Session 1
Advanced Socket Materials

“Carbon Nanotube Polymer Composites For Socket Applications”
Mark Hyman, Tim Jozokos, Heidi Sardinha, Yuanheng Zhang
Hyperion Catalysis International, Inc.

“PEEK-based Solutions For Test Socket Applications”
John Walling, Sam Brahmbhatt — Victrex USA, Inc.

“Para-phenylene Rigid Rod Polymers And Their Unique Attributes For Burn-in And Test Sockets”
Lorenzo P. DiSano — Ensinger Industries, Inc.

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Carbon Nanotube Polymer Composites for Socket Applications

2006 Burn-in & Test Socket Workshop
March 12 - 15, 2006

Mark Hyman, Tim Jozokos,
Yuanheng Zhang, Heidi Sardinha
Hyperion Catalysis International, Inc.

Introduction

• Electrostatic Discharge (ESD) Concern
• Carbon Nanotube Polymer Composites
• Requirements for Socket Applications
• Composite SEM Comparison
• Discussion
• Follow-up Work
Electrostatic Discharge Concern

- Increasing susceptibility of semiconductor devices
  - Smaller silicon features
  - Less on-chip ESD protection
- Machine Model (MM)
- Charged Device Model (CDM)

Charged Device Model Sensitivity

Source: Electrostatic Discharge Association, "Electrostatic Discharge Technology Roadmap", 2005
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ESD in Sockets

• ESD is managed throughout the device manufacturing process
• ESD management will have to extend to the burn-in and test arena
• Socket materials have traditionally been insulators
• Are socket performance and ESD management in conflict?

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Conductive Fillers
Filler Loading vs. Aspect Ratio

<table>
<thead>
<tr>
<th>Loading</th>
<th>Theoretical Percolation Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>Spheres (L/D=1)</td>
</tr>
<tr>
<td>5%</td>
<td>Carbon Black (L/D=10)</td>
</tr>
<tr>
<td>10%</td>
<td>Carbon Fiber (L/D ~100)</td>
</tr>
<tr>
<td>15%</td>
<td>FIBRIL nanotubes (L/D ~1000)</td>
</tr>
</tbody>
</table>

Structure of a FIBRIL Nanotube

- Graphitic wall structure
- Multilayer
- Hollow
Carbon Nanotubes

- Diameter: 10 nanometers
- Length: 10,000 nanometers
- Aspect Ratio: L/D = 1000

Unique Product Performance

- Conductivity “plus”
- Minimal effect on polymer properties
- Excellent surface smoothness
- Consistent electrical properties
- Chemical cleanliness
- Minimal viscosity increase

Small size

Low Loading
Commercially Successful

Hard Disk Drive Semiconductor

Requirements for Sockets (some of them)

• Static dissipative
• Maintain sufficient electrical isolation between conductors
• Minimize crosstalk / leakage
• Processability
  – Injection molding
  – Machining

While device pitch gets smaller
Samples

Commercially Available Stock Shapes

<table>
<thead>
<tr>
<th>Material</th>
<th>$V_r$ (ohm-cm)</th>
<th>$S_r$ (ohm/sq.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEI - Carbon Fiber</td>
<td>$10^1$</td>
<td>$10^1$</td>
</tr>
<tr>
<td>PEI - Carbon Nanotubes</td>
<td>$10^2$</td>
<td>$10^2$</td>
</tr>
<tr>
<td>PEEK - Carbon Fiber</td>
<td>$10^7$</td>
<td>$10^7$</td>
</tr>
<tr>
<td>PEEK - Carbon Nanotubes</td>
<td>$10^1$</td>
<td>$10^3$</td>
</tr>
<tr>
<td>PEEK - CNT and CF for comparison</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SEM of fractured surfaces

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PEI with Carbon Fiber

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PEI with Carbon Nanotubes

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PEEK with Carbon Fiber

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**PEEK with Carbon Nanotubes**

- x 200
- x 500
- x 1,000
- x 5,000
- x 10,000
- x 20,000

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**PEEK with CNT and CF (for comparison)**

- x 200
- x 500
- x 1,000
- x 5,000
- x 10,000
Processing – Ease of Molding

CNT-PEEK compound processes very much like unfilled PEEK at injection molding shear rates.

Discussion

- Resistivity is traditionally measured with macro-scale probes
- What happens when socket features approach the dimension of the carbon fiber filler?
  - Thinner walls separating socket holes
  - Carbon fiber directly conducting through wall thickness more likely
  - Signal cross-talk / leakage more likely
Discussion

- Injection molding aggravates electrical problems caused by carbon fiber
- ESD management is no longer optional
- Socket performance cannot be sacrificed

Carbon nanotubes provide an appropriately scaled microstructure for static dissipative sockets

Follow Up Work

- Characterize electrical properties in fine pitch features
- Investigate injection molding effects on electrical uniformity
- Evaluate performance of finished sockets
PEEK-based Solutions for Test Socket Applications

Sam Brahmbhatt
John Walling
Victrex USA Inc.

BiTS Conference
March 2006

Today’s Discussion…

- What is VICTREX® PEEK™?
- PEEK in the Semiconductor Industry
  - Examples of Front-end applications
  - Examples of Back-end applications
- Why is VICTREX PEEK specified?
  - PEEK performance
- BiTS application requirements
  - PEEK grades for BiTS applications
  - Case studies
  - Added value services
What is PEEK?

- Semi-crystalline polymer capable of withstanding extreme environments

- Readily modified with various filler technologies to enhance performance. i.e., carbon fiber, glass, ceramics, etc...

- Widely considered to be the highest performance, melt processable polymer

PEEK offers proven performance in the semiconductor industry
**PEEK applications (front-end)**

- Etch Components
- CMP Retaining Rings
- Wafer and Disk Carriers
- Silicon Wafer Pods

**PEEK applications (back-end)**

- High Temperature Matrix Trays
- Flexible Circuit Substrates
- Test Sockets
- Test Socket Alignment Plates
Why is PEEK specified?

PEEK performance

- Machines to very tight tolerances
  - Deburring easier with filled grades
- Low moisture absorption
  - PEEK 0.5% (at saturation)
  - PAI 4.4%
  - PI 2.0%
- Heat resistance exceeding 260°C
  - Withstands lead-free solder reflow process
PEEK performance

- Chemical resistance pH 2-14
  - Insoluble in most common semiconductor chemicals
- Excellent mechanical properties
  - Stronger and stiffer thin-wall cross-sections
- Outstanding wear resistance
  - Longer life in aggressive environment

Flexural Modulus vs. Temperature
Tensile Strength vs. Temperature

Dimensional Stability

Coefficient of Thermal Expansion of Victrex® PEEK™ Grades

<table>
<thead>
<tr>
<th>Temperature [°C]</th>
<th>Height [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50</td>
<td>99.5</td>
</tr>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>50</td>
<td>100.5</td>
</tr>
<tr>
<td>100</td>
<td>101</td>
</tr>
<tr>
<td>150</td>
<td>101.5</td>
</tr>
<tr>
<td>200</td>
<td>102</td>
</tr>
</tbody>
</table>

Victrex PEEK Standard
Victrex PEEK 30% GF
Victrex PEEK 30% CF
Victrex PEEK Bearing Grade
BiTS application requirements

- Thermal performance
  - -55 to 155°C
- Dimensional stability
  - Low CTE, low moisture absorption
- Compression and shear strength
  - Strong and stable
  - Thin walls between holes
BiTS application requirements

- High wear resistance
  - Up to 100,000 pin insertions
- Processability
  - Thin-wall molding
  - Ease of machining
  - Low residual stresses
- Electrostatic dissipative
  - Does not generate static charge
  - Dissipate incoming static charge safely

Electrostatic Dissipative (ESD)

- **Conductive Materials**
  - Will not generate a static charge
  - Grounds charges quickly (may damage component)
  - Will shield sensitive components from electric fields
- **Dissipative**
  - Will not generate a static charge
  - Will not allow a charge to remain localized on surface
  - Can safely & quickly bleed electric charge to ground
- **Antistatic**
  - Low potential to generate a static charge
  - Will not allow a charge to remain localized on surface
  - Will slowly bleed an electric charge to ground
- **Insulative**
  - May generate static charge on surface
  - Will allow a charge to remain localized on surface
### Product Solutions for BiTS applications

<table>
<thead>
<tr>
<th>Socket Type</th>
<th>Machined (stock shapes)</th>
<th>Molded (thick wall &gt;2mm)</th>
<th>Molded (thin wall &lt;2mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conductive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;E7 Ω/sq</td>
<td>Conductive filler</td>
<td>Conductive filler</td>
<td>Conductive filler</td>
</tr>
<tr>
<td><strong>Dissipative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E7-E9 Ω/sq</td>
<td>Conductive filler</td>
<td>Conductive filler</td>
<td>Conductive filler</td>
</tr>
<tr>
<td><strong>Antistatic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E9-E11 Ω/sq</td>
<td>Conductive filler</td>
<td>Conductive filler</td>
<td>Conductive filler</td>
</tr>
<tr>
<td><strong>Insulative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;E11 Ω/sq</td>
<td>Unfilled/Glass Mineral/Ceramic</td>
<td>Unfilled/Glass Mineral/Ceramic</td>
<td>Unfilled/Glass Mineral/Ceramic</td>
</tr>
</tbody>
</table>

### Case Study #1

**Molded test socket cover (top slide plate)**
Part description and requirements

- Flat plate with holes
- \( \sim 50 \text{ mm} \times 50 \text{ mm} \)
- 0.8 – 1.0 mm thick
- Part was molded with PES
- ESD: SR E9-E11 ohms
- Improved fatigue and impact toughness

**PEEK solution with unique material and filler technology to optimize rheological and ESD properties**

Case Study # 2

**Machined test socket base plate**
Part description and requirements

- Stock shape 3/8 in. thick with .010 in. & .030 in. holes
- Ease of machining
- Burr-free holes
- Dimensional stability
- Insertion wear resistance

PEEK solution with unique filler technology to optimize machining and dimensional stability

PEEK added value – Victrex

- Proven product performance – brand reliability
- Dedicated technical service support for on-site assistance
- Application development and prototype expertise
- In-depth product performance and processing data
- Machining expertise
- Global customer service network

Working hand-in-hand with channel partners and end users to reach new levels of performance and cost savings
Para-phenylene Rigid Rod Polymers and Their Unique Attributes for Burn-in and Test Sockets

2006 Burn-in and Test Socket Workshop
March 12 - 15 2006

Lorenzo P. DiSano
Ensinger Ind. – Washington, PA USA

What are Para-phenylene Rigid Rod Polymers?

- Wholly aromatic.
- Benzene rings directly bonded to each other.
- Self Reinforcing at the molecular level.
- Isotropic
- Amorphous
- Extraordinarily hard, strong and stiff.
- Previously intractable
- Commercially available
History of SRPs

- Marvel and Vogel recognized the feasibility and potential of rigid rod polymers. (1950s)
- Under Air Force Research Laboratory sponsorship a number of chemical producers such as Dow Chemical and Hoechst Celanese validated SRPs. (1960s)
- Maxdem develops process-able SRPs. (1980s)
- Maxdem launches Mississippi Polymer Technology - MPT. (2000)
- MPT introduces Parmax® SRP, a new family of thermoplastic SRPs. (2003)
- Solvay purchases MPT and the Parmax® SRP product line. (2006)
Most polymers are flexible

SRPs Have Rigid Chains
Strongest and Stiffest Thermoplastic

![Graph comparing modulus and tensile strength of different polymers](image)

**Metal Like Plastic**

![Graph comparing tensile strength of different metals](image)

**Paper #3**

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Flex Stress-Strain

Sample: W 8mm × T 2 mm × L 50 mm @ 23 ºC
Rate: 1.00 mm/min  Span: 35 mm

Tensile Stress-Strain
Compressive Stress-Strain

SRP THREAD STRENGTH

Metal Bolt Head Failure
NO SRP FAILURES

PEEK Tapped Thread Pull Out Failure

<table>
<thead>
<tr>
<th>Sample Run</th>
<th>SRP</th>
<th>PEEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
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<td>8</td>
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<td>9</td>
<td>250</td>
<td>120</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
<td>115</td>
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</table>
SRP HARDNESS

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness</th>
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<tbody>
<tr>
<td>Polycarbonate</td>
<td>B</td>
</tr>
<tr>
<td>Polycyclic Olefins</td>
<td>2H</td>
</tr>
<tr>
<td>PMMA</td>
<td>3H</td>
</tr>
<tr>
<td>SRP -1000</td>
<td>≥9H</td>
</tr>
</tbody>
</table>

SRP Abrasion Wear Resistance

![Graph showing SRP Abrasion Wear Resistance with various materials and hours]

<table>
<thead>
<tr>
<th>Material</th>
<th>PPS</th>
<th>PEEK</th>
<th>PI</th>
<th>SRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wear (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SRP TGA in Air

SRP Dimensional Stability

Paper #3
SRP Electrical Properties

- Dielectric Constant (ASTM 150) 3.1 (1MHz)
- Dielectric Strength (ASTM 149) 6.44 kV/mm
- Specific Volume Resistance (DIN IEC93) $6 \times 10^{15} \Omega \text{ cm}$
- Surface Resistance (DIN IEC 93) $2 \times 10^{16} \Omega$
- Resistance to Tracking (IEC 112) CTI 150

SRP Machinability

- There is little evidence of internal cracking, crazing or deformation due to thermal expansion, material stress or out-gasing.
- Due to a nano rigid rod microstructure SRP mills, drills and turns like the best thermoplastics even though it has a low notched Izod impact value of 0.8 ft-lbs/in (un-notched Izod impact = 18.7 ft-lbs/in)
- Metal like hardness and isotropic behavior translates into minimal burring and little or no deformation under machining loads.
Key Attributes of SRPs for Burn-in & Test Sockets

- Excellent Machinability – Like Aluminum
- Homogenous, Amorphous & Isotropic
- High Modulus
- High Creep Resistance
- Low/Uniform CLTE
- Low Moisture Pick-Up
- Exceptional Abrasion Resistance