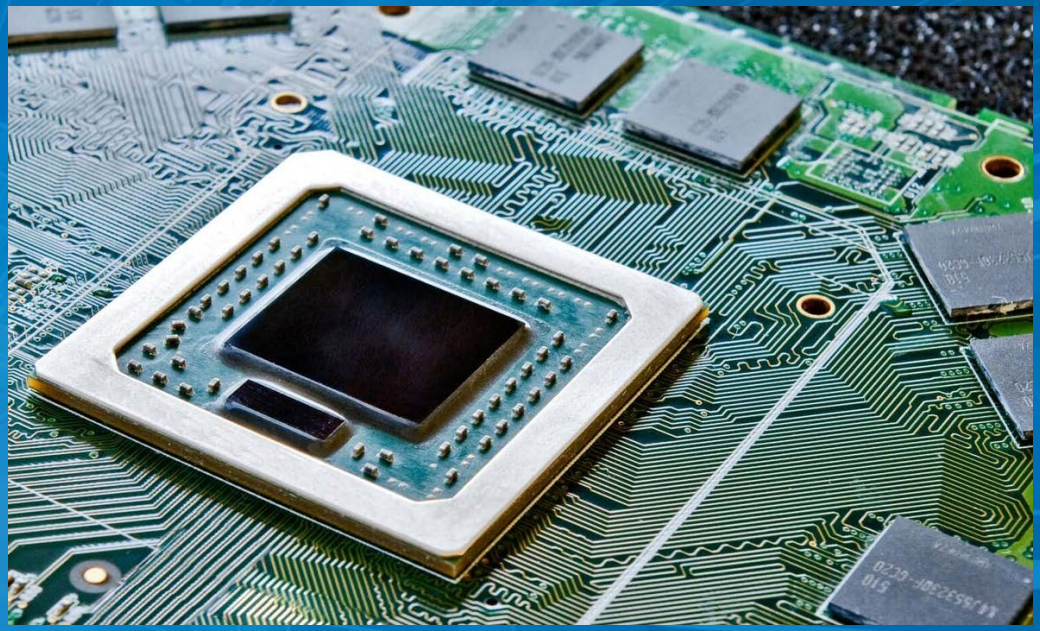
Future PCB fabrication and material requirements for the global industry segments



Steve Payne,
European Operations Manager
iNEMI

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Agenda

1. Introduction
2. Global Industry Segments (Market Sectors)
3. Future Fabrication and Material Requirements
4. Examples

   Polymer waveguides
5. Summary

Introduction

What is iNEMI?

Mission: Forecast and Accelerate improvements in the Electronics Manufacturing Industry for a Sustainable Future.

5 Key Deliverables:

- Technology Roadmaps
- Collaborative Deployment Projects
- Research Priorities Document
- Proactive Forums
- Position Papers

International Electronics Manufacturing Initiative (iNEMI) is an industry-led consortium of 100 global manufacturers, suppliers, industry associations, government agencies and universities. A Non Profit Fully Funded by Member Dues; In Operation Since 1994.

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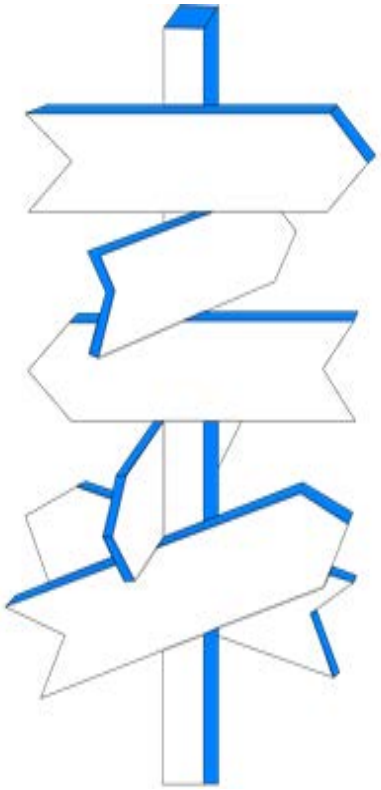
Unique iNEMI Roadmap in Electronics Industry

Outlook the next 10 years, update every other year, global participation, covers the full supply chain for electronics manufacturing

Statistics for 2017 Roadmap

- **> 500 participants**
- **> 350 companies/organizations**
- **> 20 countries**
- **Greater than 10 man years of resources in the development**
- **21 Technology Working Groups (TWGs)**
- **7 Product Emulator Groups (PEGs)**
- **Nearly 2000 pages of information**
- **Roadmaps the needs for 2017-2027**

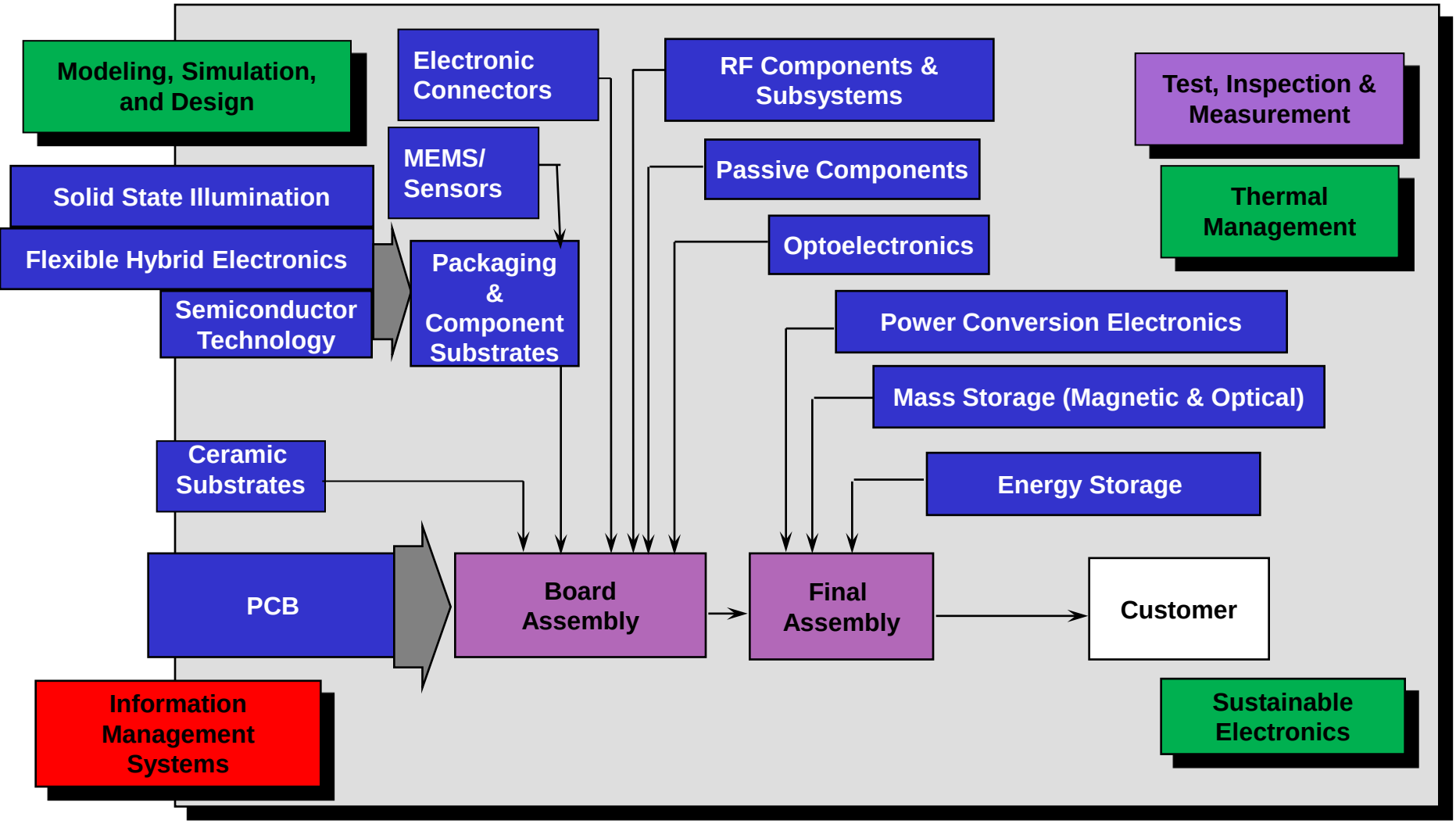
iNEMI Roadmap Process



Product Emulator Groups (PEGS)

- Aerospace & Defense
- Automotive
- High-end Systems
- IOT
- Medical
- Consumer & Office
- Portable & Wireless

2017 Technology Working Groups (TWGs)



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

Global Industry Segments

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Industry Segment PCB Requirements

- The iNEMI Roadmap looks at 7 Global Market Sectors
- Future PCB requirements are identified in each sector
- Many requirements are common such as miniaturisation
- Specific requirements can vary between Industry Segments
- The following chart summarises and simplifies a range of requirements for each market sector

Industry Segment – Key PCB Drivers

	Durability for Harsh Environment	High Reliability	Miniaturisation	HDI	Thermal	Volumes	Data Rate
Aerospace	✓	✓	✓	✓	✓	Low	✓
Automotive	-40 to 150C humidity vibration	✓	✓		✓	Medium	✓
High-end Systems		✓		✓	✓	Low	High speed high bandwidth, control impedance reduced latency
IOT inc. wearables)			✓	✓	✓	High	✓
Medical		implants bio-compatible signal integrity	✓	✓		Medium	✓
Consumer & Office			✓			High	✓
Portable & Wireless			✓	✓	✓	High	✓

Cost is a primary driver for all Segments

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Industry Segment PCB Requirements

- **There is commonality in requirements:**
  - **Miniaturisation**
  - **High density Interconnect**
  - **Reliability**
  - **Durability**
  - **Improved electrical performance: increased bandwidth, decreased latency …**
  - **Thermal performance**

- **Each requirement needs to be addressed through development of PCB Fabrication techniques, methodology and new materials.**

- **There are often multiple solutions dependant on Industry segment**

Quantification of PCB Drivers

Table 1: Selective Leading Edge TWG Drivers

Attribute	2011	2013	2015	2021
Printed Wiring Boards (PWBs)				
PWB Materials	FR-4, BI, GI Duroid	FR-4, BI, GI Duroid	FR-4, BI, GI Duroid	FR-4, BI, GI Duroid
Board Size Maximum (cm^2)	2000	2000	2000	2000
Number of Lamination cycles	1 – 6	1 – 6	1 – 6	1 – 6
PWB Pad Diameter (µm)	500	450	400	350
PWB PTV Diameter (µm)	200	200	150	150
PTV Aspect Ratio	12:1	15:1	15:1	20:1
PWB µ-via Diameter (µm)	100	100	75	50
µ-via Aspect Ratio	1:1	1:1	1.3:1	1.5:1
PWB Lines and Spaces (µm)	75/100	65/75	50/75	50/50
Components				
Max Component Complexity, I/O per package	2000	2500	2500	3000
Package I/O (perimeter) mm	0.4	0.4	0.4	0.4
Area Array Pitch (array) mm	0.65	0.5	0.25	0.25
Passive Components	01005	01005	01005	01005

Figure 2: 2017 Organic PCB Gap Analysis – Tactical

Yellow = Solution Not Optimized
Red = No Solution Known

Cluster	Priority	< 5 Years (Tactical) Gaps/Needs	Category	Comments:	2017	2018	2019	2020	2021
Electrical performance	M	Predicting loss values associated with copper trace roughness, oxide treatment and moisture content	D	Especially low loss laminates for high-speed communication and cost-sensitive but high-performance consumer categories					

Table 1 shows an example of predicted PCB requirements for a specific industry segment.

Figure 2 is an extract from the iNEMI GAP analysis showing where research is needed

Future Fabrication and Material Requirements

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Miniaturisation & High Density Interconnect

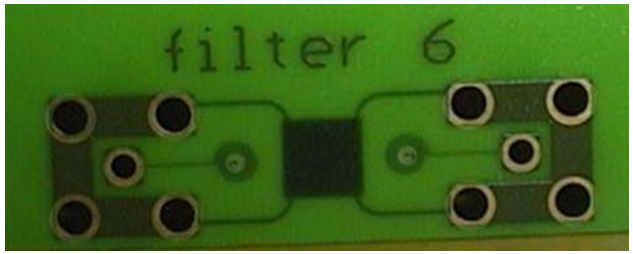
- **Motivation can vary between sectors and includes reduction in size (volume), achieving specific product form and / or reduction in weight.**
- **High Density interconnect aids miniaturisation and achieves dense interconnect routing for high I/O BGA devices or flip-chip on board**
- **Embedded components (active and passives)**
- **Requirements:**
  - **Fine lines (tracks) in volume with high yield**
  - **Proprietary build-up technology (BUT) multilayer PCB structures**
- **Achieved through**
  - **Advanced LDI and associated photomech equipment and materials**
  - **Semi-additive processing**
  - **Thin laminates (& thin coppers)**
  - **Improved conveyorised process equipment for thin materials…**

Miniaturisation & High Density Interconnect

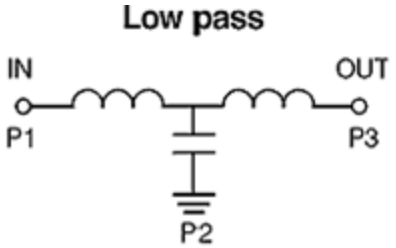
Embedded passives (R, L & C) can be either

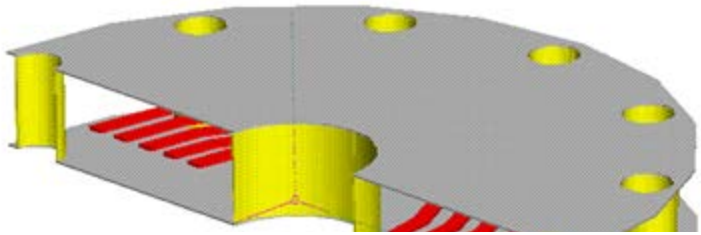
a) discrete chip components buried in inner layer structures or

b) as shown on this slide fabricated as part of the multilayer production methodology



3rd order low pass Butterworth filters fabricated as embedded passive in multilayer PCB





Integrated NiFe magnetic layers

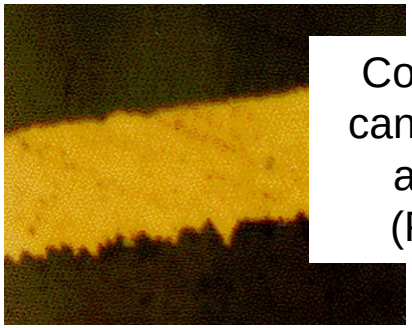
Commercially available resistive foil laminate

Data Rate (High Speed)

- High Speed and High Bandwidth, reduced latency …

Achieved through

- Material developments
  - Improved FR4 materials
  - Dedicated microwave materials



Copper surface roughness can increase conductor loss as frequency increases (Photo shows example)

Electrical performance	M	Measurement standards and improvement for smoother grain copper foil roughness	S	Standardize measurement terminology and preference for Ra vs Rs vs Rz vs RMS	
Electrical performance	H	Copper foil tooth reduction with increased adhesion to improve signal integrity	D	Improve adhesion of ultra-low profile copper foil to resin/glass laminate for use in outer layers and internal ground planes	

Extract from iNEMI 2017 Technical Plan (GAP analysis of iNEMI Technology Roadmap)

Data Rate (High Speed)

- Optical PCB (rigid & flex):
  - Polymer waveguides (materials)
  - Discrete fibres
  - Process development for consistent high yield process

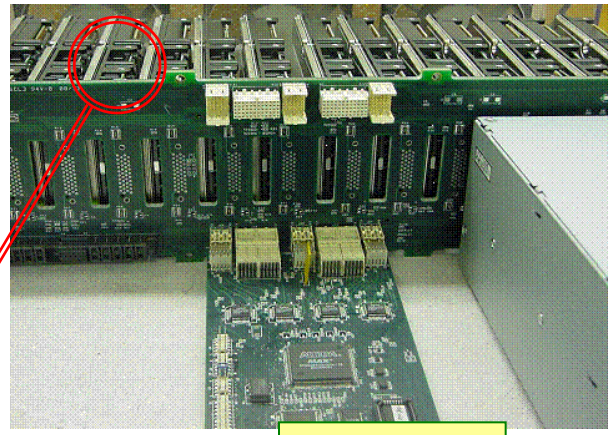
Extract from iNEMI 2017 Technical Plan (GAP analysis of iNEMI Technology Roadmap)

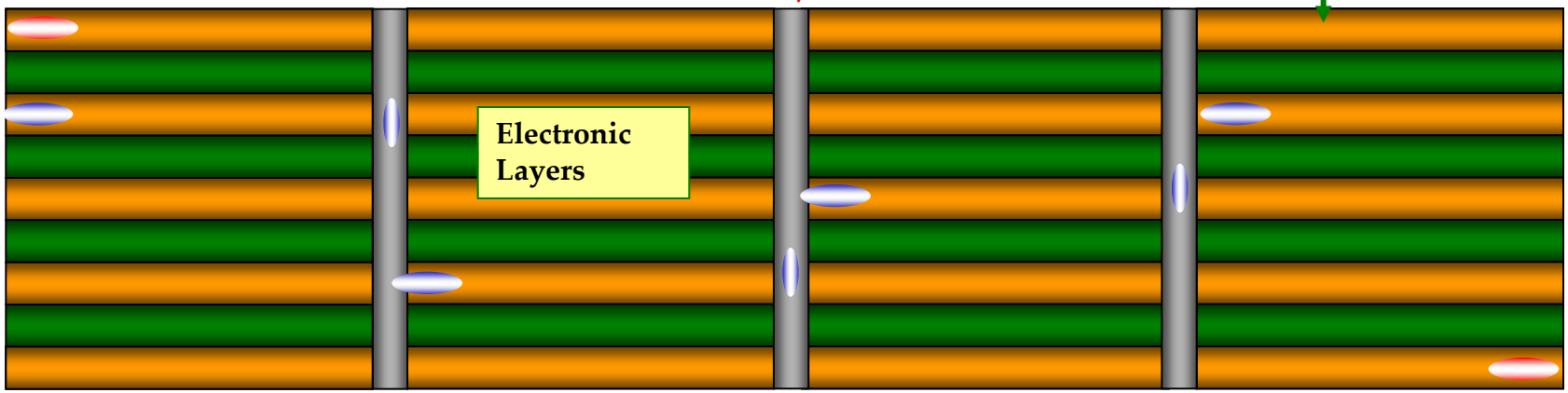
Priority	< 5 Years (Tactical) Gaps/Needs	Category	Comments:	2017	2019	2021	2023
H	Cost effective technical solution to replace copper with optical in backplanes.	D,O	Integration: Reduce power and save space in data centers. Need to reach <5pJ/bit at board level. Next generation of optical switches and routers will use the optical domain				
	Reliable modulated optical	D	Integration:				

ELECTRO-OPTICAL PRINTED CIRCUIT BOARD

Technology proposition

- Multiple layers for high and low speed communication and power distribution
- Today all copper layers
- Possibility to add optical layers for high speed traffic
- Methods and techniques available today but development needed





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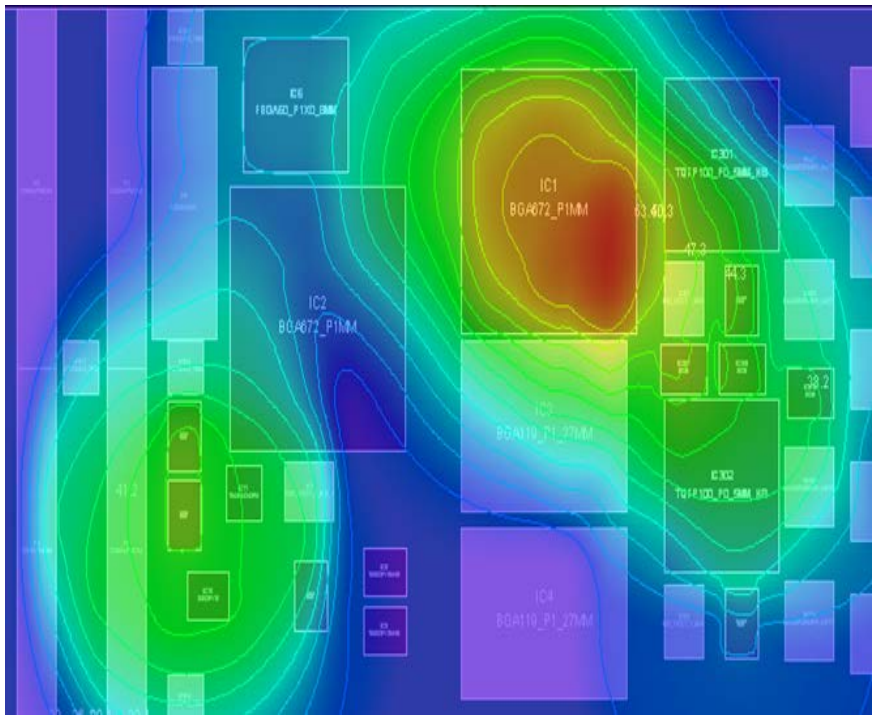
Thermal Management / High Temperature

- Thermal requirements
  - Cooling – thermal management (e.g. for LED illumination)
  - Durability at High Temperature
- Material requirements
  - High Tg & Td laminates
  - High (thermal) conductivity dielectrics
  - Metal backed laminates



Flexible Circuit Attributes

- Key trend is the rapidly growing product sector of flexible circuits
- Applications found in all market sectors from Medical to Aerospace
- High volume with high yield and low cost through Roll-2-Roll
- Very fine line circuits through semi-additive process
- Applicable for polymer wave guides
- Unique attributes:
  - Dynamic
  - Thin substrates - low weight
  - Stretchable
  - High temperature & high speed materials (PTFE / LCP)
  - No CAF concerns

Summary

Summary

- Historically PCB fabrication was undertaken by large (vertically integrated) electronic corporations that had extensive R&D resources.
- Through devolved supply chain PCB fabrication is mostly outsourced to a few very large and many medium sized companies.
- Technical capability is partly reliant on materials & equipment suppliers.
- PCB Fabricators can also benefit from participation in collaborative projects to leverage on collective expertise and involve complete supply chain.

Looking Forward

➢Business Trends

- o Over capacity in rigid PCB – consolidation of PCB fabricators
- o Increasing demand for flexible and rigid flex circuits
- o Critical material issues (copper availability) – environmental issues
- o Smart manufacturing drive

➢Technical Trends

- o Fine lines, micro-via holes and sequential build up technology
  - o Convergence of packaging and board level technologies
- o Embedded passive and actives
- o Optical & Electrical boards (polymer wave guide technology)
- o 3-D Circuits / 3-D printing

Smart Factory (Industry 4.0 & IIoT)

- An infrastructure of networked objects that interact with the physical world through sensors and actuators.

- Considerations:
  - PCB's are not commodity items
  - Large number of design variations
  - Low volumes often made in small batch production
  - All require reliability and durability
  - CAD systems output data formats for CAM

- Opportunities and Benefits
  - To influence supply chain from materials usage through to end user monitoring of manufacturing and test data
  - Optimum methods and techniques in manufacturing
  - High yield – less waste
  - Accelerates adoption of new processes and materials
  - Provides a high degree of confidence in meeting OEM requirements

www.inemi.org

Marc Benowitz
marc.benowitz@inemi.org

Grace O'Malley
gomalley@inemi.org

Steve Payne
Steve.payne@inemi.org

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