iNEMI
International Electronics Manufacturing Initiative

Board Assembly Roadmap
线路板装配路线图

Speaker: Jim McElroy, iNEMI

Chair: Dr. Dongkai Shangguan, Flextronics

Co-chair: Dr. Ravi Bhatkal, Cookson Electronics

Co-chair: Aaron Unterborn, Microsoft

Advancing manufacturing technology

Agenda 议程

- Chapter Overview 概览
- Key Trends 主要趋势
- Technology Gaps & Challenges 差距/挑战
- Disruptive Technologies 突破性技术
- Business Issues / Potential Barriers 商业问题/潜在障碍
- Summary总结

Chapter Overview 概览

Milestones 时间点

- **Team formation:**

  March 2008

- **Final report :**

  Sept. 2008

Contents 内容

- **Approximately:**

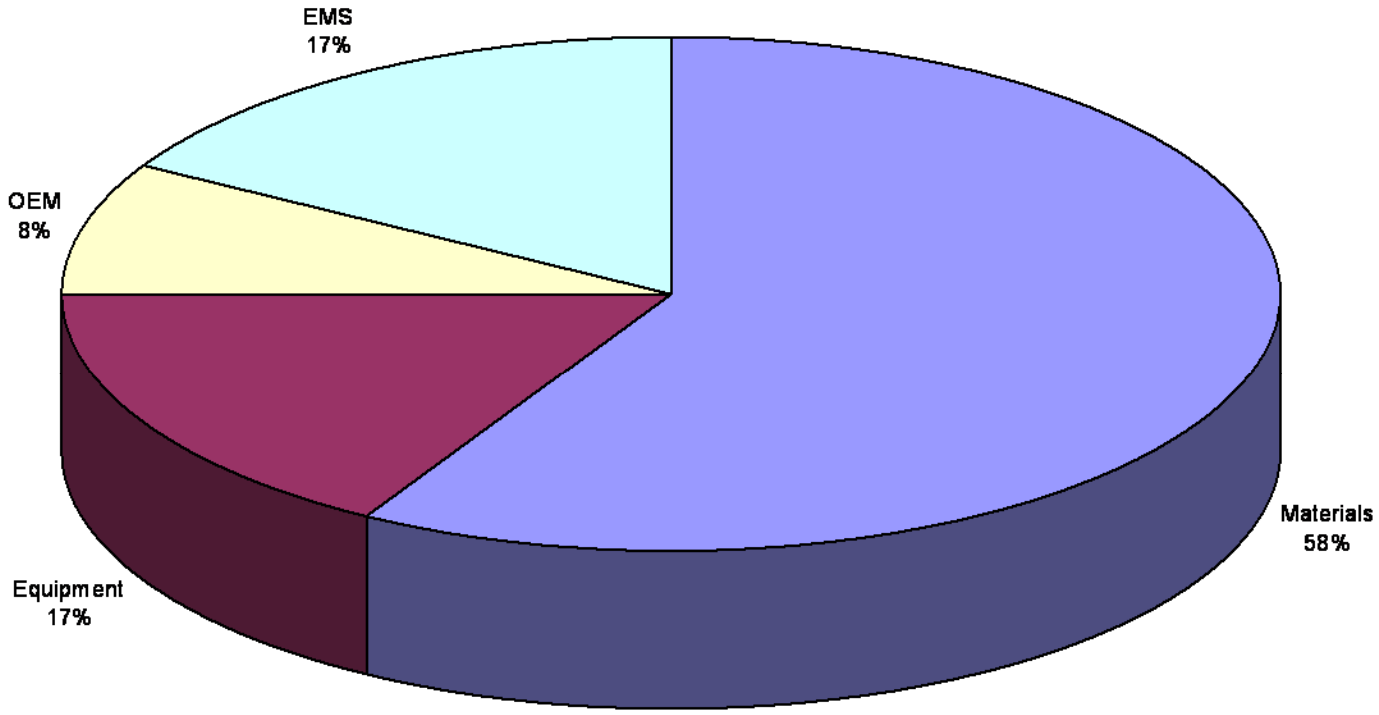
  71 pages / 26,000 words

  22 Tables / 8 Figures

- **Business / Technology**
- **Span: 10 yrs**

  (2009-2019)

Chapter Participation 参与者



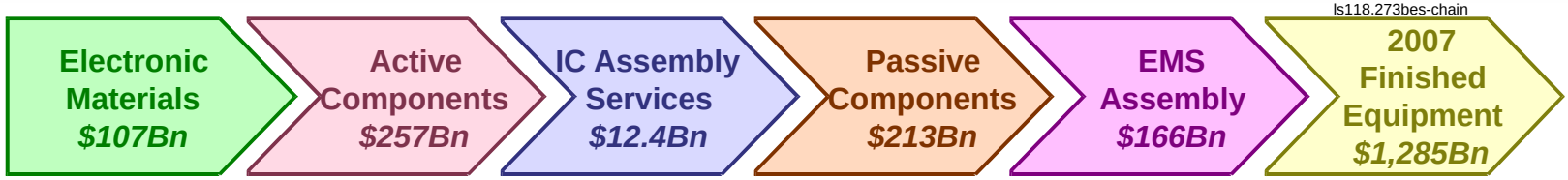
Key Trends 主要趋势

Business Environment 商业环境

- Higher level of service demand placed on EMS
- EMS companies are expanding offerings to include services in a wider range of a product's life cycle
- Increased role of EMS/ODM and materials/equipment suppliers in R&D and process development
- Continued migration to low cost regions
- Demands on cost reduction and low margins are driving consolidation among EMS companies

Value Creation in the Supply Chain 产业链的价值分布

ls118.273bes-chain



Typical Companies	Sumitomo Bakelite, DuPont, Henkel	Intel, STMicro, LSI Logic	Amkor, ASE, SPIL	Tyco, Molex, AVX, Sharp	Sanmina-SCI, Flextronics, Jabil, Hon Hai	Dell, HP, Cisco, Nokia, Teradyne, Visteon, Siemens
Gross Margin	**40%**	**40%**	**17%**	**25%**	**6%**	**30%**
Operating Margin	**10%**	**10%**	**8%**	**8%**	**2%**	**8%**
R&D	**7%**	**10%**	**2%**	**3%**	**<1%**	**3%**
Margin Value	**$11Bn**	**$26Bn**	**$0.2Bn**	**$17Bn**	**$3Bn**	**$103Bn**
R&D Value	**$5Bn**	**$26Bn**	**$0.2Bn**	**$6Bn**	**$1Bn**	**$38Bn**
%Total R&D	**7%**	**34%**		**8%**		**51%**

Source: Prismark Partners

Key Trends 主要趋势

Main Drivers for Development in Board Assembly

线路板装备的发展动力

- **Conversion cost reduction 转换成本缩减**
- **Increased Component I/O Density (miniaturization) 小型化**
- **Transition to environmental and regulatory requirements**

  环境和法规要求
- **Reduction in New Product Introduction (NPI) Time**

  新产品导入时间的缩减

NPI Capability Enhancement Priorities
增强新产品导入能力的优先级

Short-term Priorities (1 – 3 years)

- Elimination of hard tooling from current manufacturing processes
- Elimination (or easy identification) of counterfeit parts from the supply chain

Medium-term Priorities (3 – 7 years)

- Modeling and simulation tools need to push towards the reduction / elimination of Functional Verification steps.
- DfX rule systems:
  - Must accommodate new component and assembly technologies
  - DFX industry standards are valuable but development /revision cycle too long

Long-term Priorities (8+ years)

- NPI cycle time can be improved with a change to deposited materials which could replace discrete components.
- Material developments may help qualify high reliability applications.
- New interconnect technologies may provide flexible routing options, reducing PCB fabrication cycle time.

Key Trends 主要趋势

Technology Trends 技术 (examples of solutions)

- **SiP solutions 系统级封装方案**
- **Embedded components 嵌入元器件**
- **Flexible tooling solutions 柔性加工方案**
- **Optimized production equipment sets 优化生产设备配置**
- **Optimized production line configurations 优化产品线配置**

Impact of Embedded Passive Implementations
无源器件嵌入的影响

Embedded Passive Type	Board Assembly Impact
Second Level Substrate	Handling / Manufacturing Process which does not adversely impact the embedded passive performance
	Reduction in the number of placement machines
	Need for placement equipment with higher flexibility
	Known good substrate
	Increased board thickness due to additional layers
	Increased thermal mass of substrates
Package Level Substrate	Need for placement equipment with higher flexibility
	Known good substrate
	Advancements in board handling due to increased adoption of ceramic substrates
	Increased thermal mass of substrates
Interconnect Level	Equipment for integration of the passives on the termination
	Known good die
	Interconnect technologies for the passives on the termination
	Reliability understanding of integration of the passives on the interconnect

Assembly Materials Technology Needs 装配材料

Parameter	Definition	2007	2009	2011	2019
Bar Solder	Lead-free % US	30%	50%	75%	95%
	Lead-free % WW	75%	90%	95%	95%
	Alloy	SAC/Sn-Cu	SAC/Sn-Cu	SAC/Sn-Cu	SAC /Sn-Cu
	Alloy			Low Temp	Low Temp
Solder Pastes	Lead-free % US	30%	50%	75%	90%
	Lead-free % WW	60%	80%	85%	90%
	Alloy	SAC	Lower Silver SAC	Lower Silver SAC/Low Temp.	Lower Silver SAC/Low Temp. Lower Silver SAC/Low Temp.Temp
	Halogen-free	85%	90%	95%	95%
	Recycle ratio	5%	10%	25%	25%
Wave Solder Flux	VOC Free	40%	50%	60%	90%
	Halogen free	95%	95%	95%	95%
Die Attach Preforms	Thermal conductivity critical	85%	90%	90%	90%
	Matched CTE capability	5%	7%	25%	50%
Die Attach Adhesives	Lead-free compatibility JEDEC +260 reflow, small die, paste	JEDEC L1 @260	JEDEC L1 @260	JEDEC L1 @260	JEDEC L1 @260
	Lead-free compatibility JEDEC +260 reflow, large die, paste	JEDEC L2 @260	JEDEC L1 @260	JEDEC L1 @260	JEDEC L1 @260
	High thermal (polymer based) paste	>30 W/m-K	>50 W/m-K	>100 W/m-K	>100 W/m-K
	Compatibility with Low-k ILD, paste	JEDEC L2 @260 90 nm tech	JEDEC L1 @260 65 nm tech	JEDEC L1 @260 45 nm tech	JEDEC L1 @260 32 and below nm tech
	Pre-applied polymer DA to silicon	JEDEC L3 @260	JEDEC L2 @260	JEDEC L2A @260	JEDEC L1 @260

Assembly Materials Technology Needs 装配材料(2)

Underfills	Lead-free FC in package (Laminate) BGA balls only	JEDEC L3 @ 260, BGA balls only	JEDEC L2 @ 260, BGA balls only	JEDEC L1 @260, FC bump and BGA balls	JEDEC L1 @260, FC bump and BGA balls
	Lead-free FC in package (ceramic), BGA balls only	JEDEC L1 @260, BGA balls only	JEDEC L1 @260, BGA balls only	JEDEC L1 @260, FC bump and BGA balls	JEDEC L1 @260, FC bump and BGA balls
	Low K ILD	JEDEC L3 @260 90 nm tech	JEDEC L2 @260 65 nm tech	JEDEC L2 @260 45 nm tech	JEDEC L2 @260 45 nm tech
	Pre-applied FC	JEDEC L3 @260	JEDEC L2 @260	JEDEC L2A @260	JEDEC L2A @260
	Large Die	25 mm Low K	25 mm low K	30 mm low K	30 mm low K
	CSP	Pre-applied Lead-free	Reworkable 5%	Reworkable 25%	Reworkable 25%
Conformal Coatings	Lead-free	Compatible with Lead-free residues	Compatible with Lead-free residues	Compatible with Lead-free residues	Compatible with Lead-free residues
	VOC	VOC-Free	VOC-Free	VOC-Free	VOC-Free
Nano-materials	As fillers	Small Commercial Quantities	Large Quantities?		

Key
Current Capability
In Development
Research Needed

Technology Gaps and Challenges
技术差距和挑战

Materials材料

PCB / Substrate 线路板/基材

- Higher use of flexible and low loss materials 更多使用柔性低介电损耗材料
- Substrate technologies need to be able to keep up with demands of miniaturization 基材技术要能满足小型化的需要
- CTE mismatch at the 2nd level interconnect, package warpage and resulting assembly problems 热膨胀系数和二级互连、封装热变形的不匹配带来装配问题
- Reliability impact of decreasing pad diameters (2^{nd} level assembly). 焊盘尺寸对可靠性的影响
- Transition to embedded passives (in Portables) 嵌入无源器件
- Assembly process impacts of HFR-free transition 无卤转换对装配工艺的影响

01005

- Component availability for the range of values required 供应能力
- Cost 成本
- Assembly process development 装配工艺

Technology Gaps and Challenges技术差距和挑战

Materials材料

Die attach晶片粘着材料

- Low thermal resistance materials due to increased power density 低热阻材料
- Increased pre-form use driven by:要求预制
  - Thermal conductivity 导热性
  - CTE requirements 热膨胀
- Lead-free compatible 无铅供应兼容
  - Higher reflow temperatures and new materials 高回流温度和新材料
  - Compatibility with new solder masks 和新的阻焊材料兼容
- Compatibility with stress-sensitive low-K material 兼容应力敏感低K材料
- Thermal and moisture resistant polymers 抗热防潮的聚合物
- Non-Ag fillers to reduce cost 无银填充剂以降低成本
- Lower temperature cure to reduce assembly cost and reduce warpage for stress sensitive applications 较低的固化温度以降低装配成本，并降低应力敏感场合下的热变型

Technology Gaps and Challenges

Materials 材料

Conformal Coatings共性覆膜

- Conformal coating materials/processes that are compatible with lead-free solder materials/processes 和无铅工艺/材料兼容
  - Mitigate lead-free issues such as Sn-whisker formation 消除无铅问题如锡须的形成
- Compatibility with various lead-free materials 和各种无铅材料兼容:
  - Mold compounds
  - Solders
  - solder mask
- Low or non-VOC conformal coatings 低/无挥发性物质

Technology Gaps and Challenges

Materials材料

Solder焊料

- Close knowledge gaps of today's Pb-free solders:
  - Material metallurgy 材料晶相
  - Processability 工艺
  - Reliability 可靠性
- Develop next generation of Pb-free solder materials开发下一代无铅材料:
  - Replace high cost Ag-containing alloys for cost-sensitive applications 替代含银合金
  - Meet needs for low temperature attachment requirements for polymer based products 低温装配
  - Improve the SAC alloys in order to overcome several critical concerns 改善SAC:
    - Wider process window
    - Copper dissolution during wave / selective soldering and rework
    - Reliability under high strain rate (mechanical shock)
    - Reliability for smaller solder joints with low stand-off
    - Rework
  - Deployment of Alloy alternatives 开发替代合金
  - New interconnect technologies (e.g. based on nano-materials) to support tight pitch 利用纳米材料的新的互连技术来支持低间距高互连度的需求

Technology Gaps and Challenges

Materials 材料

Underfill 底胶

- Reworkable underfills for返工:
  - Large die/packages 大封装
  - Fine pitch packages 微细间距封装
- Underfill chemistries to meet fill time and voiding requirements for low stand-off components填充时间并避免低间隙器件的填充气泡
- Improved thermal and hydrolytic stability 改善热和水解稳定性
  - Driven by high temperature of Pb-free assembly
- Pre-applied underfills to both silicon and substrate 预置底胶
  - Reduce cost
- Selective encapsulation and bonding (e.g. corner bond) 选择胶接
  - Reduce cycle time
  - Improve process consistency

Technology Gaps and Challenges

Processes工艺

Paste Deposition 锡膏沉积

- **Wide range of required paste volume deposited on mixed technology boards is pushing stencil design rules to their limit!**

  锡膏体积要求的较大差异使丝网印刷设计接近极限

  - **Finer solder powder for fine pitch applications**
  - **Need for improved stencil, printing, and materials technologies to increase deposit consistency**
  - **Increased stencil design accuracy (<12.5µm for 01005)**
  - **Increased transfer efficiency with lower area ratio**
    - **Thicker stencil**
    - **Smaller aperture**
  - **Non-traditional technologies for solder paste deposition**
  - **Interconnect materials patterned on the PCB without the use of a mask, stencil or screen.**

Technology Gaps and Challenges

Equipment 设备

Placement Equipment 贴片设备

- Ability to monitor the incoming component quality检测能力:
  - Real-time, during the placement process 实时
  - While still providing a reasonable ROI 投资回报率
- Integration of press fit technology in the SMT process will improve productivity with the higher adoption of flexible tooling将连接件插装集成到SMT工艺过程
- Odd form capabilities 不规则器件
- Flexible circuit assembly 柔性电路的装配

Technology Gaps and Challenges

Processes & Equipment 工艺设备

Reflow Equipment回流设备

- More efficient reflow technologies, possibly combining reflow technologies such as thick film elements, microwave elements, positive thermal expansion elements, and induction heating, with conventional convection reflow 提高回流的效率，回流技术集成
- Vapor phase 汽相回流

Pb-Free Wave & Selective Soldering 无铅波峰和选择性焊接

- Equipment upgrades to meet needs of new alloys
- Design guidelines
- Improvement in flux chemistries to promote wetting
- Achieving adequate PTH hole-fill for large and thick boards

Reflow Technology Forecast 回流技术的预测

Parameter	Metric	2007	2009	2011	2013	2019
Temperature Delta Performance Lead-free Processing Maintenance	Cross Conveyor Uniformity at Peak temperature - LF profile (°C)	7	7	5	4	4
	Along Conveyor Uniformity at Peek temperature - LF profile (°C)	10	10	7	5	5
	Peak Temperature Repeatability of a given thermal couple (°C)	5	5	4	3	3
Inert Capability	Scfh (ppm levels)	100	100	100	100	100
Cooling rates	Solder joint reliability	4°/sec	6°/sec	6°/sec	6°/sec	6°/sec
Flux Management	Flux collection	Self Cleaning	Self Cleaning	Advanced flux chemistry and better containment	Advanced flux chemistry and better containment	Elimination of flux management
Cost of Operation, Energy & Consumption	Reduction in operating costs	70%	60%	50%	40%	40%
Traceability	Ability to link process parameters and changeovers to equipment	GEM/ SECS	Data logging XML connectivity SPC	Auto collection of data and warnings	Closed loop control	Tracking of all products and materials processed
Change over time	Total time from one product to the next with significant temperature profile change	25 minutes	20 minutes	17 minutes	15 minutes	10 minutes

Technology Gaps and Challenges技术差距和挑战

Processes工艺

Rework 返工

- Increasing package density and smaller components with lower stand-off challenge assembly cleaning and rework 高封装密度、小器件小间隙装配的清洁和返工
- High component pin counts, larger component body sizes, and tighter component pitches will challenge rework placement accuracy and reflow techniques 大尺寸、多焊脚、细间距返工
- Narrower process window for rework due to higher Pb-free process temperatures 无铅返工较窄的工艺窗口
- Rework for fine pitch (0.4mm) devices and 01005 微细间距器件和01005器件的返工

Technology Gaps and Challenges技术差距和挑战

Processes 工艺

Rework 返工

- PTH 通孔
  - Complete hole-fill and Cu dissolution for Pb-free rework (using a mini-pot) 无铅返工的满孔填充/铜分解问题
  - Process to remove and replace PTH in a single step 一步替换通孔焊接器件的工艺
- Area array packages 阵列封装
  - Mini-stencil paste printing
  - Special tooling for package size >50mm
  - MSL issue 湿气敏感性

Technology Gaps and Challenges技术差距和挑战

Processes & Equipment 工艺和设备

Press-Fit 压接

- Development of automated connector placement equipment capable of pre and post inspection of the connector开发自动的连接件插装设备，以及装配前后的连接检测:
  - Placement process is slow and manually intensive
  - Limited automatic placement due to lack of standardization of connector trays
- Development of a methodology that is capable of doing 100% inspection of pins pressed into the same barrel from both sides同孔内两端插脚进行100%检测的方法
  - methodology needs to be scaleable due to the large size of the backplanes
- Need to develop common tooling to rework connectors 返工工装
  - Especially for rework on individual pins in a connector
- Pins are spaced closer together over time, which increases the difficulty to meet the true position requirements 插脚间距减小
- Sn whisker mediation in fine pitch connectors 锡须

Technology Gaps and Challenges技术差距和挑战

Processes & Equipment 工艺和设备

- **Development of automated printing, dispensing, placement, and rework equipment capable of the pitch requirements for SiP package assembly 开发自动印刷、分注、贴片和返工设备，以满足细间距和系统级封装装配的需要**

- **The increased need for 3D board assembly requires innovation in *every step* of the board assembly process**

  3D线路板装配要求装配工艺的每一步都需要有创新

  - **Paste deposition, component placement and attachment, inspection and test, etc.**
  - **Equipment supply base to support material handling of flexible/low loss substrates**

- **Optical interconnects will generate challenges for Board Assembly materials, methods and equipment 光纤连接**

Technology Gaps and Challenges技术差距和挑战

Inspection, Test and Reliability检查、测试和可靠性

- Inspection/Test technologies need to keep up with the increasing density of board designs and complexity of component packages 检查/测试技术要跟上密度和器件封装复杂性日益增加的步伐

- Industry standard for ion chromatography testing as related to product reliability 离子色谱法测试产品可靠性的标准

Disruptive Technologies and Events突破性技术和事件

1. **Environmental Drivers环境问题:**
   - **New interconnect materials development driven by REACH regulations?**
   - **New industry (iNEMI) pro-activity toward HFR-free and other issues**
2. **Development of alternative materials (nano solder, conductive adhesives) and processes (warm assembly, nano-velcro)** 替代材料和工艺 （纳米焊料、导电胶、热装配、纳米连接）
3. **Printing Process** 印刷工艺**:**
   - **The need for finer pitch, smaller volume deposits, & non-planar surfaces may drive alternative deposition schemes**
   - **Divergence of package sizes will drive new assembly approaches**
   - **Fine pitch packages developed for Portable products may get used for larger boards in other segments.**

Disruptive Technologies and Events突破性技术和事件

1. **Energy Costs Will Drive New Process and Materials Development as well as Geographic Footprint for Assembly. 能源成本将驱动新材料和工艺的开发以及装配制造的地区性转移**
2. **Convergence of Packaging & Board Assembly Will drive changes in industry supply chain. 封装和线路板装配的综合将引起供应链的改变**
3. **Embedded PCBs 嵌入器件线路板:**
   - **Embedding active, passive, and optical components in PCBs, in various formats will present challenges for the PCB fabrication & assembly processes.**
   - **Will inevitably impact the configuration of the supply chain.**
4. **Printed Electronics印刷电子:**
   - **Printed Electronics may have direct impact on many elements of the Board Assembly supply chain, including equipment, materials, and processes.**

Business Issues / Potential Barriers 商业问题/潜在障碍

- **Supply chain readiness to deal with the transition to Pb-free/HFR-free/REACH/ 供应链是否准备好无铅/无HFR/REACH的转移?**
  - **Ability for the supply chain to support both SnPb containing and Pb-free BoM's**
  - **Ability to support the cost reduction targets with the transition to Pb-free/HFR-free**
    - **Increased energy consumption, material cost increase, and yield issues**
    - **EMS, ODM, and OEM companies need to work on creative engineered solutions to bridge these gaps**

Business Issues / Potential Barriers 商业问题/潜在障碍

- **Emerging technologies 新技术的需求**
  - **Board assembly is a low margin business and this limits R&D funding 线路板装配的低利润空间，有限的研发投入**
  - **Government, academia and industry consortia will need to formulate ways to encourage technology development for closing gaps identified 需要合作**
- **DFM in the global outsourcing environment requires closer interaction and collaboration across the supply chain 面向生产的设计（DFM）要求产业链各部门的沟通和合作**
  - **Industry standards need to be further developed to facilitate and streamline information flow 工业标准**

Summary 总结

- Miniaturization is a key driver in electronics industry小型化:
  - IC Packaging
  - Board Assembly
  - Increased functionality of End Product
- End product manufacturing is increasingly commoditized: 制造的商业化
  - Migration to low cost geographies
  - Relentless cost pressures
  - Low margin business
- New technologies are required to keep pace 新技术:
  - Green materials
  - Nanomaterials (e.g. temp. reduction of Pb-free solders)
  - Warm Assembly
- Have covered only highlights from Board Assembly Roadmap 只覆盖了线路板装配的一部分概要

www.iemi.org

Contact info.

Dr. Dongkai Shangguan
Chair – Board Assembly

Vice President
Assembly Technology & Platform Realization
Corporate Technology Group
FLEXTRONICS

(408) 428 1336
Dongkai.Shangguan@Flextronics.Com

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