Opportunities for SEMI Members in Flexible Hybrid Electronics

Michael Ciesinski, President
FlexTech
Today’s Presentation

• FlexTech Introduction
• A New Era in Electronics is Emerging
• Customer Interest in FHE
• Summary
• Q&A and Discussion
The 
Mission --- now as part of SEMI

Advocate for the FHE Industry

Build awareness within stakeholder communities about flexible hybrid electronics (FHE) and the impact of the technology on products and markets.

Champion R&D Funding

Work with the community to create advanced systems that leverage FHE strengths of lower weight, lower power, printable and large area electronics.

Connect & Educate

Develop and sponsor conferences, workshops, webinars and other networking opportunities for our community.
What If....?

Medical information is immediate, digital and wireless?

Cheap, smart sensors are embedded in everything from aircraft surfaces to human tissue?

Displays are the product?

Power is truly lightweight, robust and extremely thin?
SEMI Members Currently Supply the IC and FPD Industries
A New Era of Electronics is Emerging

Flexible Electronics

Health Monitoring

The Internet of Things

Personal Devices
Flexible, Hybrid Electronics \textit{(simplified)}

- **Display\,*\**
- **Polymer Solar Cell\,#**
- **Processor\,+\**
- **Flexible Substrate**
- **Sensors\,*\**
- **Memory\,+\**
- **Thin Film Battery\,#**
- **Communications Interface\,*\**
- **Antenna\,#**

\textbf{Notes:}
\begin{itemize}
  \item \# Mostly printed
  \item \* Can be printed
  \item \+ Not usually printed
\end{itemize}

Source: FlexTech Alliance
Changes in Substrates and in Manufacturing

• The new substrates flex, expand, contract, shift and are sometimes transparent
• The eventual manufacturing objective is roll-to-roll instated of plate-to-plate or wafer-to-wafer
  • Printing electronics can replace some vacuum processes
• For flex hybrid electronics multiple components are integrated
  • Sensor, Power, Memory, Display, Communications, Other
• Integration and automation will be key
Flexible Hybrid Electronics are....

**Flexible:**
- Not rigid: plastic, paper, fabric. Also glass, metal foil, ceramic

**Hybrid:**
- Combination of printing & silicon-based die (usually thinned)
- Combine intelligence + printed (see →)
- Components must stay attached when flexed and stretched

**Printed Electronics:**
- Using conventional printing technique
- At atmosphere
- Conductive inks
- Bigger market, but less challenging
Advantages of Devices Based on FHE

- Enable electronics to use less power & be lighter
- Manufacture more economically and closer to the customer
- Conform to people and things (get out of the box!)
- Enable new electronics markets: Internet of Things, Smart Packaging, medical and healthcare devices
- Environmentally more friendly

**Manufacturing Challenges:**
- Integration Strategies
- Modeling & Simulation Tools
- Prototype Development
- Moving to Pilot line
- Roll-to-Roll Web Processing
- Packaging & Pick-Place
- Toolsets
- Printers throughput
- Material Handling
- Test & Reliability

**Applications/IoT:**
- Human Health Monitoring/Wearables
- Structural Health Monitoring
- Consumer Goods
- Smart Packaging/Secure Packaging
- Solar/PV/Energy harvesting
- Pharmaceuticals
- Smart Sensor Systems
- And Many More.....

**Advanced Materials:**
- Functional Inks
- Nanomaterials
- Graphene
- Adhesives
- Encapsulants
- Substrate Materials
- Bio-recognition Elements
Interest in FHE Across Multiple Industries

[FlexTech FHE MII diagram]

- Workforce Training
- End-Users
- Deposition/Printing
- Flex Substrates
- Nano-Bio
- Design, Modeling & Testing
- Packaging
- CMOS Thinning
- Equipment & Materials
- Standards
- Education & Workforce Development
- Commercialization
- Technology Development TRL & MRL 4-7
- Hands-On Demo Facility
- Commercialization Centers
- Dedicated Staff for Workforce Development
- Dedicated Staff for Technology Dev.
- Dedicated Staff for Commercialization

[Logos and companies mentioned]
Participation at Flex Conferences 2015-2016

**Japanese Companies**
- Asahi Glass
- FujiFilm Dimatix
- Kimoto
- Mitsubishi Gas and Chemical
- SCREEN
- Sharp
- Sumitomo

**Global R&D Institutes**
- AIST
- Fraunhofer
- Holst Center
- IMEC
- ITRI
- NextFlex
- SRI
- VTT
- Xerox PARC
In your opinion, will flexible and printed electronics become widely integrated into commercial products within...

- 40.5% within 1 Year
- 35.7% within 3 Years
- 14.3% within 5 Years
- 9.5% within More than 5 Years
If your company or organization is planning on purchasing flexible, printed electronics in the next 1-3 years, roughly what is the annual unit volume expected?

- 42.9%: <100K units
- 26.2%: 100K - 1M units
- 16.7%: 1M units - 10M units
- 11.9%: 10M units - 50M units
- 2.4%: >50M units
- 0.0%: N/A
Flexible Electronics Market Forecast

IDTechEx: Total market for printed, flexible and organic electronics will grow from $26.54 billion in 2016 to $69.03 billion in 2026. The majority of that is OLEDs (organic but not printed) and conductive ink used for a wide range of applications. On the other hand, stretchable electronics, logic and memory, thin film sensors are much smaller segments but with huge growth potential as they emerge from R&D.
Printed and Organic Sensors

- Printed blood glucose test strips: a $6 billion market today (mainly carbon and some silver ink)

Emergence of organic optical sensors: hybrid CMOS image sensors will combine organic layers with CMOS silicon to out-perform normal CMOS sensors (higher sensitivity and better dynamic range).

Key drivers for printed and flexible sensors: smartphone sensors, touch interfaces, large area capability, flexibility and thin form factors

*$ Data Excludes Glucose Test Strips

## Wearable Electronics

<table>
<thead>
<tr>
<th>Market Sector</th>
<th>2015</th>
<th>2016</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health, Medical, Fitness, Wellness - Regulated</td>
<td>8.92</td>
<td>9.61</td>
<td>14.67</td>
<td>28.49</td>
</tr>
<tr>
<td>Health, Medical, Fitness, Wellness - UnRegulated</td>
<td>1.61</td>
<td>1.78</td>
<td>1.43</td>
<td>1.01</td>
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<tr>
<td>Infotainment</td>
<td>11.61</td>
<td>14.24</td>
<td>19.00</td>
<td>20.89</td>
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<tr>
<td>Industrial, Commercial, Military</td>
<td>1.37</td>
<td>1.71</td>
<td>4.22</td>
<td>7.58</td>
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<tr>
<td>Fashion &amp; Other</td>
<td>0.70</td>
<td>0.79</td>
<td>2.57</td>
<td>6.31</td>
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<tr>
<td>TOTAL</td>
<td>24.21</td>
<td>28.13</td>
<td>41.89</td>
<td>64.28</td>
</tr>
</tbody>
</table>

Multiple Entry Points for FHE
nScrypt tool can print 3D structures, dispense conductive materials, move the entire structure to be cured by Novacentrix’s state-of-the-art PulseForge system, and finally place discrete electronic components. From digital design to physical product, this system has fully realized a digital 3D additive manufacturing system.
Ceramic Substrate
### Sensor Selection Summary: Market and Technical Assessment

<table>
<thead>
<tr>
<th>Overall</th>
<th>Sensor type</th>
<th>Strategic Priority / Customer Feedback</th>
<th>Technical Assessment b. Priority</th>
<th>Differentiation vs. existing sensor</th>
<th>Key Applications for Thin Film</th>
<th>Other Applications</th>
<th>Cost Reduction (printed vs. conventional)*</th>
<th>Market Size (printed + conventional)*</th>
<th>Printed CAGR: 2015-2025</th>
<th>Printed Forecast 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>Temperature</td>
<td>1</td>
<td>1</td>
<td>Low</td>
<td>Food/Floral, Life Science</td>
<td>Industrial</td>
<td>Medium $6.05B</td>
<td>65%</td>
<td><strong>$25M</strong></td>
<td></td>
</tr>
<tr>
<td>✓</td>
<td>Humidity</td>
<td>2</td>
<td>2</td>
<td>Low</td>
<td>Food, Small Molecules Drugs</td>
<td>Tobacco, scientific</td>
<td>Medium $800M</td>
<td>75%</td>
<td><strong>$25M</strong></td>
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<tr>
<td>✓</td>
<td>Ethylene</td>
<td>3</td>
<td>5</td>
<td>High</td>
<td>Food spoilage/ripeness</td>
<td>Plants</td>
<td>Medium New</td>
<td>New</td>
<td><strong>New</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure (incl vibrations)</td>
<td>4</td>
<td>6</td>
<td>Medium, if cumulative</td>
<td>Vibration, relative weight measurement;</td>
<td>Automotive, textile, touch screen,</td>
<td>Medium $9.4B</td>
<td>15%</td>
<td><strong>$250M</strong></td>
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<tr>
<td>✓</td>
<td>Other Gas Sensors (CO2, O2, etc.)</td>
<td>5</td>
<td>4</td>
<td>Low</td>
<td>Food</td>
<td>Automotive, scientific, indoor air quality</td>
<td>Medium O2: $70, CO2: $150M</td>
<td>30%</td>
<td><strong>$10M</strong></td>
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<tr>
<td>✓</td>
<td>Light</td>
<td>6</td>
<td>Limited</td>
<td>Low</td>
<td>Supply chain, biologics, tamper evidence</td>
<td>Automotive, meteor station</td>
<td>Medium $767M</td>
<td>56%</td>
<td><strong>$50M</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Thin Film market is a sub-set of this market size. Further investigation in progress.
Examples of FlexTech R&D Program
Examples of FlexTech R&D Program
Global Events Platform

FHE Processing & Packaging
July 12, 2016, San Francisco, CA
www.SemiconWest.com

Next Generation Flexible Health Monitoring Devices (@ World of IoT)
July 13, 2016, San Francisco, CA
www.SemiconWest.com

2016 FLEX
Building the Innovation Ecosystem for Flexible Electronics
Monterey, California
Feb 29 – Mar 3

2016 FLEX Korea
International Printed Electronics Conference
June 29-30, 2016
Seoul, Korea

2016 FLEX Europe
Building the Innovation Ecosystem for Flexible Electronics
October 25-27, 2016
Grenoble, France
SEMICON Japan 2016

- **Date/Place:** 2016 December 14\(^{th}\) (Wed) – 16\(^{th}\) (Fri) @ Tokyo Big Sight
- **NEW:**
  - FHE Aera in the World of IOT pavillion
  - FHE Seminar at TechSTAGE
# FHE Seminar

<table>
<thead>
<tr>
<th>Time</th>
<th>12/14</th>
<th>12/15</th>
<th>12/16</th>
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<tbody>
<tr>
<td></td>
<td>Super THEATER</td>
<td>TechSTAGE NORTH</td>
<td>TechSTAGE SOUTH</td>
</tr>
<tr>
<td>10:20 - 12:00</td>
<td>Opening Keynotes</td>
<td>STS Power Device - 1</td>
<td>STS Power Device - 2</td>
</tr>
<tr>
<td></td>
<td>STS MEMS - 1</td>
<td>STS MEMS - 2</td>
<td>STS MEMS - 2</td>
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<tr>
<td>12:50 - 14:30</td>
<td>Semiconductor</td>
<td>Flexible Hybrid</td>
<td>Flexible Hybrid</td>
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<td>Executive Forum</td>
<td>Electronics Forum</td>
<td>Electronics Forum</td>
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<tr>
<td></td>
<td>STS Power Device 2</td>
<td>STS MEMS - 2</td>
<td>STS MEMS - 2</td>
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<tr>
<td></td>
<td>STS Lithography - 1</td>
<td>STS Lithography - 2</td>
<td>STS Lithography - 2</td>
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<td>15:10 - 16:50</td>
<td>Market Forum</td>
<td>CGMG</td>
<td>MIRAI (Student) Collage</td>
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<td></td>
<td>Flexible Hybrid</td>
<td>STS Special Session</td>
<td>TBD (Academia/Org)</td>
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<tr>
<td></td>
<td>Electronics Forum</td>
<td>- AI -</td>
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<td></td>
<td>IT</td>
<td>STS TEST</td>
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<td></td>
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<td>Academia</td>
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<td>INNOVATION VILLAGE</td>
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<td>Pitch</td>
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<td>GSA</td>
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<td>Used Equipment</td>
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<td>STS Packaging</td>
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<td>IOT Technology - 1</td>
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<tr>
<td></td>
<td></td>
<td>IOT Technology - 2</td>
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</tbody>
</table>

**Venue:**
- **Super THEATER:** North, South
- **TechSTAGE:** Innovation & IOT
- **Innovation & IOT Joint Session**
Summary

• FHE is a New Opportunity in Electronics
• Leading Companies and Research Centers Are Participating
• Materials and Equipment Challenges Present Opportunities for SEMI Members
• SEMI is Source of Information and Networking
Thank you for your attention.

Q&A and Discussion