High Performance Polyimide Composite for Precise Micro-Machining in Advanced Socket Designs

Hau-Nan Lee, Peter Fox,
Takuya Miyauchi, Shin-Ichi Nakagawa

DuPont de Nemours, Inc.

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Outline

- Trends in Material Requirements for Test Sockets
- Introduction to Vespel® Polyimide
- Polyimide Materials for Advanced Socket Designs
  - SCP-5000 and SCS-5700 polyimide composite
  - Micro-Machinability Evaluation
  - Customer Feedback
- Future Materials Development

Semiconductor Testing Equipment

Front-end → **Back-end**

Probe Cards	Probe Heads	Test Sockets	Burn-in Sockets
Hole & pitch 10~80 μm	Hole & pitch 50~100 μm	Hole & pitch 100~300 μm	Hole & pitch 300~500 μm
Materials • Ceramics • Aluminum oxide with specialized coating	Materials • Ceramics • **Polyimide** • PEEK composite	Materials • Torlon (PAI) • **Polyimide** • Polyether ether ketone (PEEK) composite	Materials • Ultem (PEI) • Polyethersulfone (PES) *Injection Molding

Mechanical strength & stiffness, machinability

The trends in semiconductor testing materials requirements

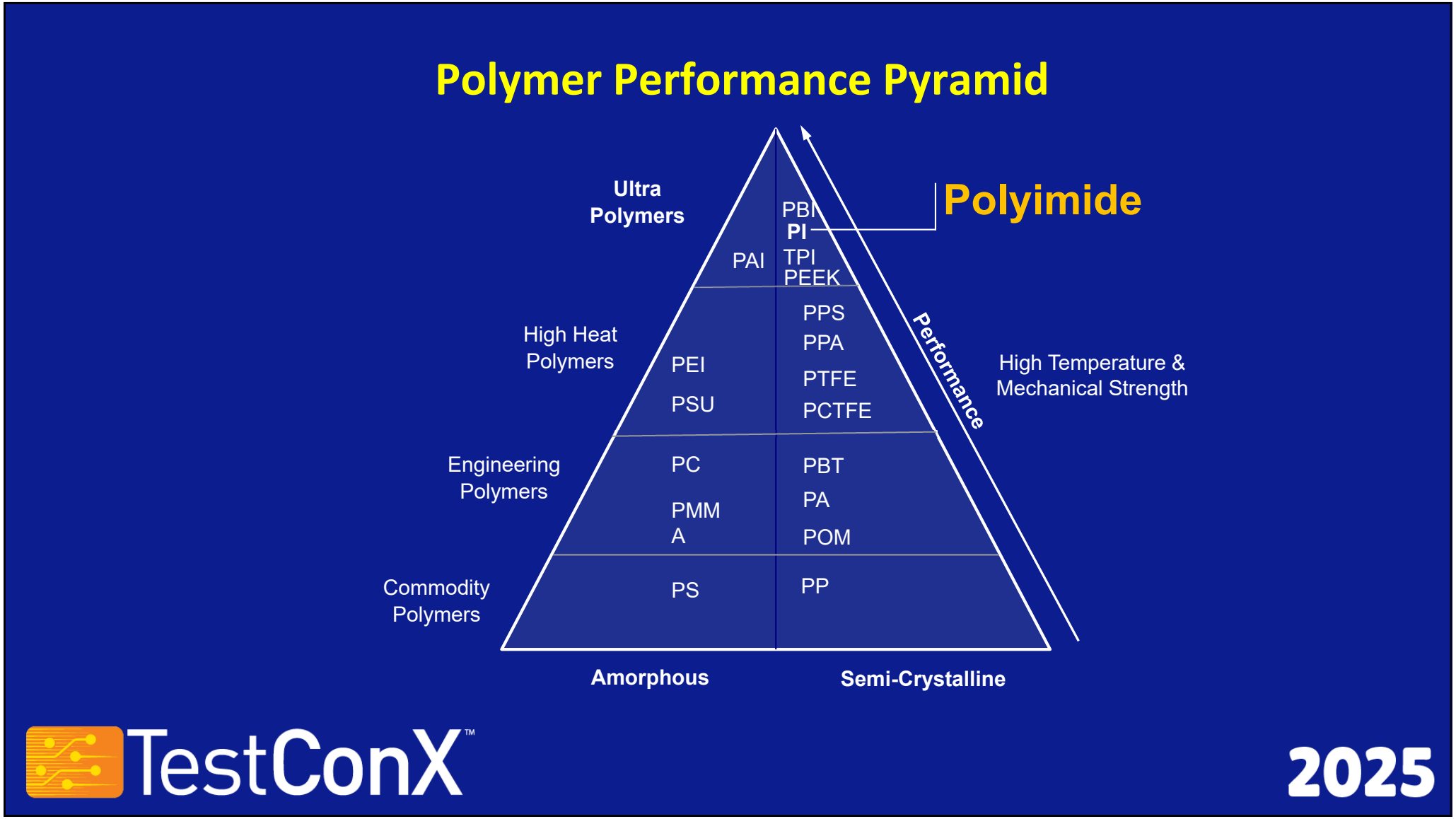
Driven by technological advancements and industry demands, these trends reflect the ongoing evolution in the fields of semiconductor testing:

- **Greater Mechanical Strength:** As devices become smaller and more complex, the need for materials that offer high mechanical strength and stiffness is critical to endure the forces during testing and handling.
- **Machinability and Precision:** There is a growing demand for materials that can be easily machined to create intricate features with high precision, as new designs often include complex geometries.
- **Improved Electrical Properties:** Enhanced electrical insulation are essential for preventing interference and ensuring accurate test results. This includes materials with low dielectric constants and high dielectric strengths.
- **Improved Dimensional Stability:** Essential for maintaining consistent dimensions under temperature fluctuations and moisture exposure, ensuring precise contact and reliable performance in test sockets.

What is Vespel® Polyimide?

- The Vespel® polyimide product line consists of high-performance polyimide parts and shapes, produced through a process that compresses polyimide powder into green parts, which are then sintered to form fully imidized materials.
- The polyimide products are used in demanding applications requiring thermal and wear resistance, as well as good dielectric properties and mechanical performance.

Polyimide shapes or custom direct-formed parts


Polymer Performance Pyramid
Ultra Polymers
High Heat Polymers
Engineering Polymers
Commodity Polymers
PBI
PI
PAI
TPI
PEEK
PPS
PPA
PEI
PTFE
PSU
PCTFE
PC
PBT
PA
PMM A
POM
PS
PP
Amorphous
Semi-Crystalline
Performance
Polyimide
High Temperature & Mechanical Strength
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Industries and Applications for Polyimide Composites

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High Performance Polyimide Composite for Precise Micro-Machining in Advanced Socket Designs

Polyimide for Test Sockets

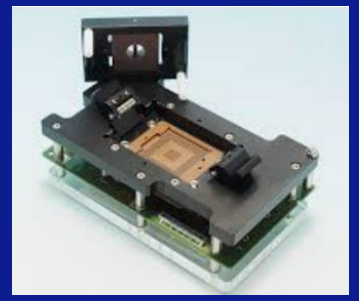
Polyimide is chosen for its excellent properties

Features:

- High mechanical strength and stiffness
- Low dielectric constant
- Dimensional stability
- Superior wear resistance
- Excellent machinability

Benefits:

- Ease of machining to achieve narrow pitch and pin hole
- Wear resistance and low friction to withstands numerous cycles of probe pin insertion processing
- Electrical insulation to avoid cross-talk
- Known and predictable reliability and long Life



Polyimide Products for Different End User Requirements

Grades	Performance	Application
SCP-5000	High stiffness (100-300 μm pitch)	High-end 5G test sockets
SCS-5700	Higher stiffness (50-100 μm pitch)	High-end 5.5G/6G test sockets Probe heads Probe cards

Targeted Performance for SCS-5700:

- **High Flexural Modulus**: Exceeds 10 GPa, ensuring exceptional stiffness and bend resistance, enabling the fabrication of high pin count testing components.
- **Superior Machinability:** Provides enhanced ease of machining compared to ceramics and PEEK composites.
- **Reduced CTE and Water Absorption**: Exhibits excellent dimensional stability in relation to temperature variations and minimizes water absorption.

Targeted applications for SCS-5700: Fine pitch and high pin count design (Ex. RF test sockets & probe heads)

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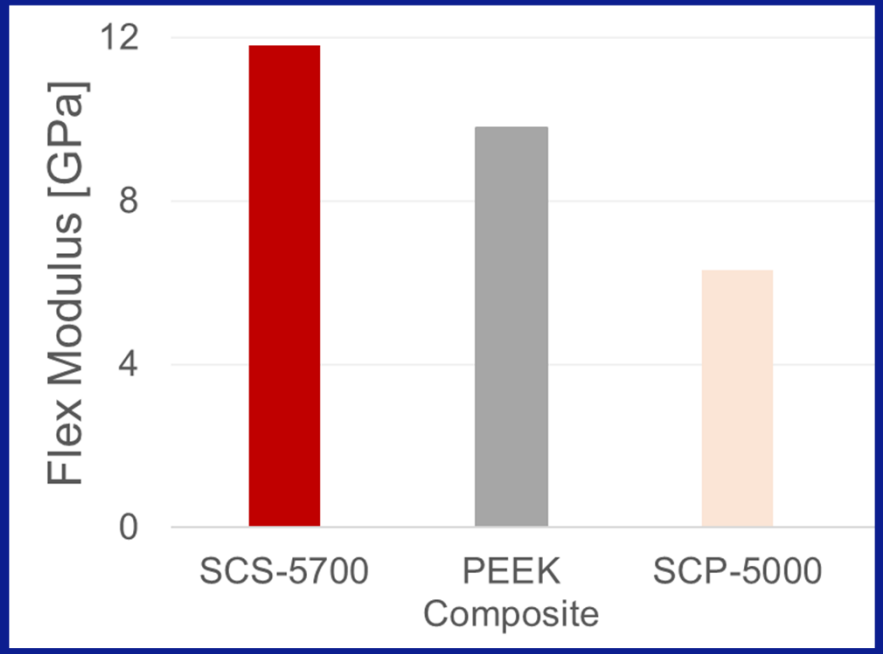
SCS-5700 Polyimide Composite Technology

SCS-5700 is molded insulating polyimide shape useful for electronic components. In particular, the molded insulating polyimide shape has low dielectric constant and excellent flexural modulus, which is formed from a polyimide composition comprising high amount of sheet silicate.

** Patent pending: WO/2024/211079 MOLDED POLYIMIDE ARTICLE

Higher Flexural Modulus



Benefits:

- Minimizing warpage
- Higher pin count
- Finer pitch

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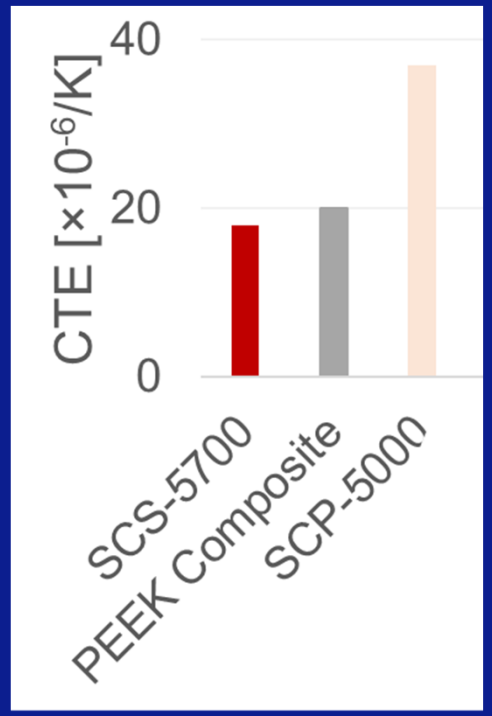
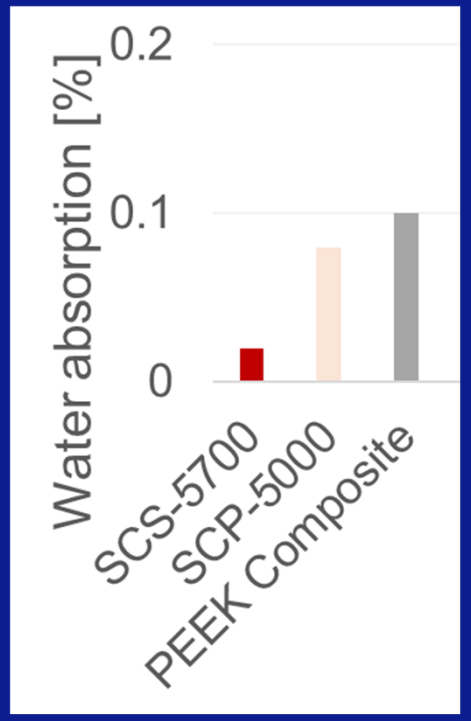
Excellent Dimensional Stability : Low CTE & Low Water Absorption





Benefits:

- Testing at high temp
- High reliability in precise machinability – minimized dimensional change by humidity

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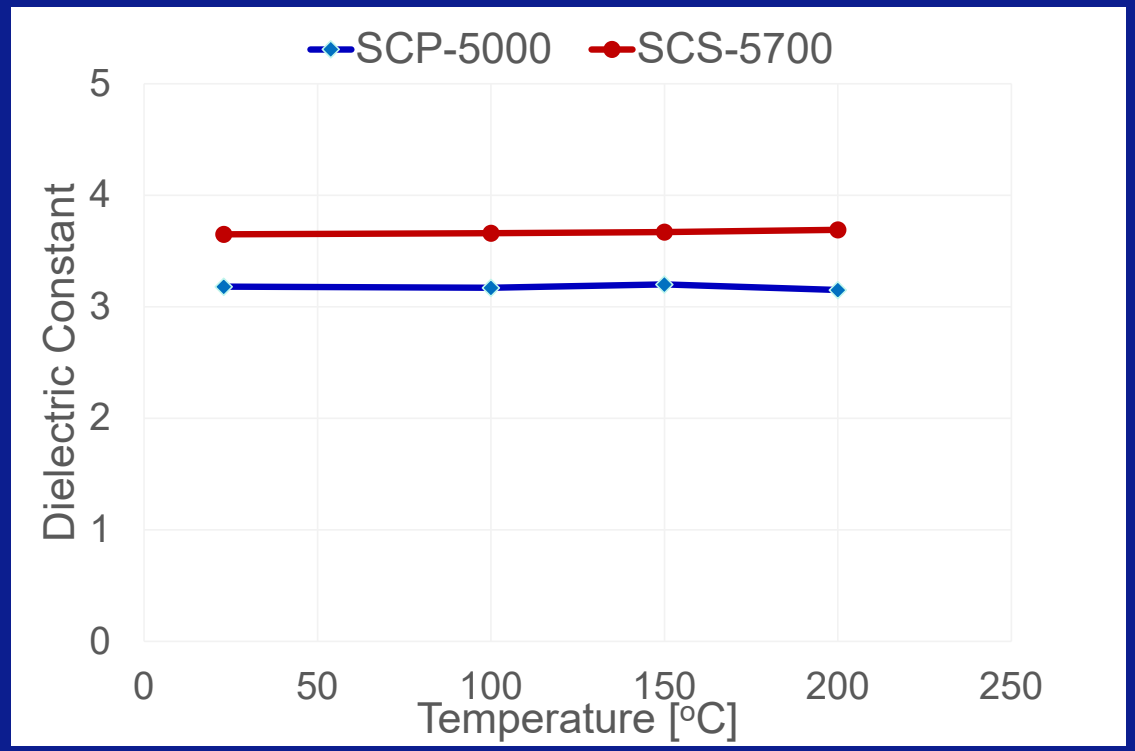
Stable Dielectric Constant



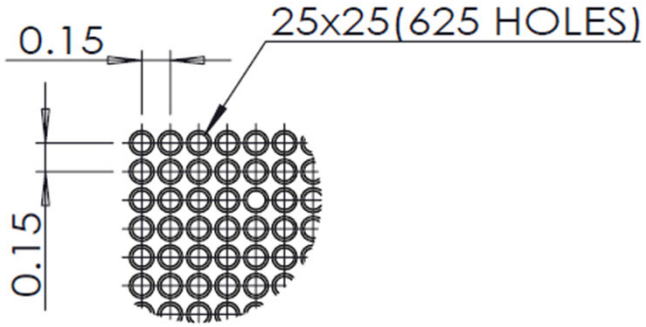
Benefits:

- Enabling reliable testing operation in 5G, 5.5G and 6G RF devices

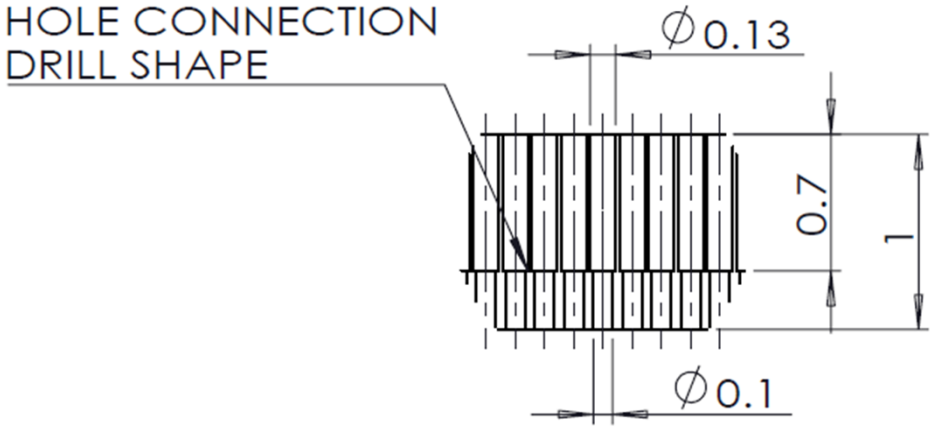
Micro-machinability : Step Hole Drilling Evaluation

Evaluation performed by an external machine shop

- Hole Diameter: 0.13 mm (Depth 0.7 mm) + 0.1 mm (Depth 0.3 mm)
- Pitch: 0.15 mm; Wall Thickness: 0.02 mm
- Hole Count: 675 (25 x 25)
- Standard Machining Conditions for Plastic Material
- Tool: Carbide with Coating (General Purpose)
- Rotation Speed: 20,000 – 30,000 rpm
- Condition: Dry
- Deburring: None



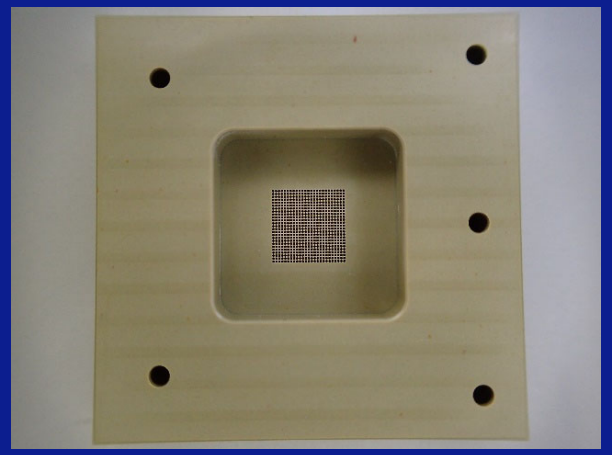
HOLE PITCH



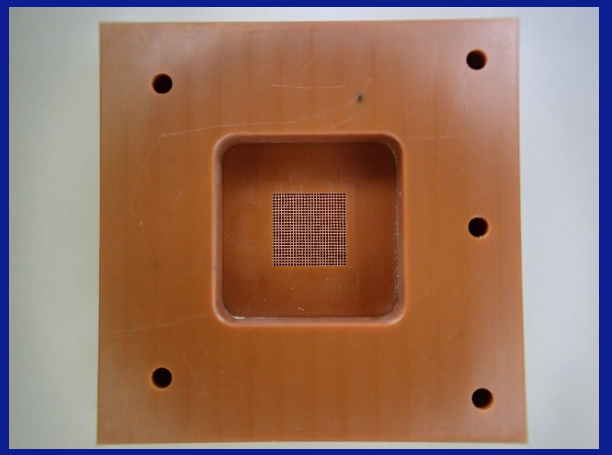
SECTION OF HOLE

Micro-machinability：Step Hole Drilling Evaluation

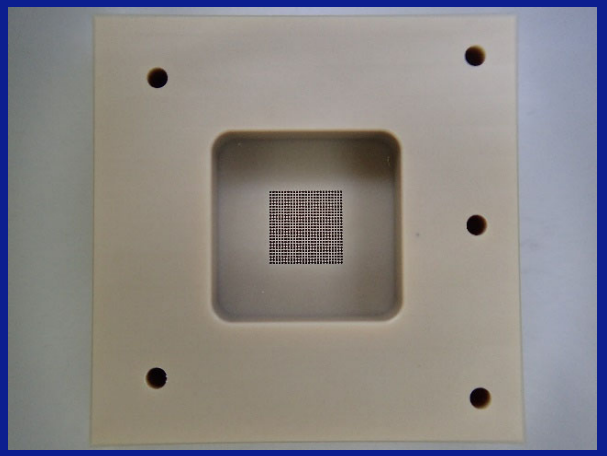
SCS-5700



SCP-5000



PEEK composite



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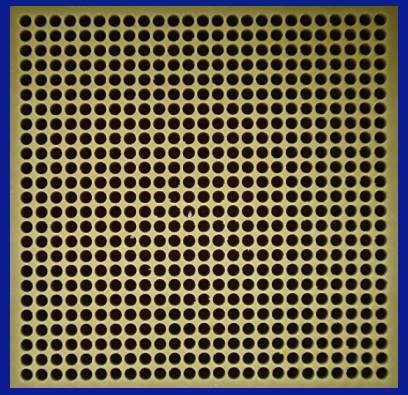
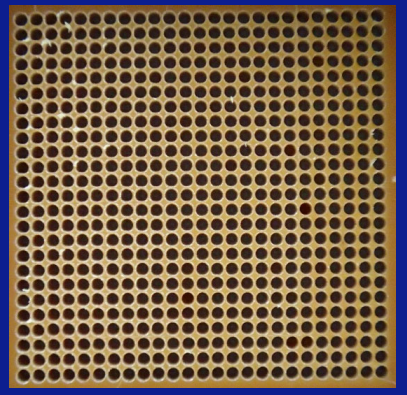
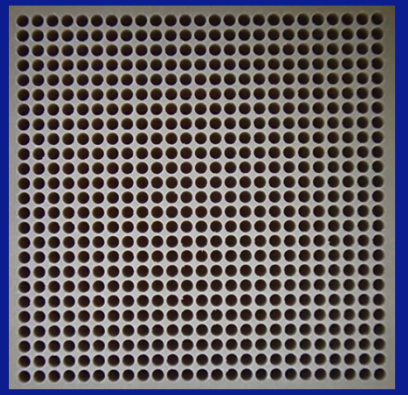
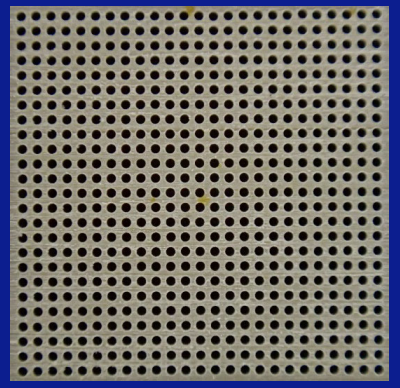
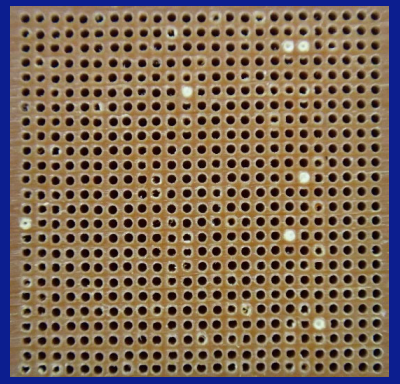
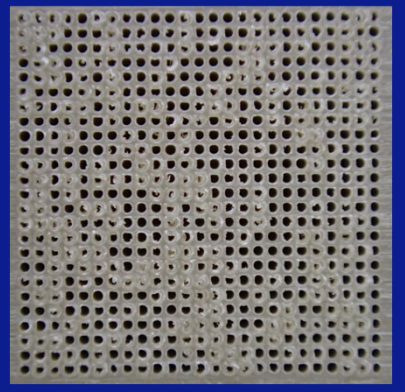
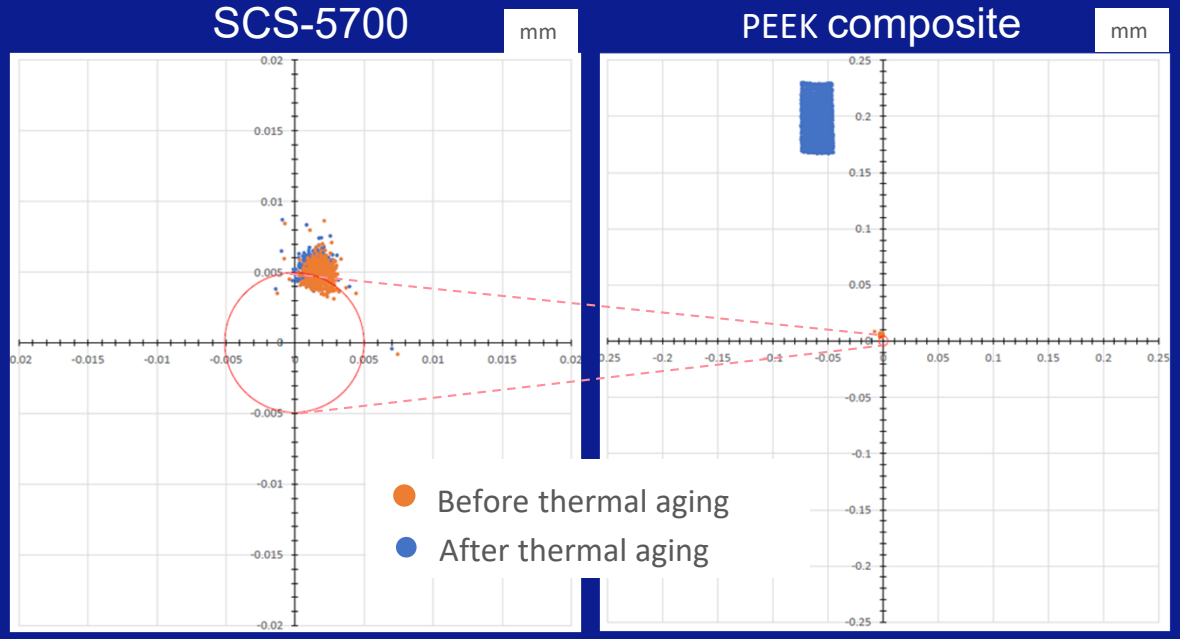
Step Hole Drilling Evaluation – Burr Formation

	SCS-5700	SCP-5000	PEEK Composite
Dia. 0.13 mm side	 Minor burr present	 Increased burr presence and minor hole distortion	 Minor burr present
Dia. 0.1 mm side	 Minor burr present	 Significant burr formation and hole distortion observed	 Extensive burr formation and severe hole distortion observed

Benefits:

- Finer pitch
- Less burr
- Minimizing machining time
- Less damage on tool in SCS-5700

Excellent dimensional stability : Less deformation through thermal aging



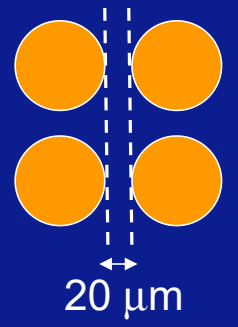
*Plot of Hole Position Error Before and After Thermal Aging
*Thermal Aging Condition : 250°C for 8 hours

Benefits

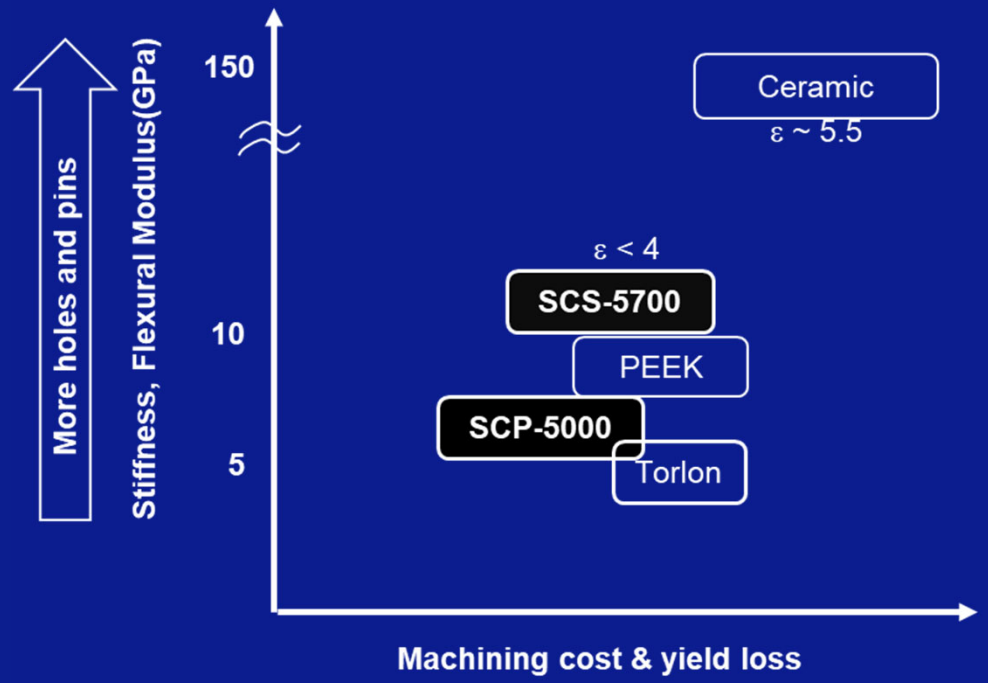
- Lifetime in high-temp testing operation

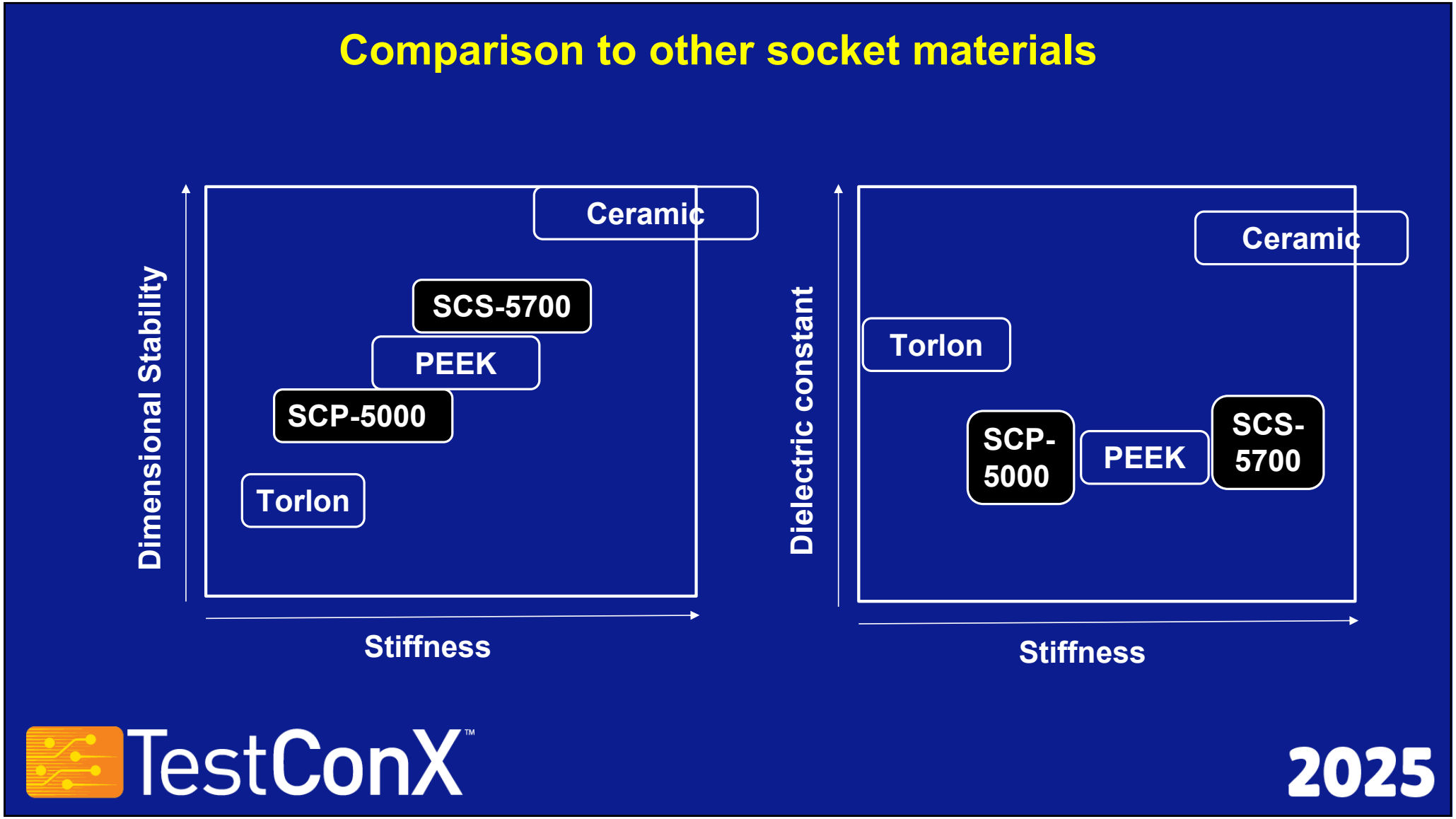
Customer Feedback

- SCS-5700 polyimide composite has been qualified by a prominent company in the test socket and probe head manufacturing industry.
- Probe heads constructed from SCS-5700 have received approval from a leading semiconductor manufacturer.
- SCS-5700 exhibits superior machinability, featuring fewer burrs and more precise hole dimensions compared to a PEEK composite material.
- In a probe head application, both a PEEK composite and a ceramic exhibited cracking at wall thicknesses below 50 µm after 50,000 cycles of testing, whereas SCS-5700 maintains stability at wall thicknesses greater than 20 µm.



Comparison to other socket materials




Comparison to other socket materials
Dimensional Stability
Ceramic
SCS-5700
PEEK
SCP-5000
Torlon
Stiffness
Dielectric constant
Ceramic
Torlon
SCP-5000
PEEK
SCS-5700
Stiffness
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2025

What's in the **pipeline…**

Electronics & Industrial
Vespel® Parts & Shapes

DuPont™ Innovation Pipeline

Creating the next generation high-performance materials for challenging applications

DuPont engineers are developing next generation high stiffness, low Dk, and electrically-insulative polyimide products

- Thickness: Up to 50 mm
- Dimensions: Up to 300 mm x 300 mm
- Flexural modulus: > 18 GPa
- Dielectric constant: < 3.2
- Coefficient of thermal expansion: < 6 ppm/°C
- Temperature stability: Up to 350 °C
- Dielectric strength: > 6 kV/100 microns

Materials in our pipeline are not for commercial sale currently, but samples may be provided.
For additional details please contact your DuPont TS&D contact.

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Materials performance comparison

	Temperature	Method	Unit	SCS-5700	SCP-5000	PEEK composite	Ceramic
Mechanical Properties							
Tensile Strength	23 °C	ASTM D-1708	MPa	**113.5**	174	118	
Tensile Elongation	23 °C	ASTM D-1708	%	**3.9**	8.4	2.0	<0.1
Flex Strength	23 °C	ASTM D-790	MPa	**212**	265	141	
Flex Modulus	23 °C	ASTM D-790	GPa	**11.8**	6.3	9.8	157
Dimensional Stability							
CTE (x-y)	23 °C – 150 °C	ASTM E-831	µm/m°C	**18**	37	20	1.4
HDT	50 °C – 400 °C	ISO75-2A	°C	**Over 400**	330.9	210	
Water Absorption (24 hr)	23 °C	ASTM D-570	% weight change rate	**0.02**	0.08	0.1	<0.01
Electrical Properties							
Dk at 1 MHz	23°C	ASTM D-150	-	**3.65**	3.3	3.37	5.5
Tan δ at 1 MHz	23°C	ASTM D-150	-	**0.002**	0.001	0.007	
Surface Resistivity	23°C	ASTM D-257	Ohm/Sq	**10^{16}**	10^{15}	10^{12}	

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