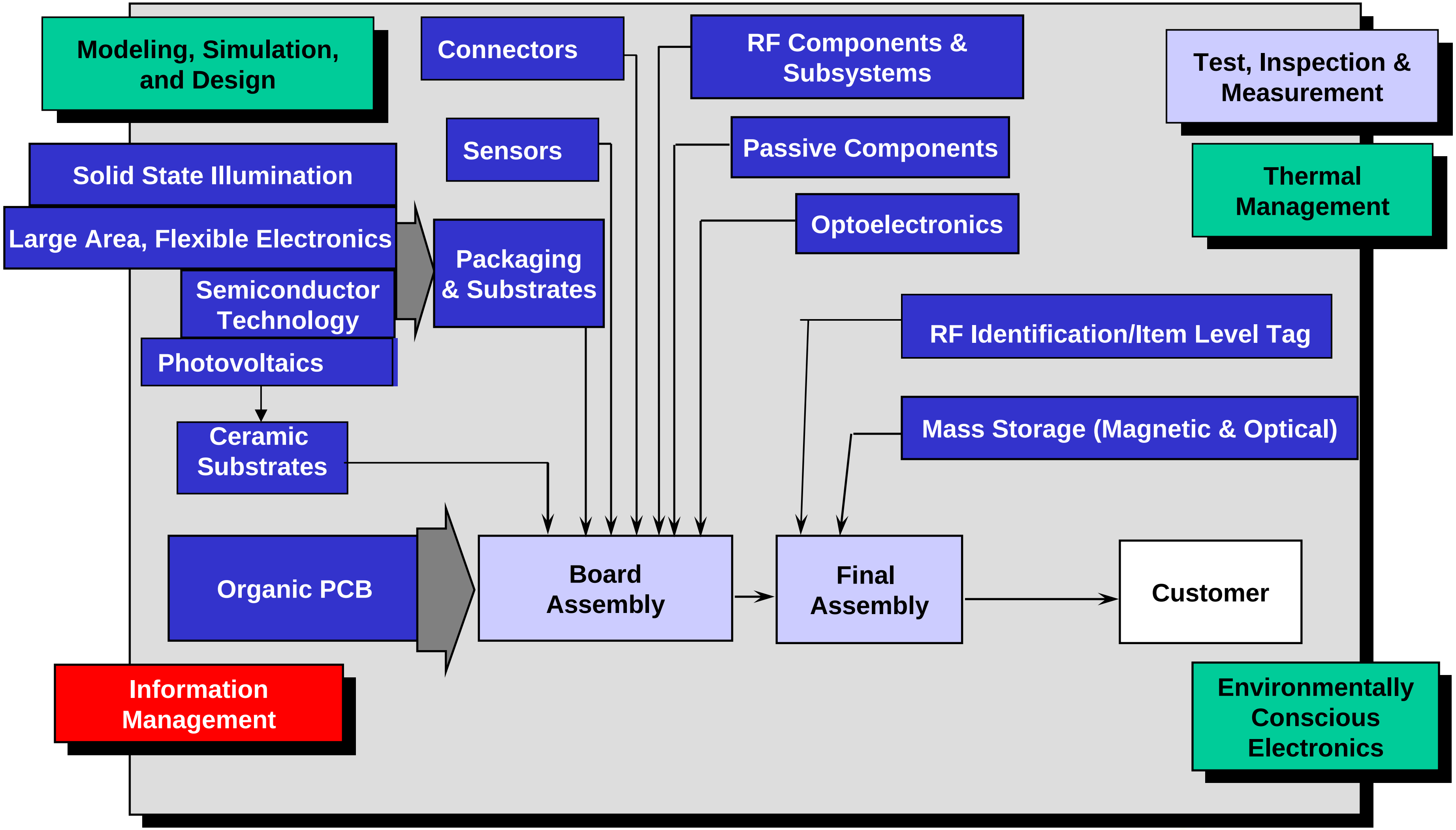
2009 Technology Working Groups (TWGs)

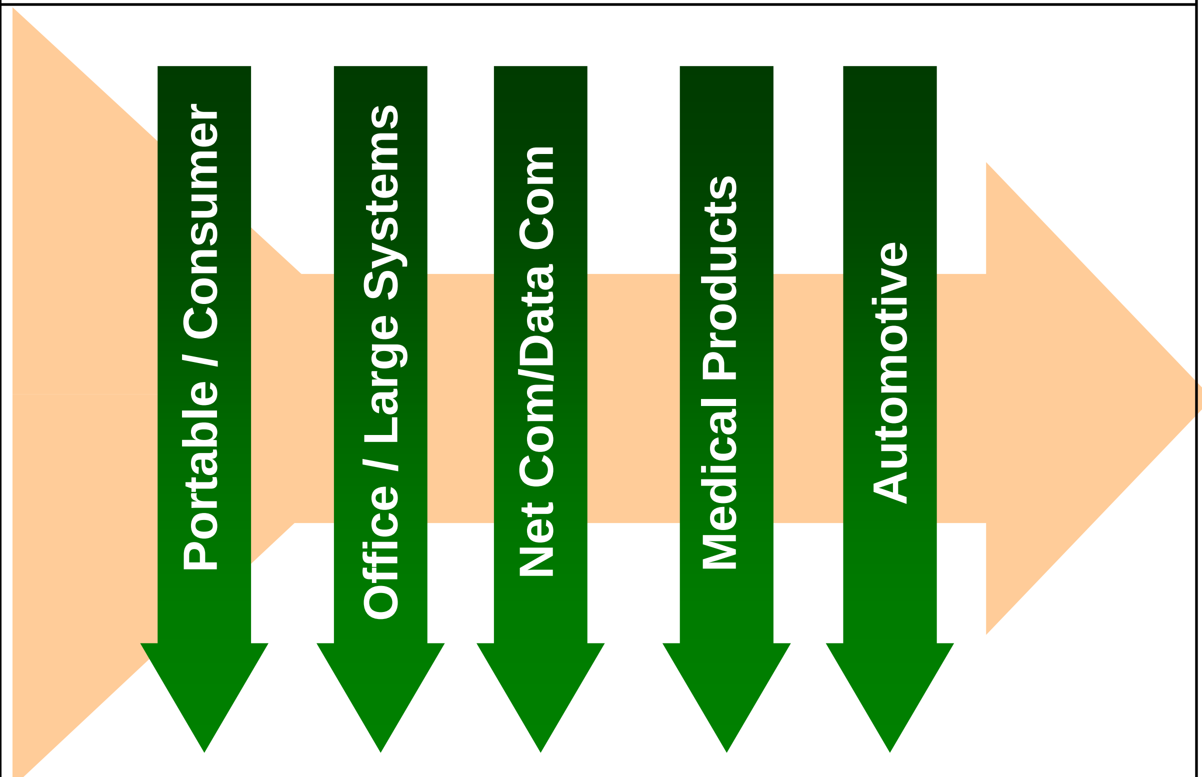


Red=Business Green=Engineering Blue=Manufacturing Blue=Component & Subsystem

Roadmap Development

Product Sector Needs Vs. Technology Evolution

TWGs	Product Emulator Groups
Semiconductor Technology	
Business Processes **Prod Lifecycle Information Mgmt.**	
Design Technologies Modeling, Thermal, etc.	
Manufacturing Technologies Board Assy, Test, etc.	
Comp./Subsyst. Technologies Packaging, Substrates, Displays, etc.	



2009 Product Emulator Groups

Product Emulator	Chair(s) 2009
Automotive Products	Jim Spall
Medical Products	Anthony Primavera, MSEI Bill Burdick, GE Research
Consumer / Portable Products	Susan Noe, 3M
Office/Large Business System Products	David Lober, Intel David Copeland, Sun
Network, Data, Telecom	John Duffy, Cisco

2009 TWG Leadership

Business Processes / Technologies	Chair(s)	Co-Chair(s)
Information Management	Eric Simmon, NIST	Jeff Pettinato, Intel
Design Technologies		
Modeling, Simulation & Design Tools	Yishao Lai, ASE	S.B. Park, Binghamton U.
Environmentally Conscious Electronics	Bob Pfahl, iNEMI	
Thermal Management	Ravi Prasher, Intel	Azmat Malik, Consultant
Manufacturing Technologies		
Final Assembly	John Allen, Celestica	Reijo Tuokko, Tampere U.
Board Assembly	Dongkai Shangguan, Flextronics	Aaron Unterborn, Flextronics Ravi Bhatkal, Cookson
Test, Inspection & Measurement	Mike Reagin, Delphi	Michael J. Smith, Teradyne

2009 TWG Leadership (cont.)

Component / Subsystem Technologies	Chair(s)	Co-Chair(s)
Semiconductor Technology	Paolo Gargini, Intel	Alan K. Allan, Intel
Optoelectronics	Dick Otte, Promex	William Ring, WSR
Photovoltaics	Alain Harrus, Cross Link Capital	Jim Handy, Objective Analysis
Packaging	Bill Bottoms, NanoNexus William Chen, ASE	
Passive Components	Philip Lessner, Kemet	John Galvagni, AVX
Connectors	John MacWilliams, Consultant	
RF Components	Ken Harvey, Teradyne	Eric Strid, Cascade MicroTech
Large Area, Flexible Electronics	Dan Gamota, Motorola	Jan Obrzut, NIST Jie Zhang, Motorola
Interconnect Substrates (Ceramic)	Howard Imhof, Metalor	Ton Schless, Sibco
Interconnect PCB (Organic)	John T. Fisher, IPC	Henry Utsunomiya, Consultant
Mass Data Storage	Roger F. Hoyt, Consultant	Tom Coughlin, Coughlin Associates
Solid State Illumination	Marc Chason, Consultant	

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Business Issues

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Situation Analysis

- Growth of Automotive Electronics
- Convergence (Driven by wireless/portable products)
  - Medical-Consumer
  - Automotive-Entertainment
  - Communication-Entertainment

- Medical Electronics focus shifting towards diagnostics/prevention vs. therapy.
  - Motivations: reduce cost & improve outcomes
  - High volume consumer oriented
  - Challenge for getting quick regulatory acceptance

Situation Analysis

- Miniaturization and Thinner
- Quality, reliability, cost
- Counterfeit Products
- Time to market
- Increasing Material Restrictions
- Increased focus on Energy Reduction
  - Both product & manufacturing
  - Life-cycle approach

Strategic Infrastructural Changes

- The restructuring of the electronics industry over the last decade from vertically integrated OEMs to a multi-firm supply chain has resulted in a disparity in R&D needs versus available resources.
- Restructuring has created skill gaps at various nodes of supply chain.
- Critical needs for research and development exist in the middle part of the supply chain (IC assembly services, passive components and EMS assembly) and yet these are the firms least capable of providing the resources.
- A partial solution has been the development of vertical teams to develop critical new technology while sharing the costs.

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Technology Issues and Needs

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Key Technology Issues

- **Semiconductors:**
  - **Scaling and next generation technology**
- **Packaging: More than Moore**
  - **New level of packaging blending Semiconductor back end and assembly/packaging, infrastructure.**
  - **Stacked Die**
    - **Cooling**
    - **Through hole via process and reliability**
    - **Assembly accuracy required for PoP, stacked die, etc. not consistent with today's Board Assembly equipment.**
  - **New capability to close the gap between chip and substrate interconnect density: "Shortstopper"**
    - **Silicon Interposer**
    - **Organic**

Identified Needs

Manufacturing Technologies

- **Manufacturing processes to accelerate miniaturization**
- **Assembly processes that support 3-D structures and low temperature processing.**
- **Warpage Reduction**
  - **Wafer**
  - **Package**
  - **PWB**
- **Lower testing costs, particularly for new non-digital technologies**

Paradigm Shifts

- Touch Screens becoming main stream.
- MEMs oscillators replacing quartz crystals.
- Emergence of photovoltaics.
- Energy Efficient Lighting.
- Printed electronics.
- Flash memory instead hard drives for lower power.
- Wafer level packaging is coming of age.
- ODMs for Cell Phones:
  - Especially for low cost models
  - Can also be used to level load OEM factories
- Migration of where and how passive devices are used.

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Board Assembly

Chuck Richardson will discuss

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Highlights from Board Assembly

- Miniaturization is a key driver in electronics industry:
  - IC Packaging
  - Board Assembly
  - Increased functionality of End Product
- End product manufacturing is increasingly commoditized:
  - Migration to low cost geographies
  - Relentless cost pressures
  - Low margin business
- New technologies are required to keep pace:
  - Green materials
  - Nanomaterials (e.g. temp. reduction of Pb-free solders)
  - Warm Assembly
- Have covered only highlights
- Many more details in full Roadmap

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Systems Packaging Evolution

Packaging TWG is common group between ITRS and iNEMI.

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The pace of change in Packaging is increasing

- As traditional CMOS scaling nears it natural limits other technologies are needed to continue progress
- This has resulted in an increase in the pace of systems packaging innovation.
- Many packaging processes have outpaced Roadmap forecasts. Among these are:
  – Wafer thinning and handling of thinned wafers/die
  – Wafer level packaging
  – Incorporation of new materials
  – 3D integration

"Consumerization" of electronics is the primary driving force.

System level Integration in the Package

The most important trend in packaging is the incorporation of system level integration through System-in Package

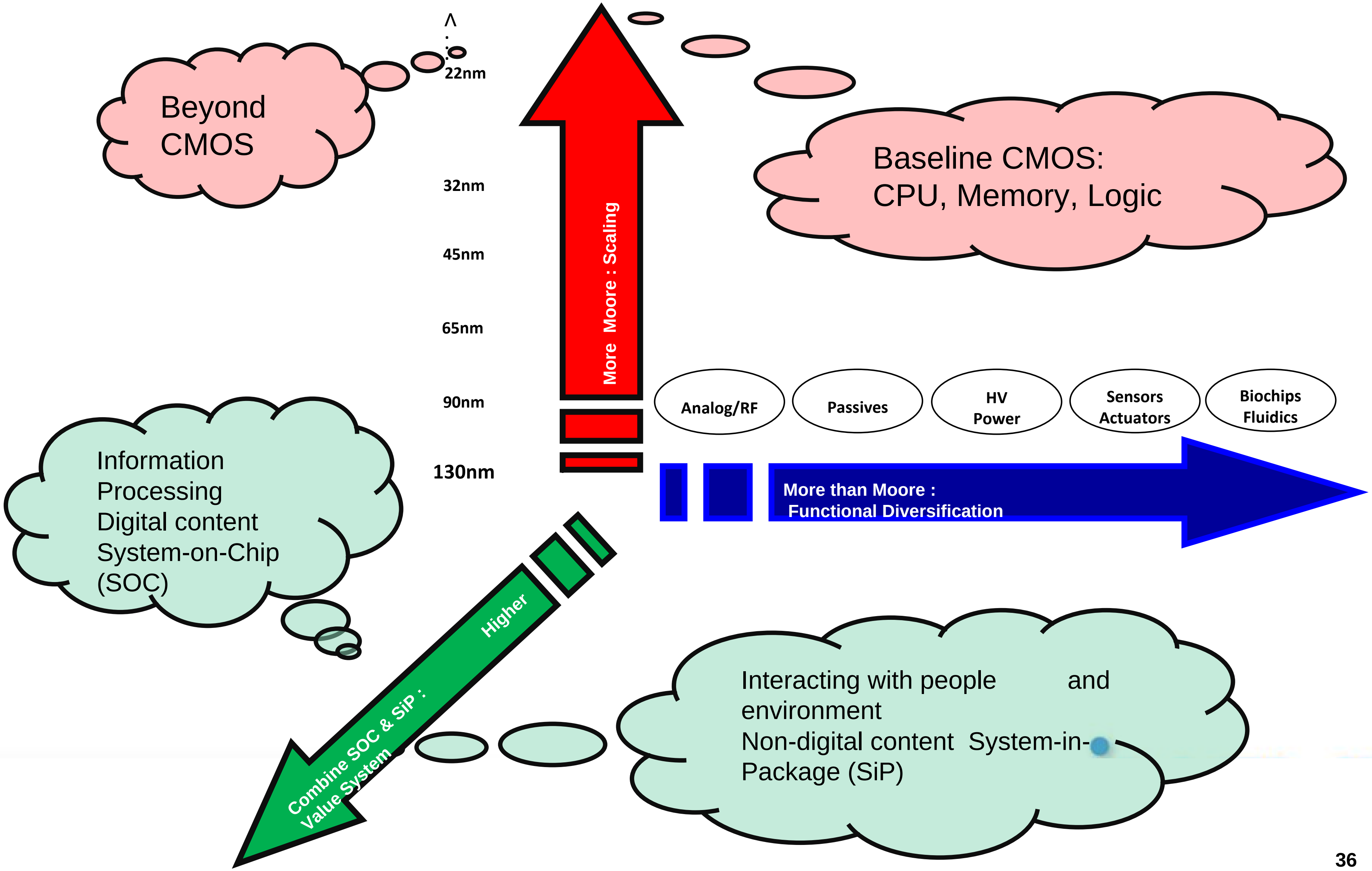
- **This enables equivalent scaling through functional diversification**
- **The result is a demand for new packaging capability requiring new technology and new materials:**
  - **Higher interconnect density in package**
  - **Increases thermal density**
  - **Test access challenges**
  - **More difficult demands associated with ensuring reliability**

All are addressed in the 2009 Roadmap

"More than Moore" is key to growth until a post CMOS switch is ready

- **Packaging innovation enables "More than Moore"**
  - **3D packaging technologies**
  - **Equivalent scaling through functional diversity**
- **Consumer markets drive innovation in packaging**
  - **Size, power, performance**
  - **Cost, time to market**
- **New materials required to meet today's market demand but will also enable many future advances in packaging.**

Moore’s Law Scaling can not maintain the Pace of Progress and Packaging enables equivalent scaling



Impact of Recession on System Packaging

- Will reduce the introduction of new high-tech products
- Increased packaging density at the SIP level will be achieved with current technology
  - Current technology uses a variety of existing approaches
  - Capital investment in new equipment and processes will be curtailed
  - Introduction of thru silicon vias (TSV) will be delayed
  - End of recession will require a rapid increase in introducing new packaging technology.

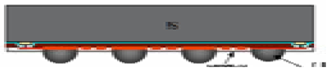
Wafer Level Packaging

- The answer to the historical lack of scaling in packaging to match the scaling in IC production.

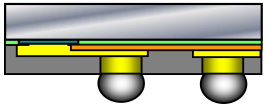
- WLP offers portable consumer products :
  - inherent lower cost
  - improved electrical performance
  - lower power requirements
  - Smaller size.

Wafer Level Packaging

Several architectural variations are in use today

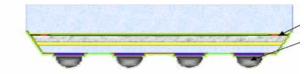


Wafer level CSP in the simplest structure



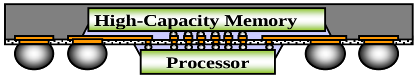
Wafer level CSP with copper post and resin mold

Opto wafer level CSP with tapered TSV interconnection

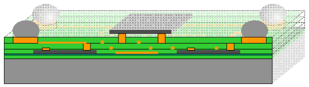


Opto wafer level CSP with beam lead metallurgy

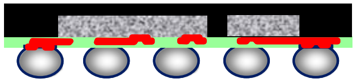
IPD embedded silicon substrate



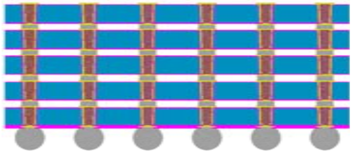
Build-up substrate through wafer level fabrication



Thin Chip Integration (Embedded device in polymer dielectric)



embedded Wafer Level Ball Grid Array



Stacked devices with Through Silicon Via´s (TSV)

System in Package

- The key to MtM functional diversification is System in Package. This technology enables:
  - Embedded active and passive components
  - MEMS integration
  - Wireless integration
  - Sensor integration
  - Analog circuit integration

---with traditional logic and memory integrated circuits

- ITRS Assembly & Package System In Package White Paper

http://www.itrs.net/Links/2007ITRS/LinkedFiles/AP/AP_Paper.pdf

SiP presents new challenges for Thermal management

- **High performance generates high thermal density**
- **Heat removal requires much greater volume than the semiconductor**
  - **Increased volume means increased wiring length causing higher interconnect latency, higher power dissipation, lower bandwidth, and higher interconnect losses**
  - **These consequences of increased volume generates more heat to restore the same performance**
- **ITRS projection for 14nm node**
  - **Power density >100W/cm2**
  - **Junction to ambient thermal resistance <0.2degrees C/W**

3D Packaging increases Performance Density and enables system level integration

Package Requirements

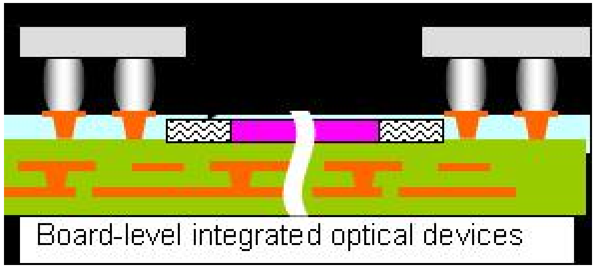
Year of Production	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Number of terminals—low cost handheld	800	800	900	900	1000	1000	1000	1000	1000
Number of terminals—high performance (digital)	3190	3350	3509	3684	3860	4053	4246	4458	4670
Number of terminals—maximum RF	200	200	200	200	200	200	200	200	200
Low cost handheld / die / stack	8	9	10	11	12	13	14	14	15
High performance / die / stack	3	3	4	4	4	5	5	5	6
Low cost handheld / die / SiP	8	9	11	12	13	14	14	14	15
High performance / die / SiP	6	6	7	7	7	8	8	8	9
Minimum TSV pitch	8	6	5	4	3.8	3.6	3.4	3.3	3.1
TSV maximum aspect ratio	10	10	10	10	10	10	10	10	10
TSV exit diameter(um)	4	3	2.5	2	1.9	1.8	1.7	1.6	1.5
TSV layer thickness for minimum pitch	20	15	15	10	10	10	10	8	8
Minimum component size (micron)	400X200	400X200	400×200	400×200	200X100	200×100	200×100	200×100	200×100
Maximum reflow temperature (°C)	260	260	260	260	260	260	260	260	260

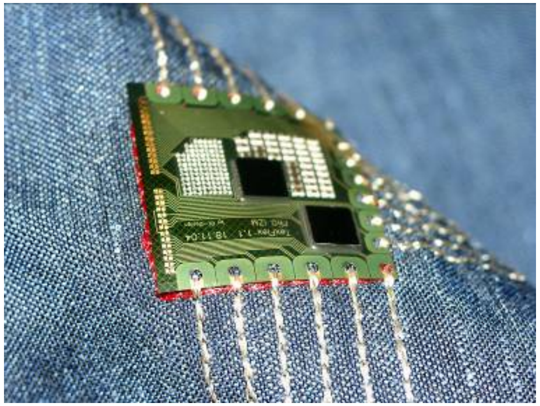
Current demands on Packaging technology present difficult challenges

- Major changes will be required in many areas to meet these challenges. These include:
  - Pb free transition presenting cost, reliability and process compatibility problems that are not resolved (High Rel. apps.)
  - A new generation of DFM and DFT will be required for complex SiP and SoC packaging
  - Stress induced changes in electrical properties for very thin die will require new solutions as thinner die emerge
  - Reliability for through wafer vias and die layer bonding is unproven
  - Warpage control for stacked die is essential for large die with fine pitch interconnect
  - Interconnect for nano-scale structures
  - Self assembly for very small die

New Packaging Technologies will be essential

- Thinned wafers
- 3D systems integration
- Wafer level packaging
- Bio-chips
- Integrated optics
- Embedded/integrated active and passive devices
- MEMS
- Flexible (wearable) electronics
- Printable circuits
  - Semiconductors
  - Light emitters
  - RF
  - Interconnect





Texflex embroidered interconnects (Fraunhofer IZM)

Summary of Packaging Evolution

- Packaging innovation enables "More than Moore"
  - 3D packaging technologies
  - Equivalent scaling through functional diversity
- Consumer market drives innovation in packaging:
  - Size, power, performance
  - Cost, time to market
- New materials are required to meet today's market demand but will enable many future advances in packaging.

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Evolution of Organic Substrate Technology

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Bifurcation of Organic Substrate Roadmap

- Packaging (and Organic Substrate) Roadmap
  - High Density Interconnect
    - May use embedded passive or 01005 discretes
    - May employ silicon "short stopper"
- Organic Printed Circuit Board Roadmap
  - High density PCB: will continue to use discrete devices
  - Low Density PCB

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Alternative Component Technologies:

Embedded Passives

Printed Electronics

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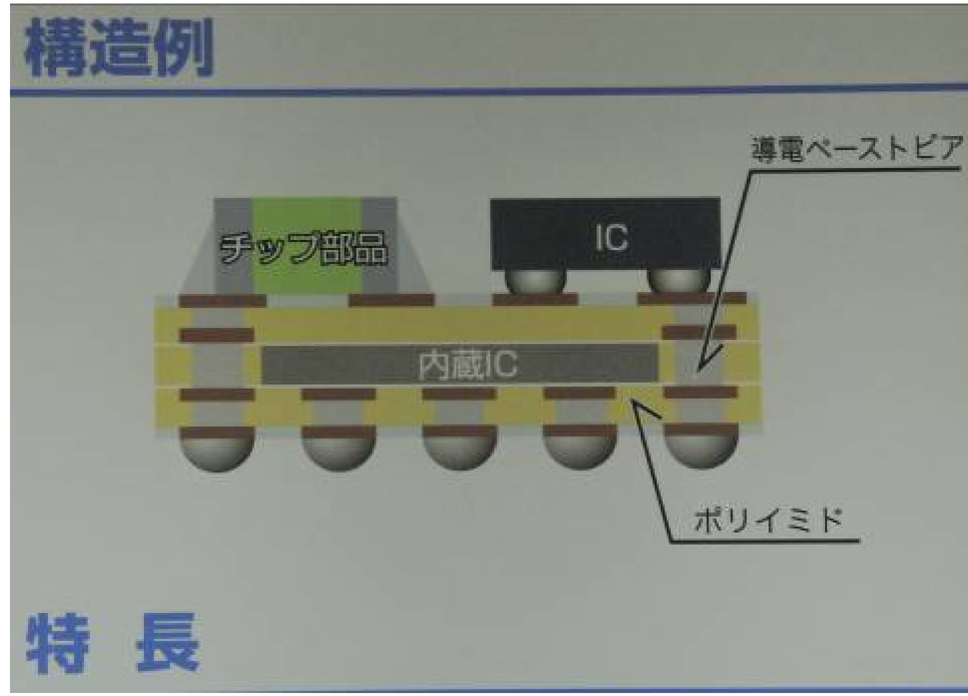
Examples of New Substrate Technology: 1) Embedding Active Devices

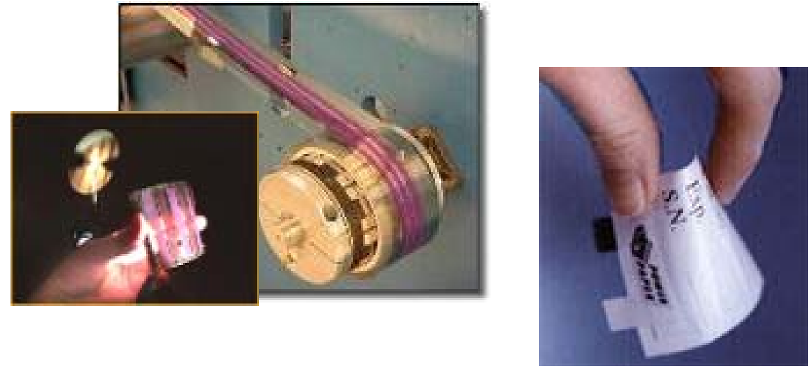


Embedding technology to improve performance at a lower cost

Printed Electronics Applications

Signage - $10B

Power - $16B



Lighting - $15B

Displays - $20B

*Data compiled from press and industry reports.

Printed Electronics Applications

Sensors - $10B

Logic/Memory - $30B

Air Baggage/Freight, Ticketing, RFID - $20B

*Data compiled from press and industry reports.

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2009 Environmentally Conscious Electronics (ECE) Roadmap: Future Initiatives for Sustainability

Scott O'Connell
Dell Inc.
Will Present

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Highlights of ECE Roadmap

- New global environmental requirements continue to multiply – faster than industry can effectively respond
- Industry needs to be more proactive in developing solutions that:
  - Are based on science and engineering, delivering value to customers
  - Are available in advance of new regulations
  - Can influence future regulations and stakeholder groups for more sustainable results
- iNEMI and its members plan to play a significant role in preparing industry for these future needs.
- Sustainability will be a major undertaking for industry as well as society.
- Electronic solutions can help to empower people to live a more sustainable lifestyle

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Emerging Energy Efficient Technologies

Solid State Illumination

Photovoltaics

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Highlights of These Emerging Technologies

- The advantages of energy efficiency is readily understood.
- Technology is attracting the attention
- The challenges is to increase energy efficiency while producing the products at a competitive cost.
- Alignment of supply chains for cost reduction to drive consumer acceptance is needed for solid state illumination
- Currently incentives are imperative for photovoltaics

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Conclusions

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Conclusions

- Consumer electronics has become the major driving force for our industry:
  - New technology to enable miniaturization
  - Relentless cost reduction
  - Volume manufacturing capability
- Packaging is Key Enabler providing higher density & smaller size:
  - More than Moore
  - 3D configurations, Improved performance
- New global environmental requirements continue to multiply – faster than industry can effectively respond
  - iNEMI and its members plan to play a significant role in preparing industry for these future needs.
- Sustainability will be a major undertaking for industry as well as society.
- Electronic solutions can help to empower people to live a more sustainable lifestyle.

www.inemi.org

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