# BiTS

# Burn-in & Test Socket Workshop

**March 2 - 5, 2003**
**Hilton Phoenix East / Mesa Hotel**
**Mesa, Arizona**

IEEE COMPUTER SOCIETY

**Sponsored By The IEEE Computer Society Test Technology Technical Council**

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# Session 8
# Wednesday 3/05/03 10:30AM

# Properties Of Socket Materials

**"Materials For Test Sockets"**
**Richard W. Campbell** – Quadrant Engineering Plastic Products

**"Permittivity Determination Of Contactor Dielectrics At RF Frequencies"**
**Jason Mroczkowski** – Everett Charles Technologies

**"High Flow Glass Filled Polyetherimide Resins For Burn-In Test Sockets"**
**Ken Rudolph** – General Electric Plastics
**Robert R. Gallucci** – General Electric Plastics
**Chisato Suganuma** – General Electric Plastics

# Materials For Test Sockets

**Richard W. Campbell, Ph.D.**
**Manager of Product Development**

**Quadrant Engineering Plastic Products**
**Reading, PA USA**

# *Industry Trends / Materials Needs*

| Trends | Impact |
|---|---|
| • Smaller Foot Print | » Higher Insertion Pressure - Stronger Materials |
| • Smaller Pitch | » Greater Tolerance Control / More Stable |
| • Increased Functionality | » More Sensitive to Static Charge / ESd Materials |
| • New Package Designs | » Innovative Solutions / New Materials |

## *Performance Concerns for Materials Used in BiTS*

- **Mechanical Strength to Withstand Insert Loads**
- **Thermal Resistance from -55°C to +155°C**
- **Tight Dimensional Control Over the Full Temperature Range**
- **Does not Generate Static Charge**
- **Safely Dissipates Static Electricity**

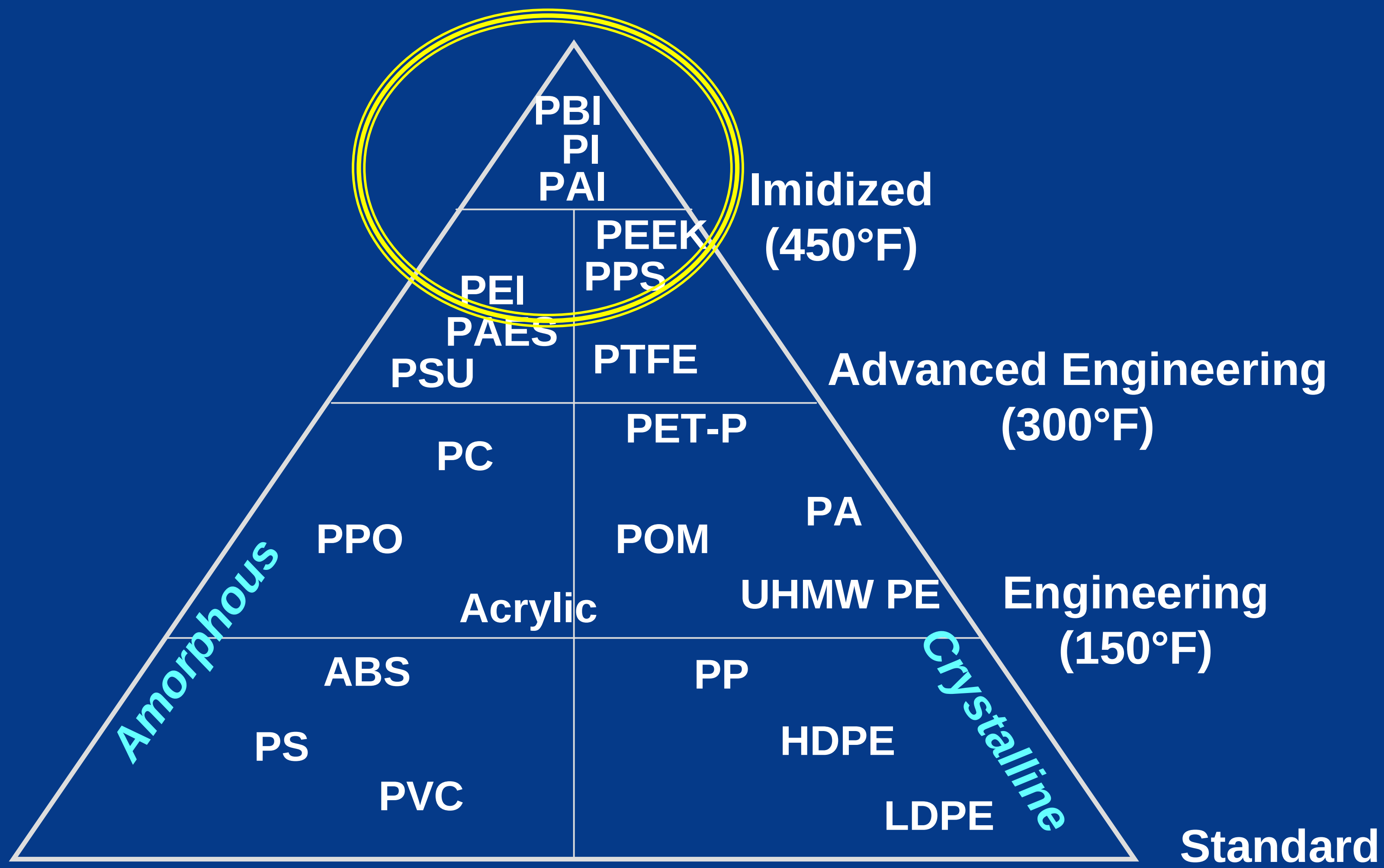
***How does an Engineer select the best plastic material(s) for the application?***

**There are many factors to take into consideration...**

# *Among Selection Factors*

- **Thermal Environment**
- **Electrical Requirements**
  - Static Dissipation
  - Dielectrics
- **Dimensional Stability**
  - Thermal
  - Moisture
- **Mechanicals**
- **Longevity in Service**
- **Availability of Materials**
- **Ease of Fabrication**
- **Cost**

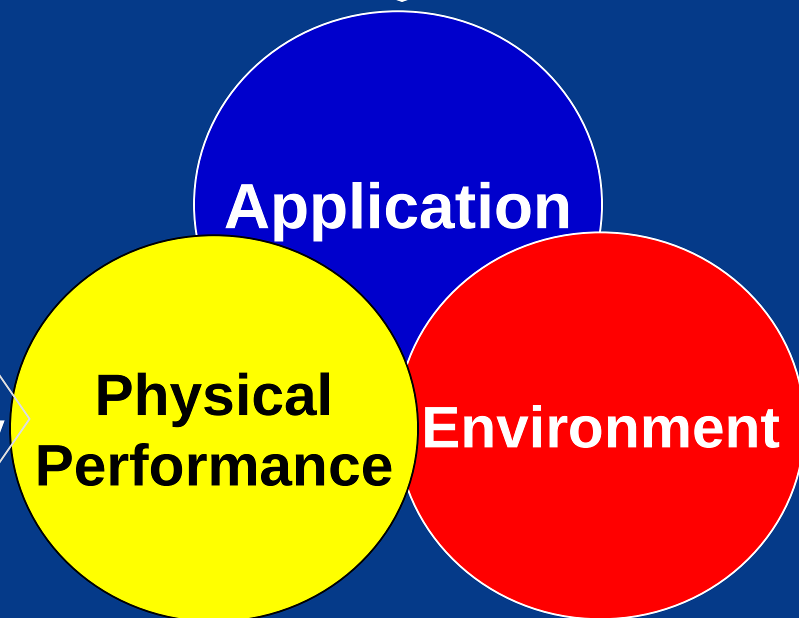
# The Plastics Pyramid



# The Material Selection Process

**Application Considerations**
- Bearing & Wear ?
- Static/Structural ?

**Physical Performance**
- Bearing & Wear
- Dimensional Stability
- Strength & Stiffness
- Electrical



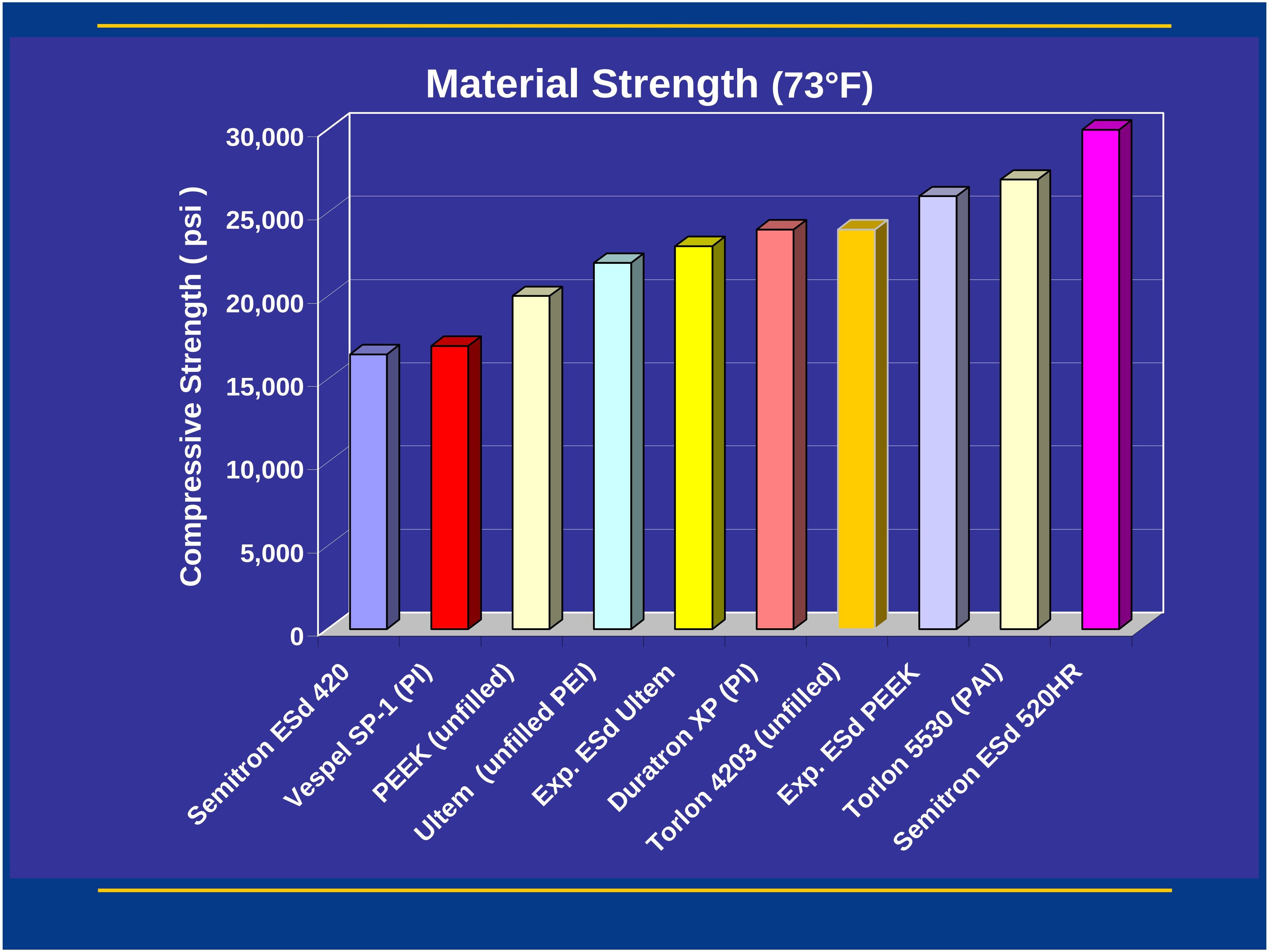

**Environmental Considerations**
- Thermal
- Chemical
- Regulatory

# *Needs vs. Materials for Bits*

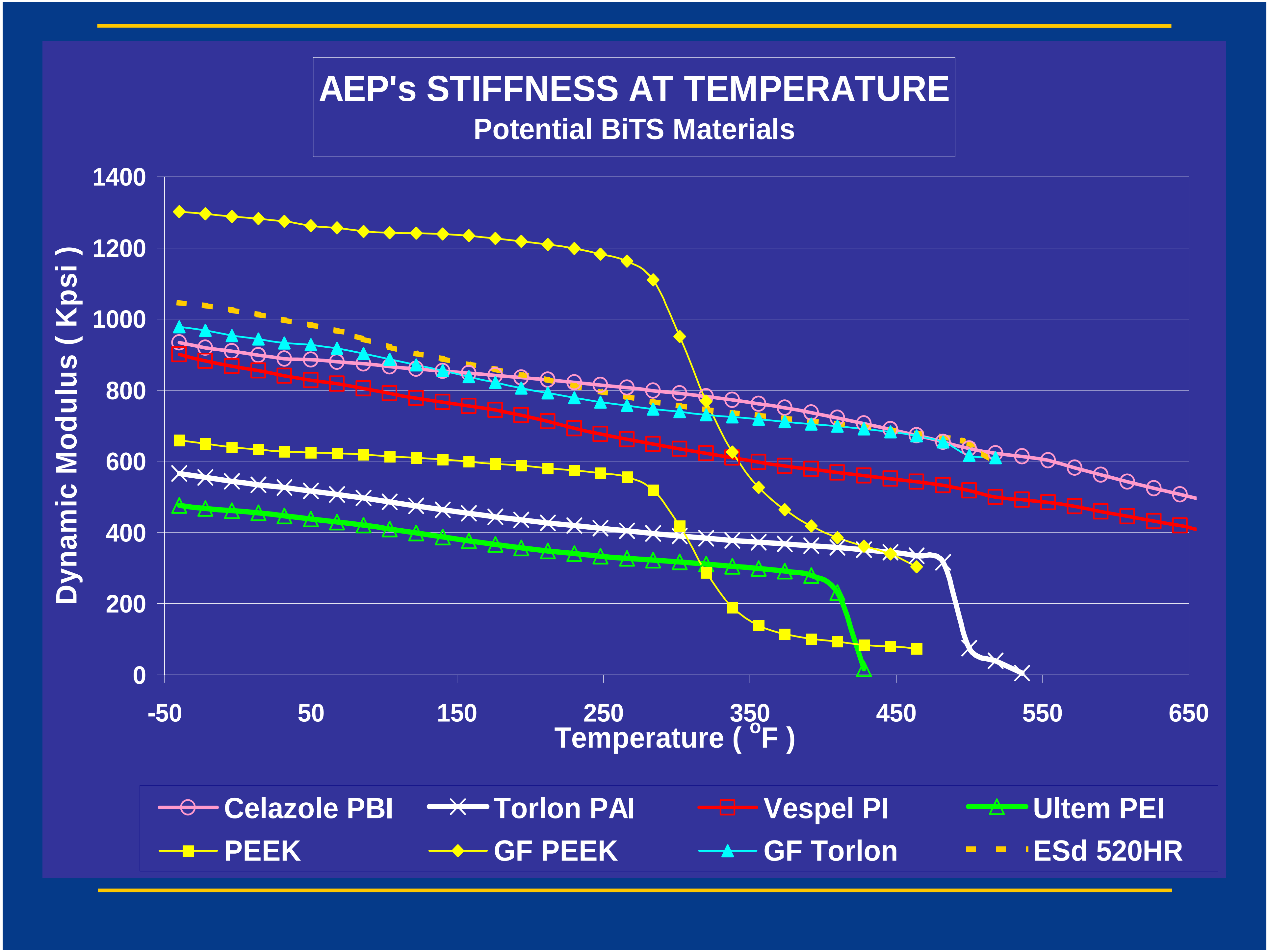
| | | *Past* | *Now* | *Trend* |
|---|---|---|---|---|
| Performance Characteristics | BiTS Requirements | Vespel SP-1 | Torlon 5530 | Semitron ESd 520HR |
| Thermal Stability | -55°C to +155°C | OK | OK | OK |
| Dimensional Stability | <2.0 x $10^{-5}$ in/in/°F | 3.0 | 1.5 | 1.5 |
| Mechanical Strength (Compression) | Repeated Compressive Loads / Long Life | 16 Kpsi | 27 Kpsi | 30 Kpsi |
| Static Dissipation (ESd) | $10^{10}$ – $10^{12}$ Ohms / sq | >$10^{14}$ | >$10^{14}$ | $10^{10}$ - $10^{12}$ |
| Low Particulation / No Sloughing | None | N/A | N/A | Non-Sloughing |

## *Mechanical (Strength) Properties*

- **Wear Resistance or Crush Resistance ??**
- **Pins and Wires Pressed onto a BiTS Device Are Likely to Compress the Contact Surface More than “Wear” It.  Compare Relative Compressive Strengths.**
- **Maintain Strength at Elevated Temperatures**

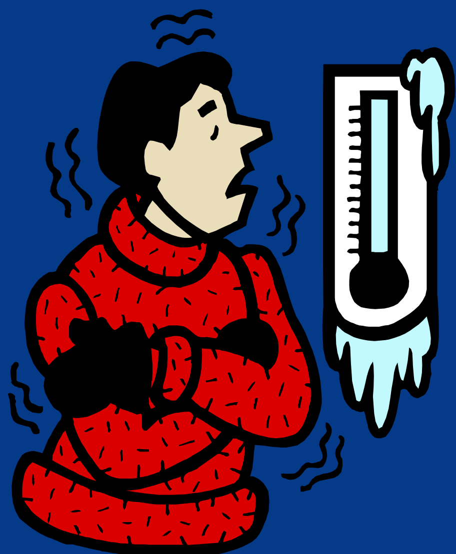


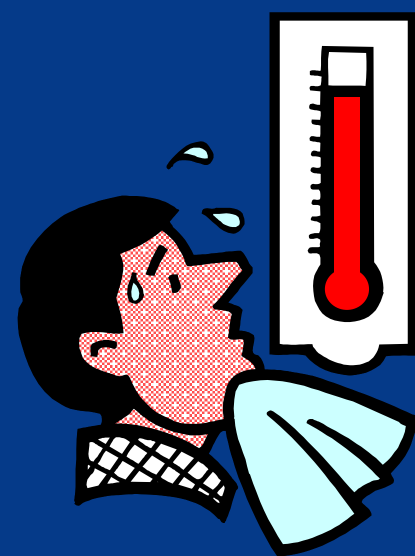
Material Strength (73°F)
Compressive Strength ( psi )
30,000
25,000
20,000
15,000
10,000
5,000
0
Semitron ESd 420
Vespel SP-1 (PI)
PEEK (unfilled)
Ultem (unfilled PEI)
Exp. ESd Ultem
Duratron XP (PI)
Torlon 4203 (unfilled)
Exp. ESd PEEK
Torlon 5530 (PAI)
Semitron ESd 520HR



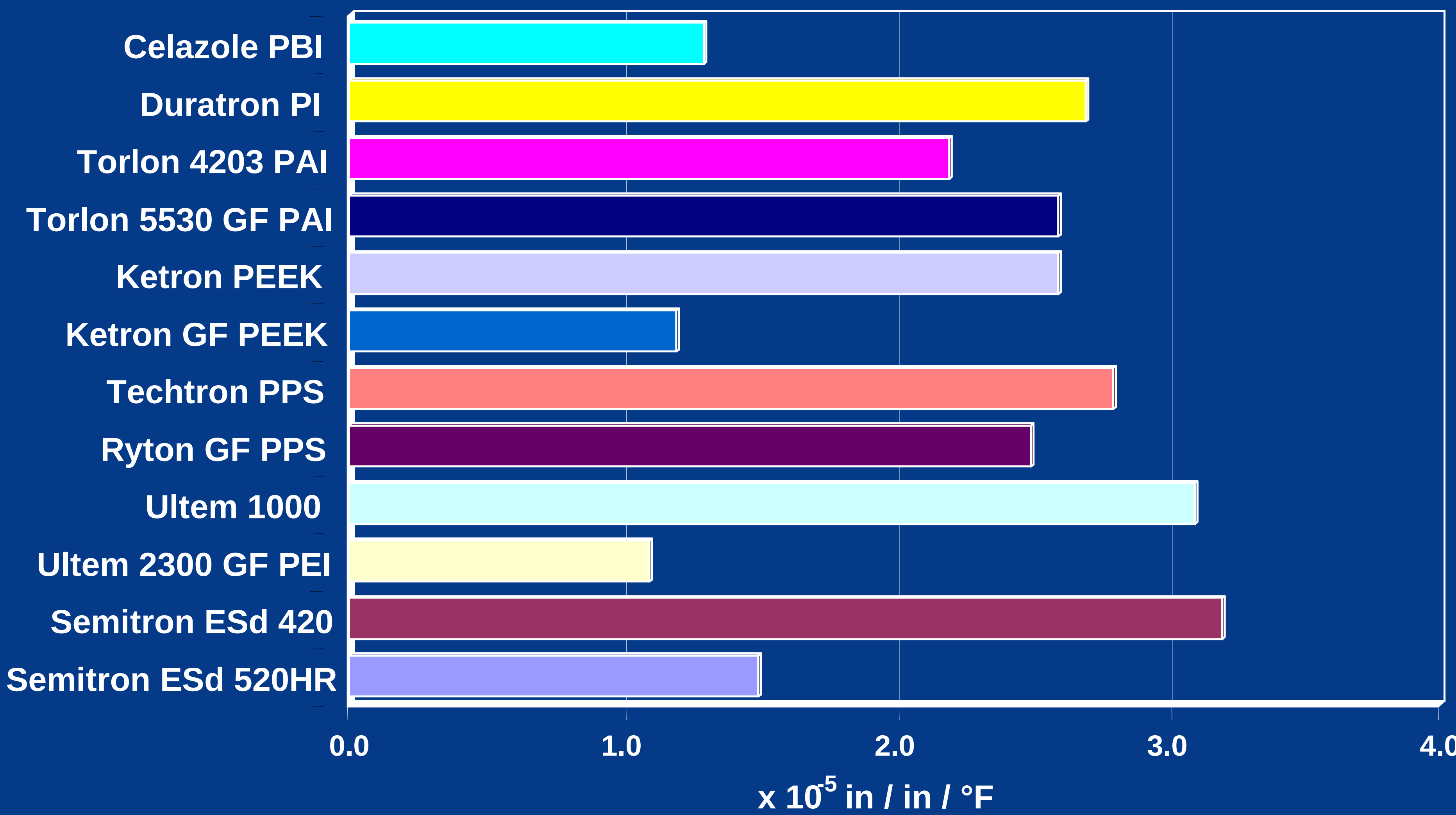
AEP's STIFFNESS AT TEMPERATURE
Potential BiTS Materials
Dynamic Modulus ( Kpsi )
1400
1200
1000
800
600
400
200
0
-50
50
150
250
350
450
550
650
Temperature ( $^{o}$F )
Celazole PBI
Torlon PAI
Vespel PI
Ultem PEI
PEEK
GF PEEK
GF Torlon
ESd 520HR

# *What About Dimensional Stability?*





# Coefficient of Linear Thermal Expansion

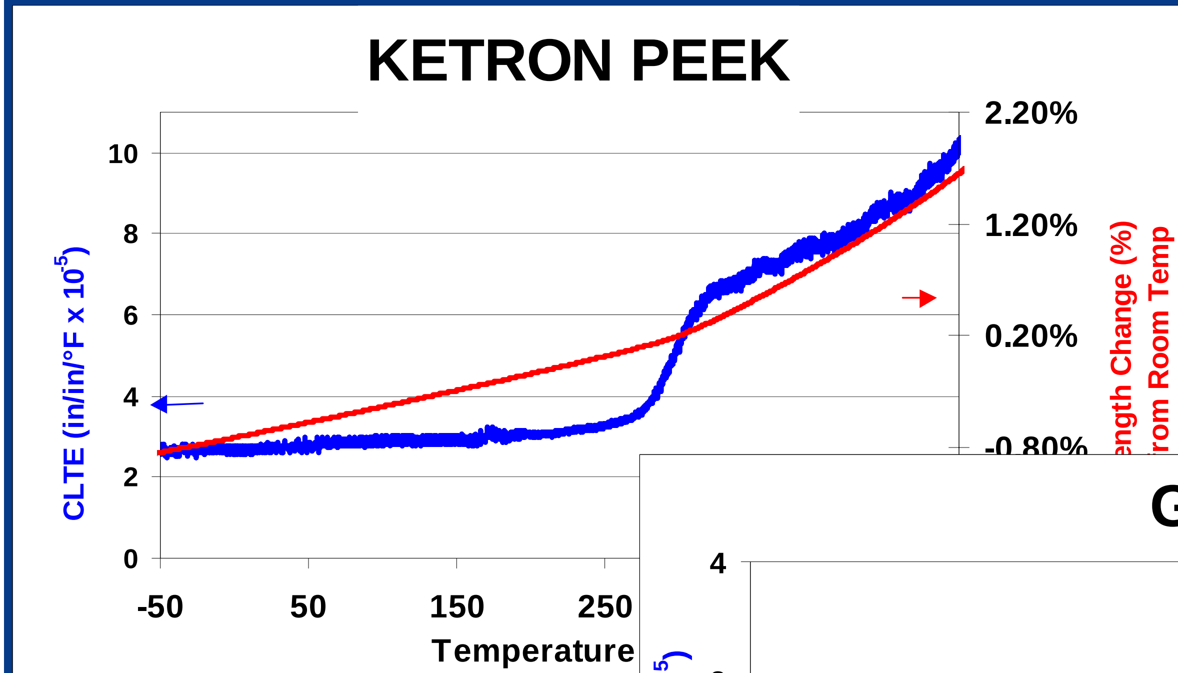


# *There's More to CLTE Than A Single Point*

***Data Sheets Typically Show A Single Value for CLTE.***

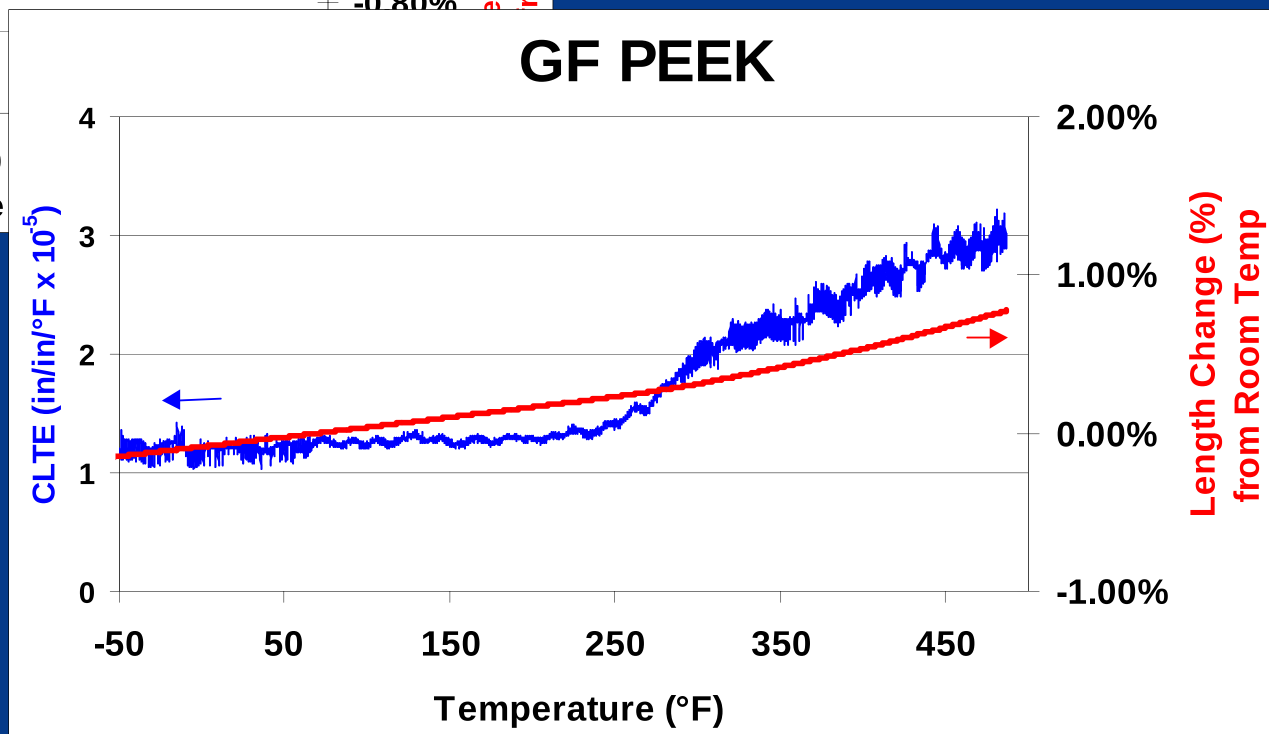
***The World Is Not That Simple...***

# There's More to CLTE Than A Single Point



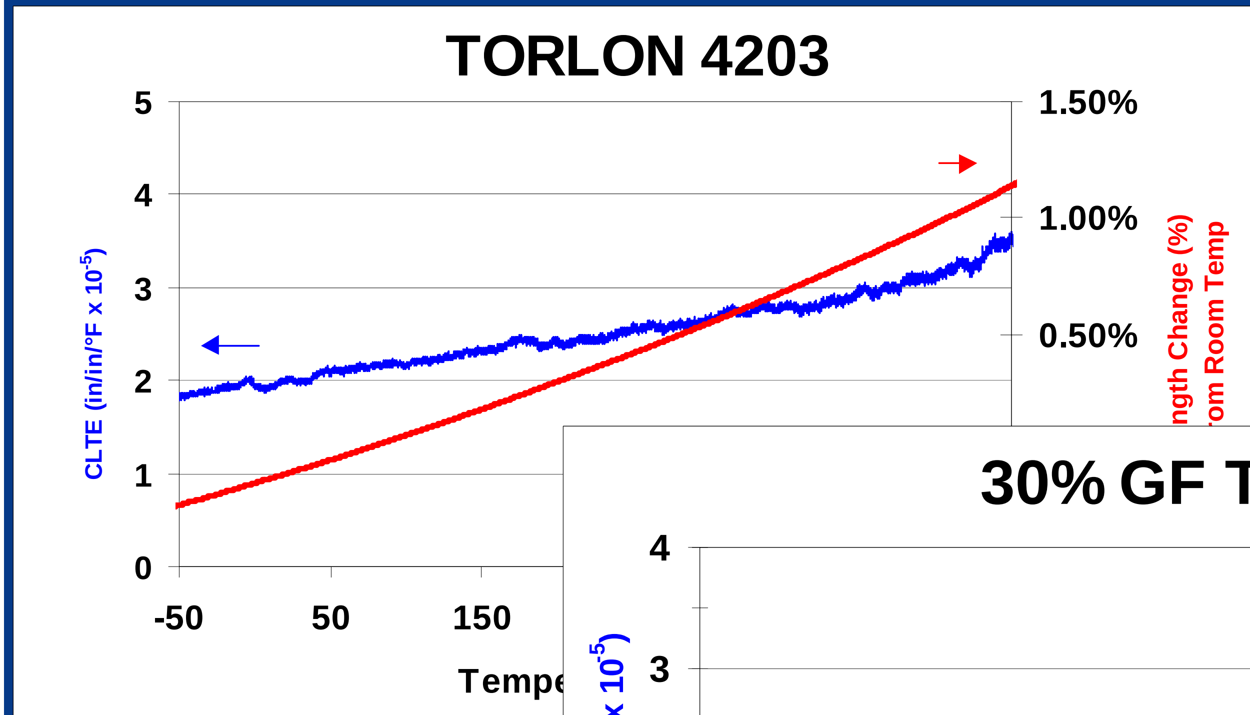

PEEK is Crystalline,

But Still Exhibits $T_g$ Effect

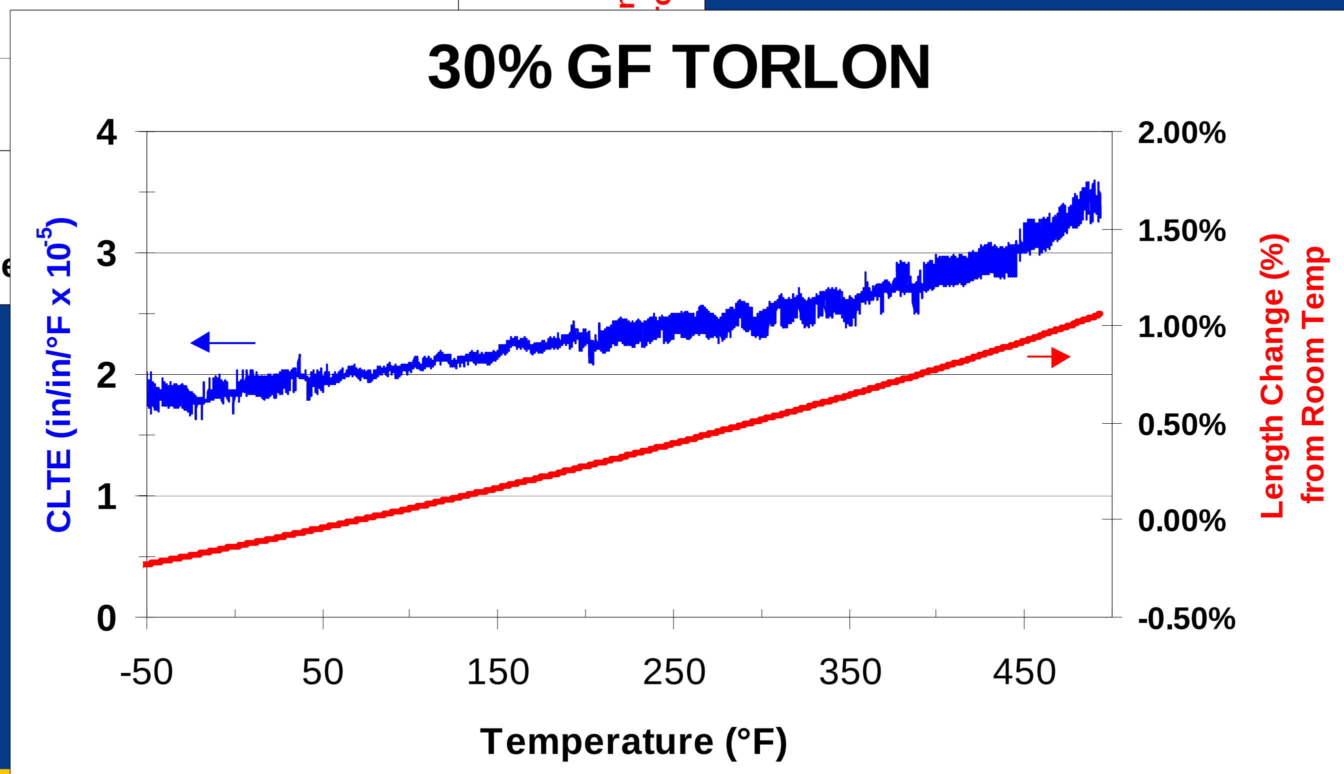



Glass Fibers Enhance Dimensional Stability, Especially in Crystalline Polymers

# *Amorphous Polymers' CLTE*

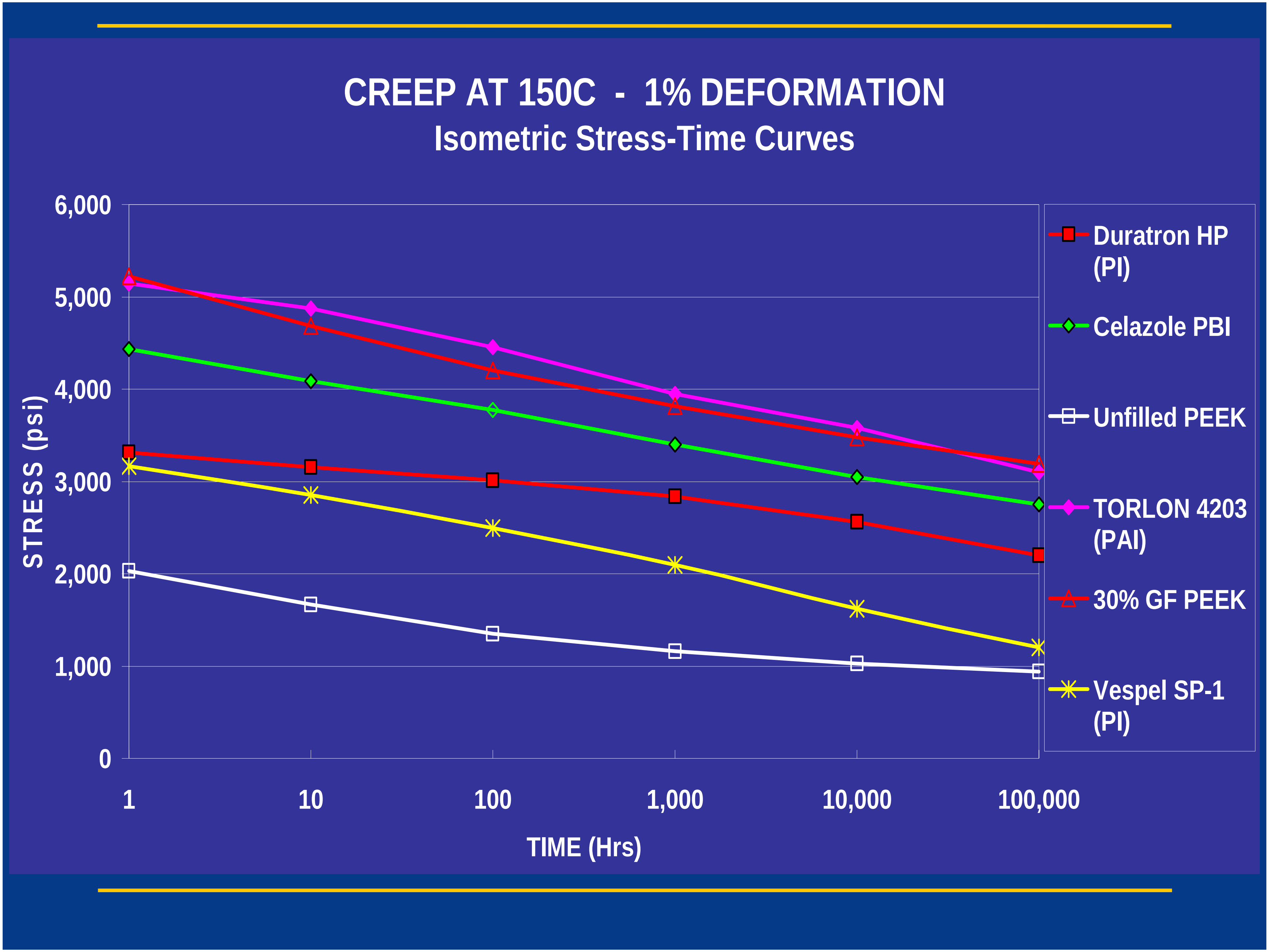



No Abrupt Transitions

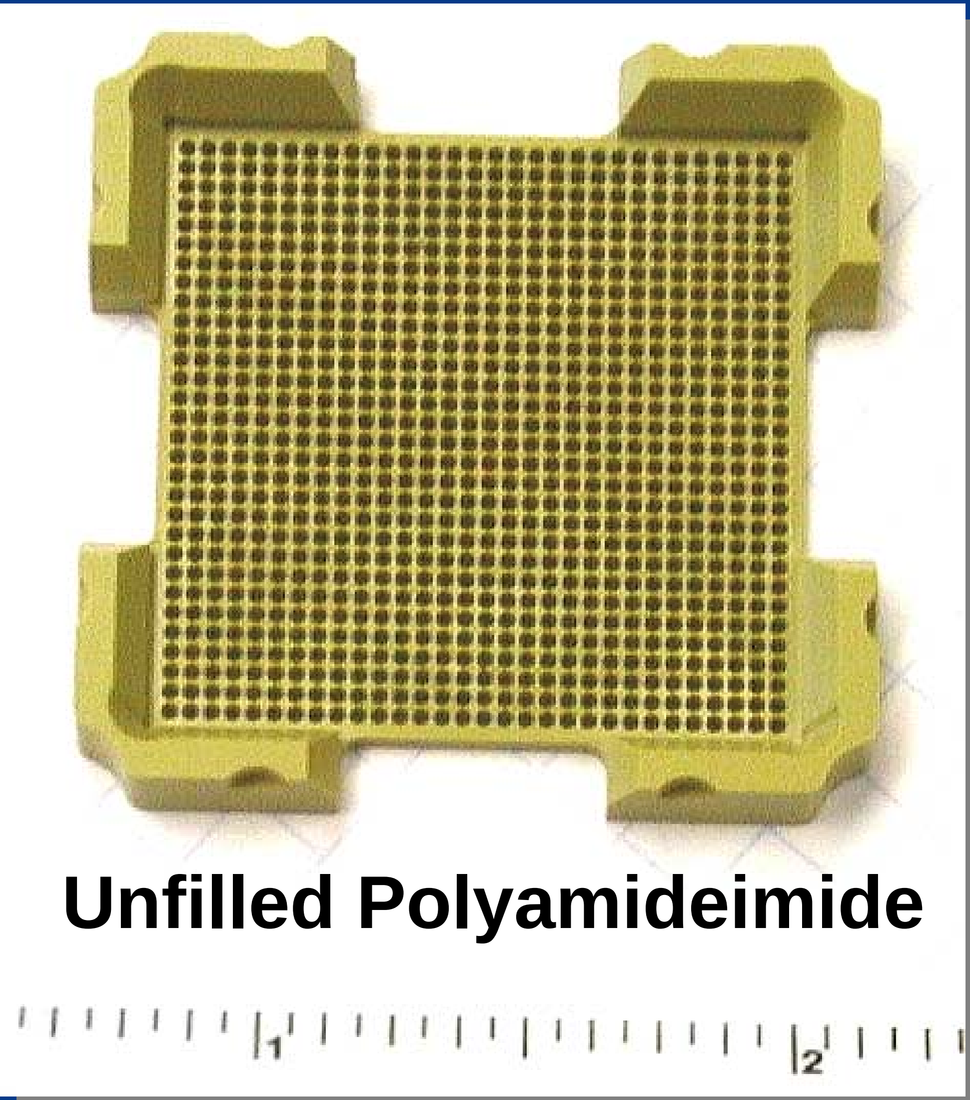


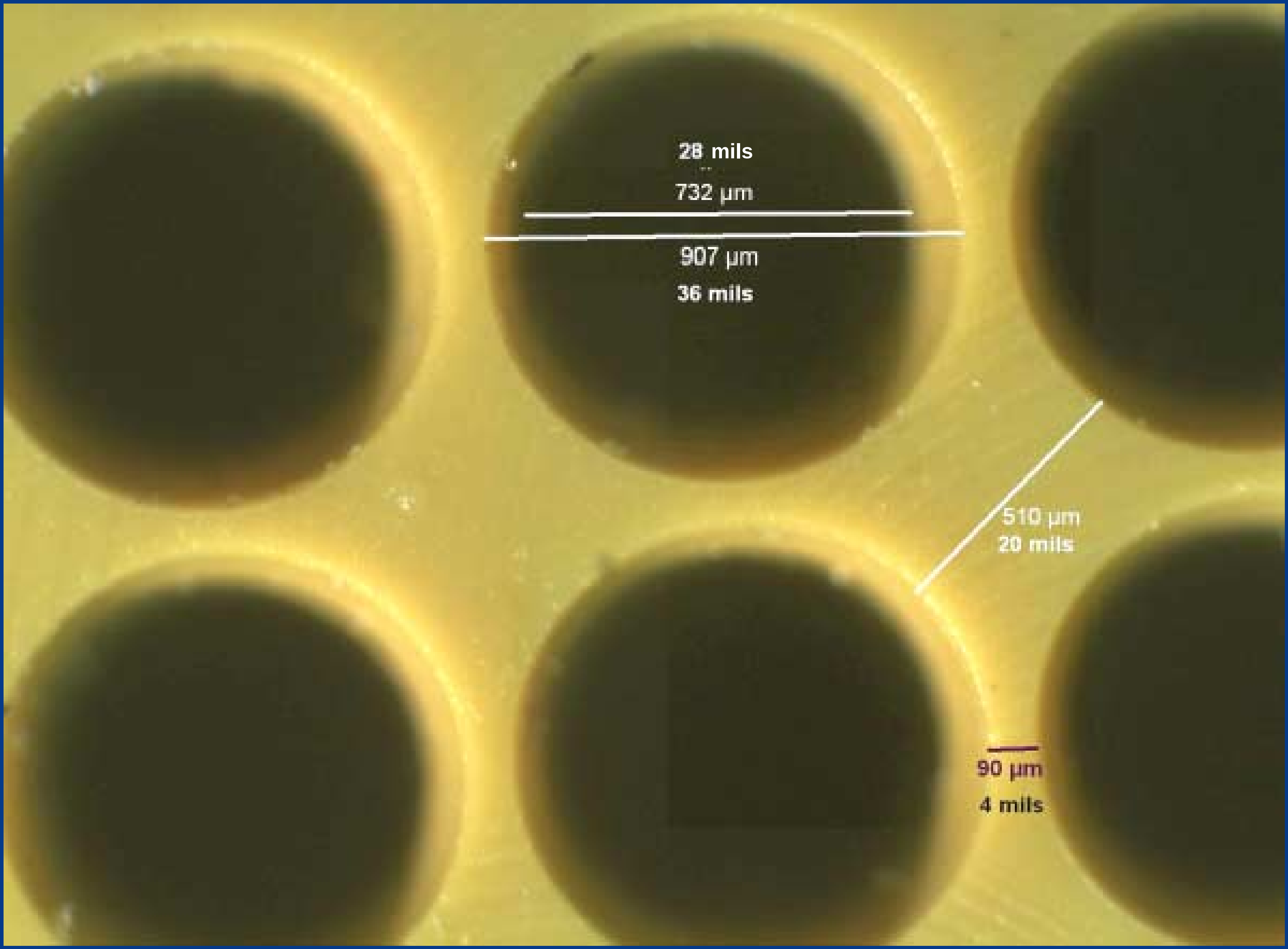

GF's Have Less Effect in Amorphous Polymers

(than in crystalline polymers)


CREEP AT 150C - 1% DEFORMATION
Isometric Stress-Time Curves
STRESS (psi)
6,000
5,000
4,000
3,000
2,000
1,000
0
1
10
100
1,000
10,000
100,000
TIME (Hrs)
Duratron HP (PI)
Celazole PBI
Unfilled PEEK
TORLON 4203 (PAI)
30% GF PEEK
Vespel SP-1 (PI)

# *Socket Machined from Torlon 4203*




28 mils
732 µm
907 µm
36 mils
510 µm
20 mils
90 µm
4 mils

# *Hole Density and Size*

- Ever Higher Performance Demands Higher Density / More Complexity
  - MPU, Video Graphics
  - Approaching 100 µm Hole to Hole Geometries
- BiTS Materials Must Be Able To Deliver

## *Hole Size and Density Study*

- 10 and 5.5 mil holes drilled into 75 mil plates
- Spacing 10, 8, 6, 4 mils wall to wall
- 4 x 4 grid pattern
- Examined by optical microscopy
- Materials:
  - Unfilled Ultem Polyetherimide
  - PEEK Polyetheretherketone
  - GF PEEK (30% GF)
  - Torlon Polyamideimide
  - Torlon 5530 (30% Glass Fibers)
  - Semitron ESd 520HR - Static Dissipative Filled Torlon

# *Machining Conditions Used*

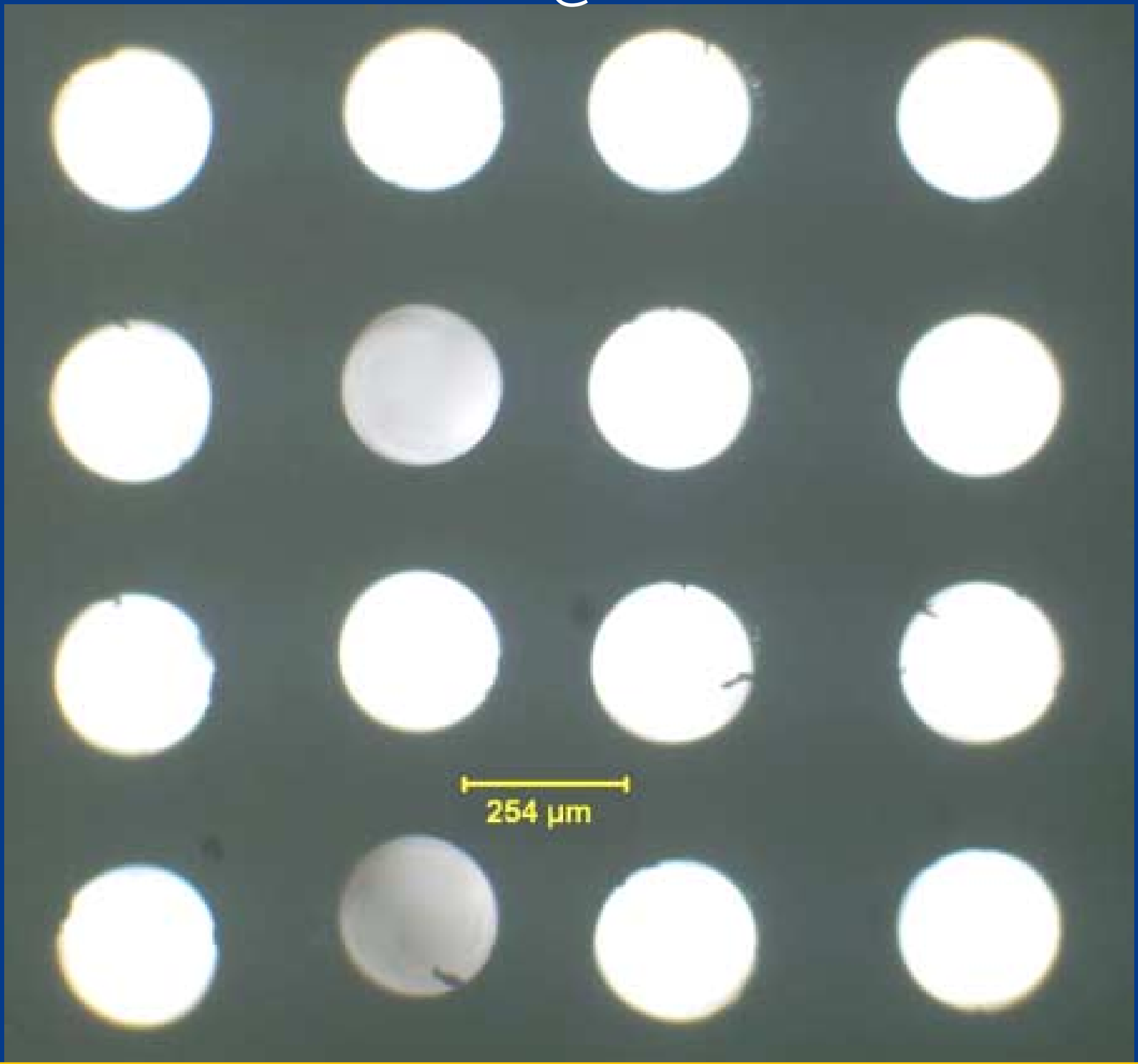
– Carbide High Speed Drill Bits

– For 10 Mil Holes:
  - 8,500 RPM
  - 15 inches per minute feed rate
  - 15 mils “peck”

– For 5.5 Mil Holes
  - 10,000 RPM
  - 20-25 inches per minute
  - 20 mils “peck”

# PEEK (unfilled)

**10 mils @ 5 mils**



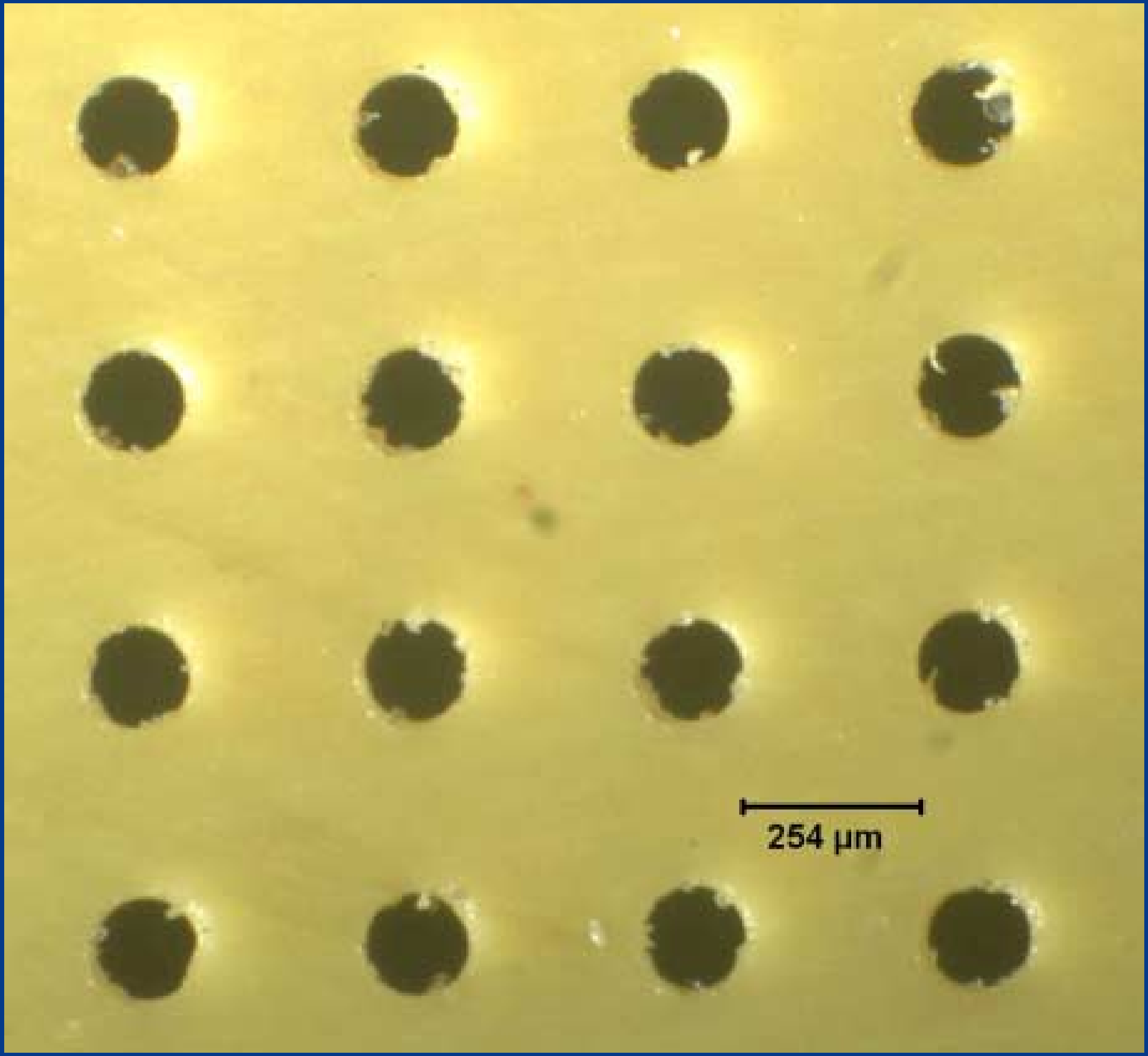

254 μm

# PEEK (30% Glass Fibers)

**10 mils @ 3 mils**

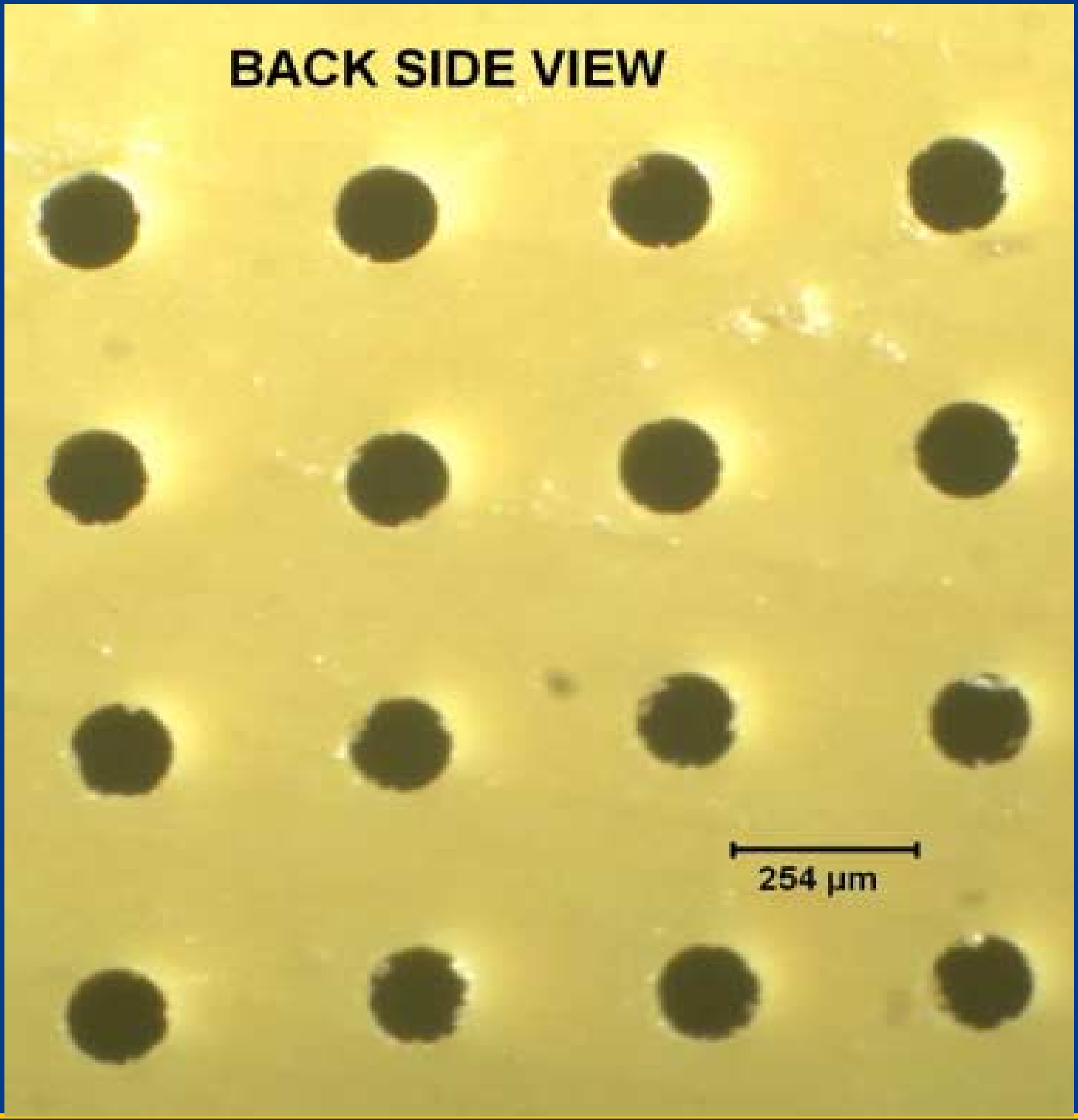
# Torlon 4203 PAI

**5.5 mil @ 10 mils**



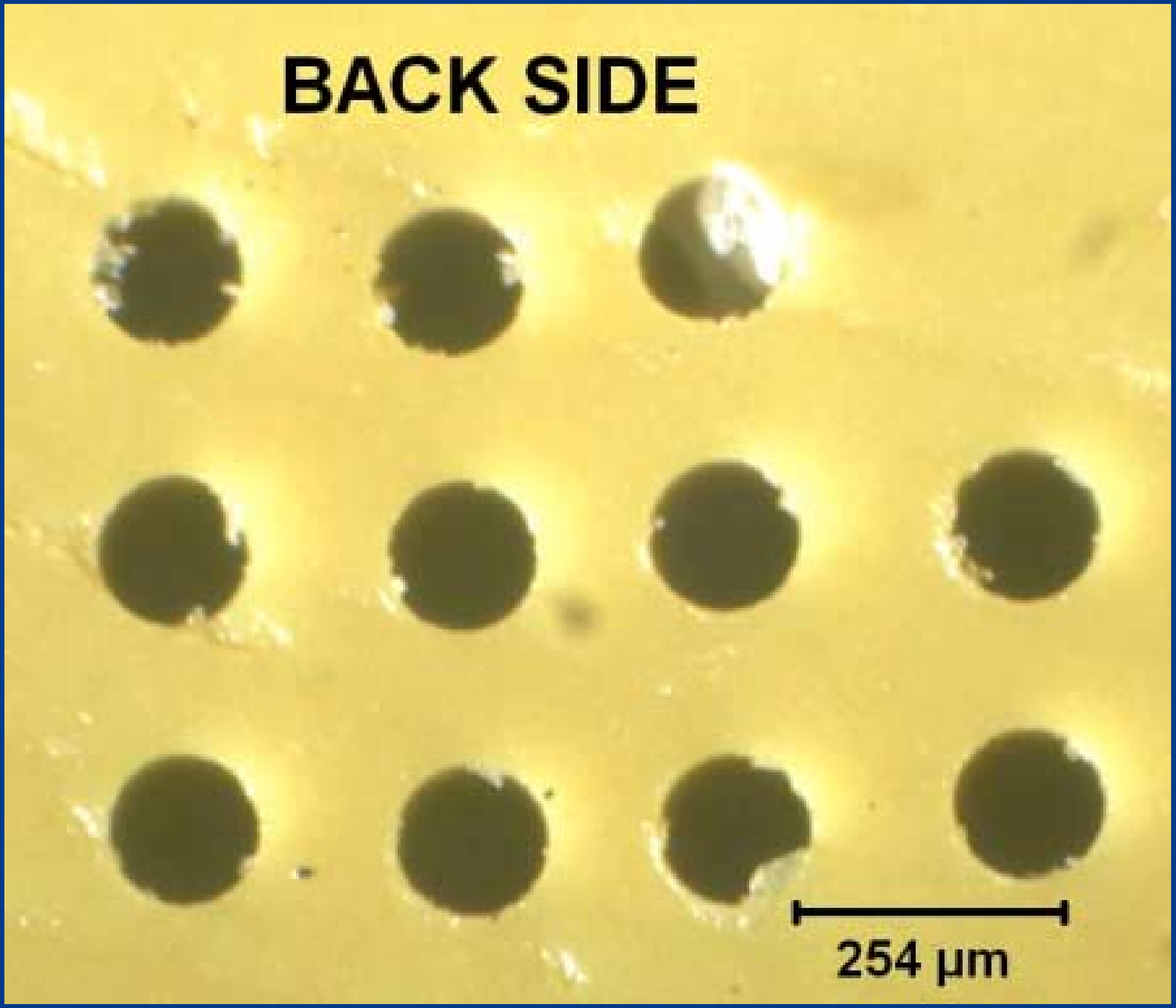
# Torlon 4203 PAI.

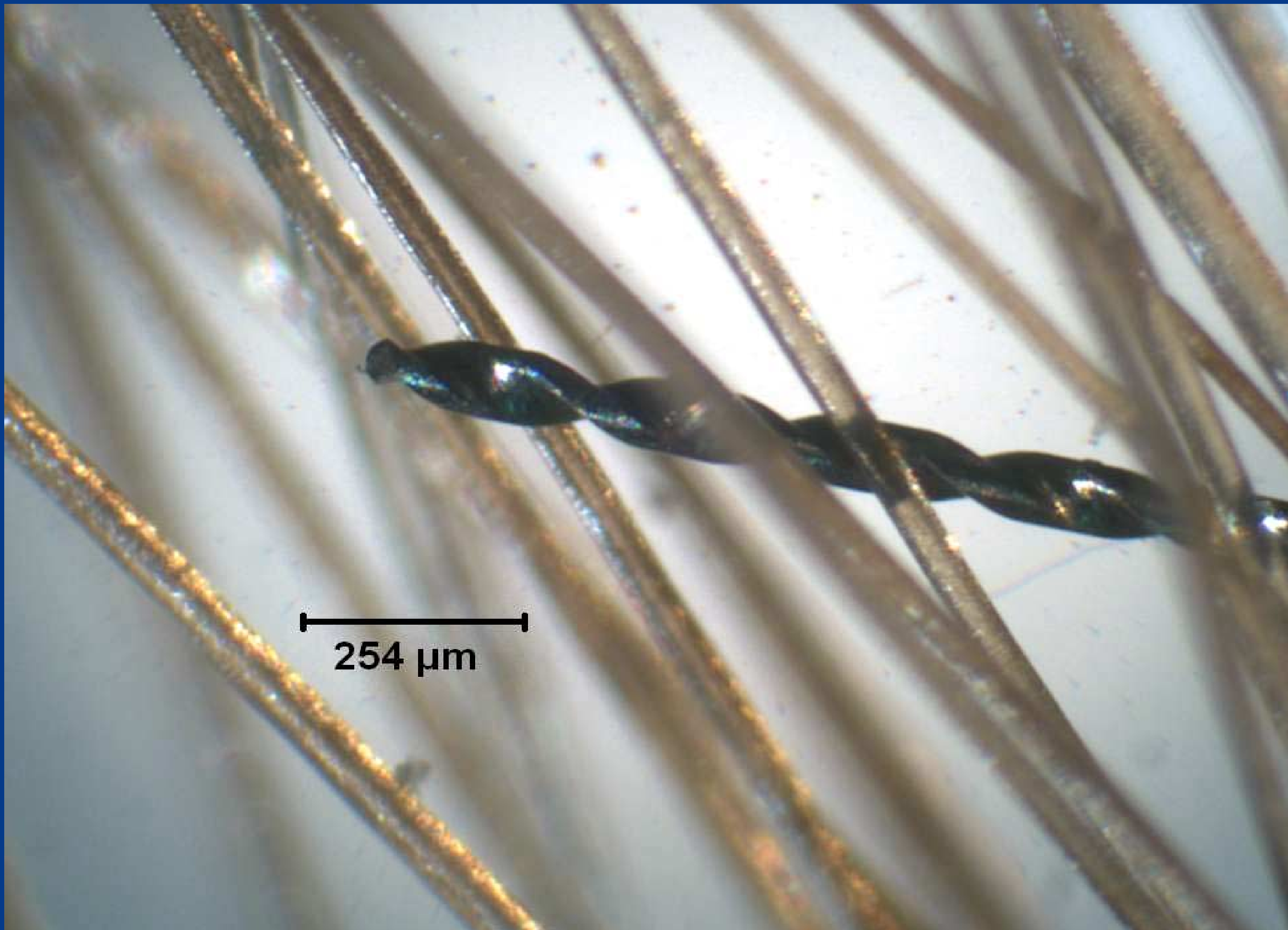
**5.5 mil @ 10 mils**



# Torlon 4203 (Unfilled)

***5.5 mils @ 5 mils***



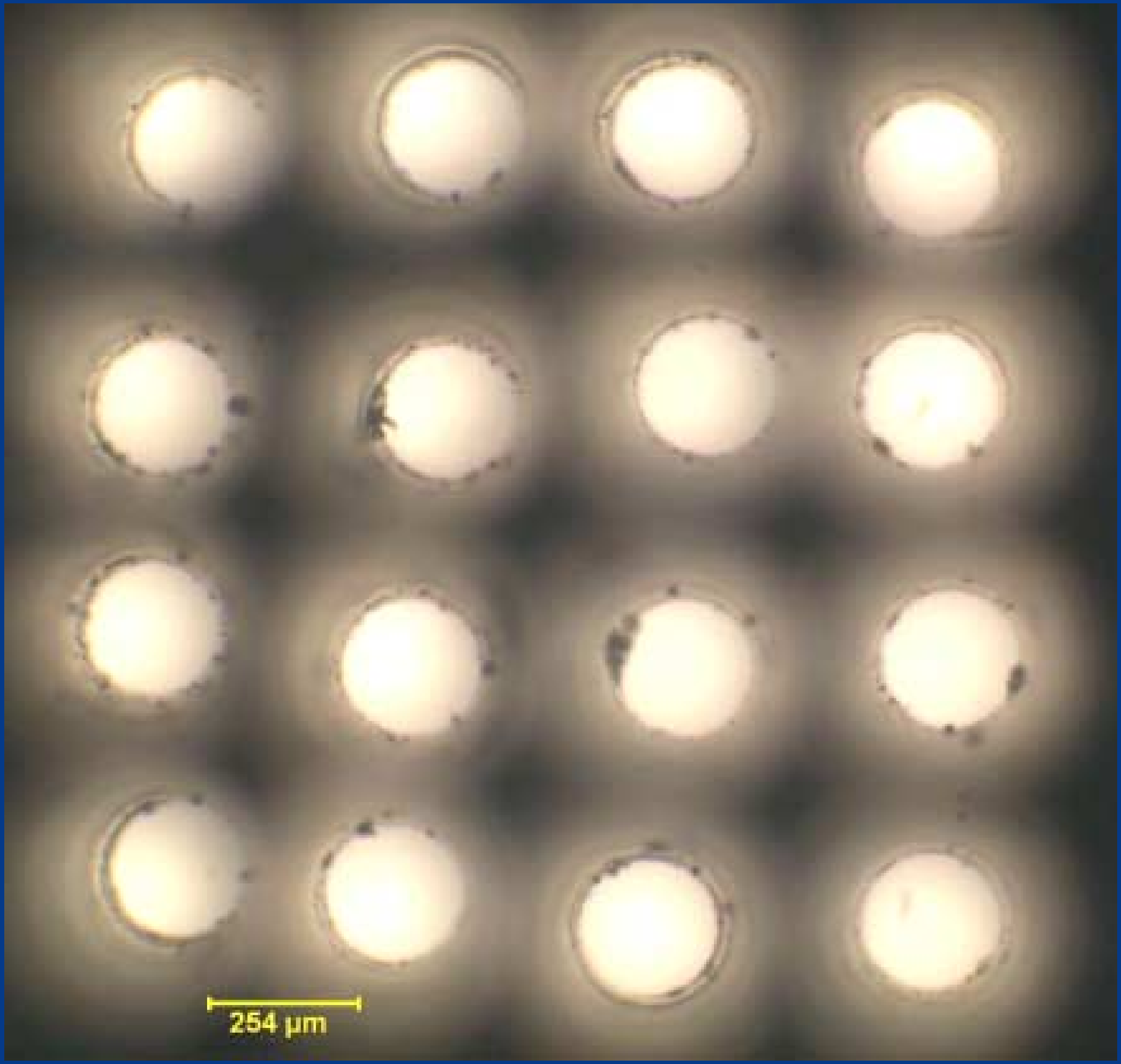

254 µm

# Ultem PEI (unfilled)

**5.5 mils x 4 mils**

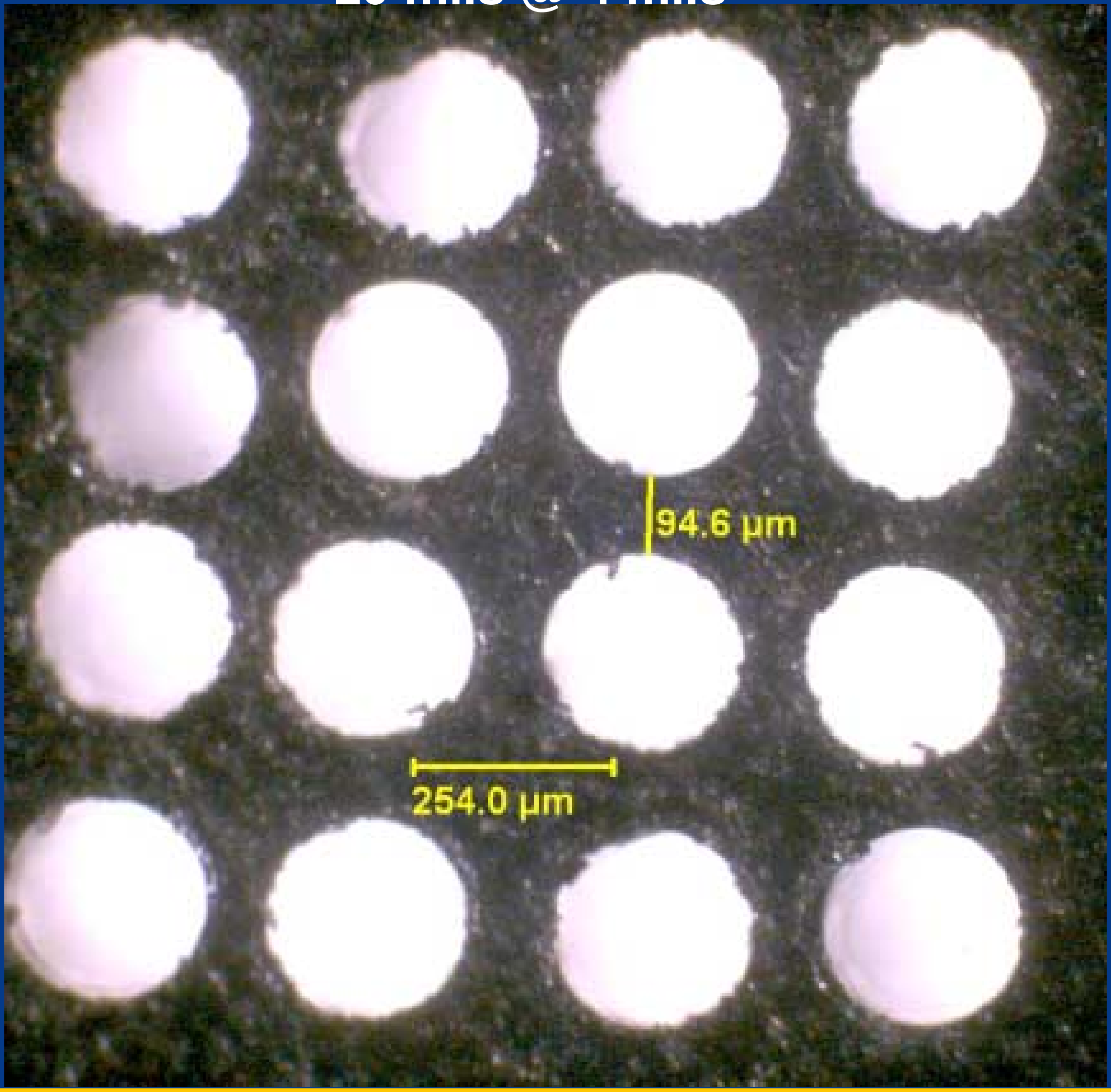
# Celazole PBI

**10 mils @ 5 mils**



# Semitron ESd 520HR

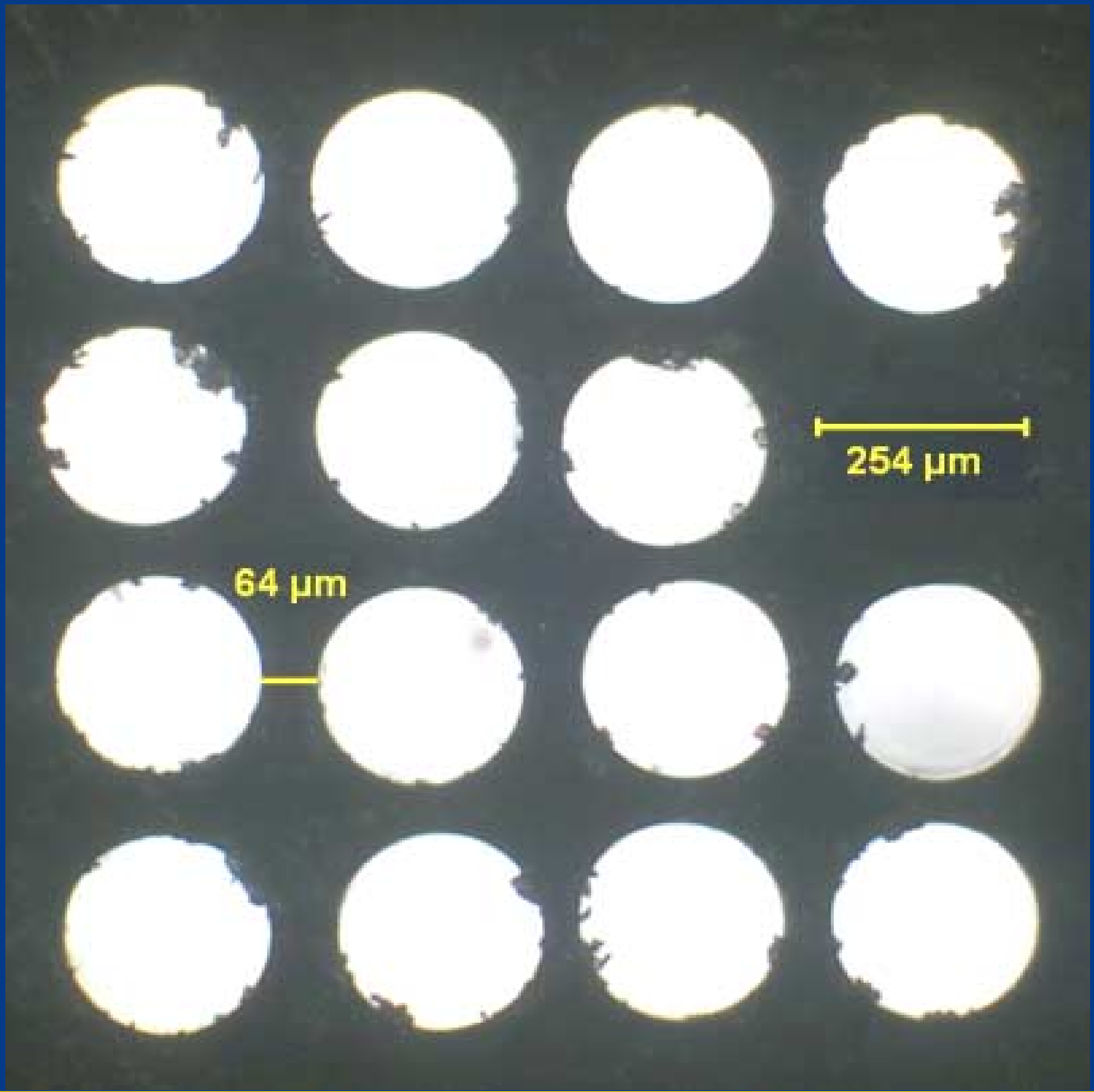
**10 mils @ 4 mils**




Semitron ESd 520HR
5.5 mils @ 10 mils
254 µm

# Torlon 5530 (30% Glass Fiber)

**10 mils @ 3 mils**



# *All These Materials Can Be Machined into BiTS Well*

- **Key:  Sharp Bits and Experience**
- **Unfilled**
  - **Softer; More difficult to do cleanly**
  - **But can be done well with technique**
- **Filled**
  - **Tendency to machine more cleanly**
  - **Smaller geometries make it more difficult to get accurate hole to hole spacing**
  - **Dulls drill bits faster**
  - **Generates more heat during drilling**

# *Issues in Small Drilling Holes*

- Drill Bits are Small and Break Easily
- Bits Dull Quickly, Especially in GF and CF
- GF or CF Can Deflect the Drill Bit
- If There are Several Hundred Holes, Bits Can Break or Dull Well Before Finishing
- Heat, thus CLTE, Can be Issues in High Tolerance Alignment in Unfilled Plastics
- Stress Relief - By Supplier and In-Process

***CAD Designing is Easy.  Making Parts is Tougher***

# What About Those Static Discharges?

- Degrade or Destroy Semiconductor Devices
  - $\Rightarrow$ Discharge to the Device
  - $\Rightarrow$ Discharge from Device
  - $\Rightarrow$ Field Induced Discharge

- Disruption of an Electronic System Leading to Malfunction or Failure

# *Electrostatic Dissipative (ESd)*

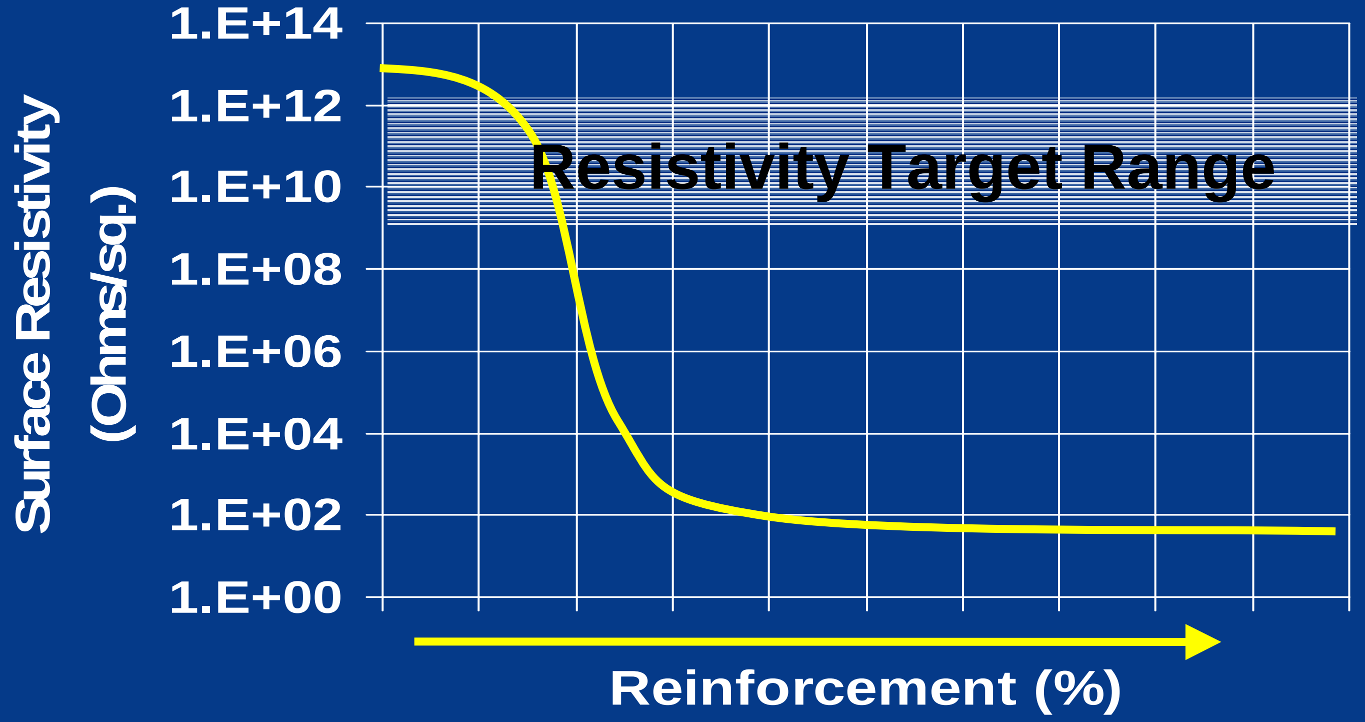
**ESd materials are capable of slowly bleeding away static electricity in a controlled manner…**

**Surface Resistivity ( Ω / sq )**

| | $10^2$ | | $10^5$ | | $10^{10}$ | | $10^{12}$ | |
|---|---|---|---|---|---|---|---|---|
| Conductive Materials | | Conductive Range | | Dissipative Range | | High Resistivity Range | | Insulative Range |

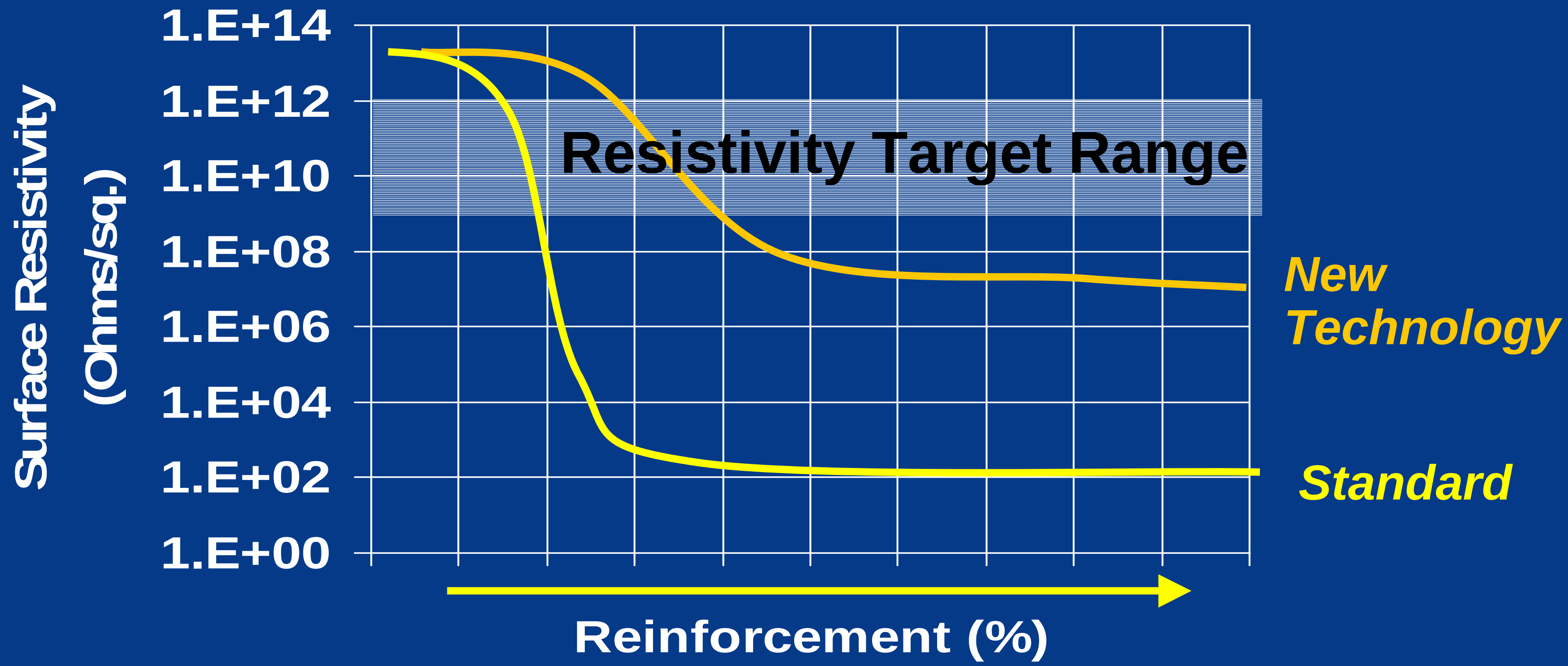
**Engineers specify ESd performance based on the application and the sensitivity of the product to ESD**

# *Typical Impact of Conductive Reinforcement Loading on Electrical Performance*




**Reliably Maintaining Resistivity Target in Production Environment is Not Feasible via CF Loading Alone**

# *New Technology Was Developed to "Flatten The Percolation Curve"*




**New Technology Ensures Control and Reliability**

# *Machining or Injection Molding ?*

- **Large Runs of Same Design** — » **Injection Molding**
- **Highest Precision and Closest Tolerances** — » **Machining**
- **Complex Design Freedom** — » **Machining**
- **New Design Evaluation** — » **Machining**
- **Thicker and/or Thinner Cross-sections Possible & Combined** — » **Machining**
- **Lowest Internal Stresses** — » **Machining**
- **No Weld Lines** — » **Machining**
- **Quickest Turn-Around** — » **Machining**

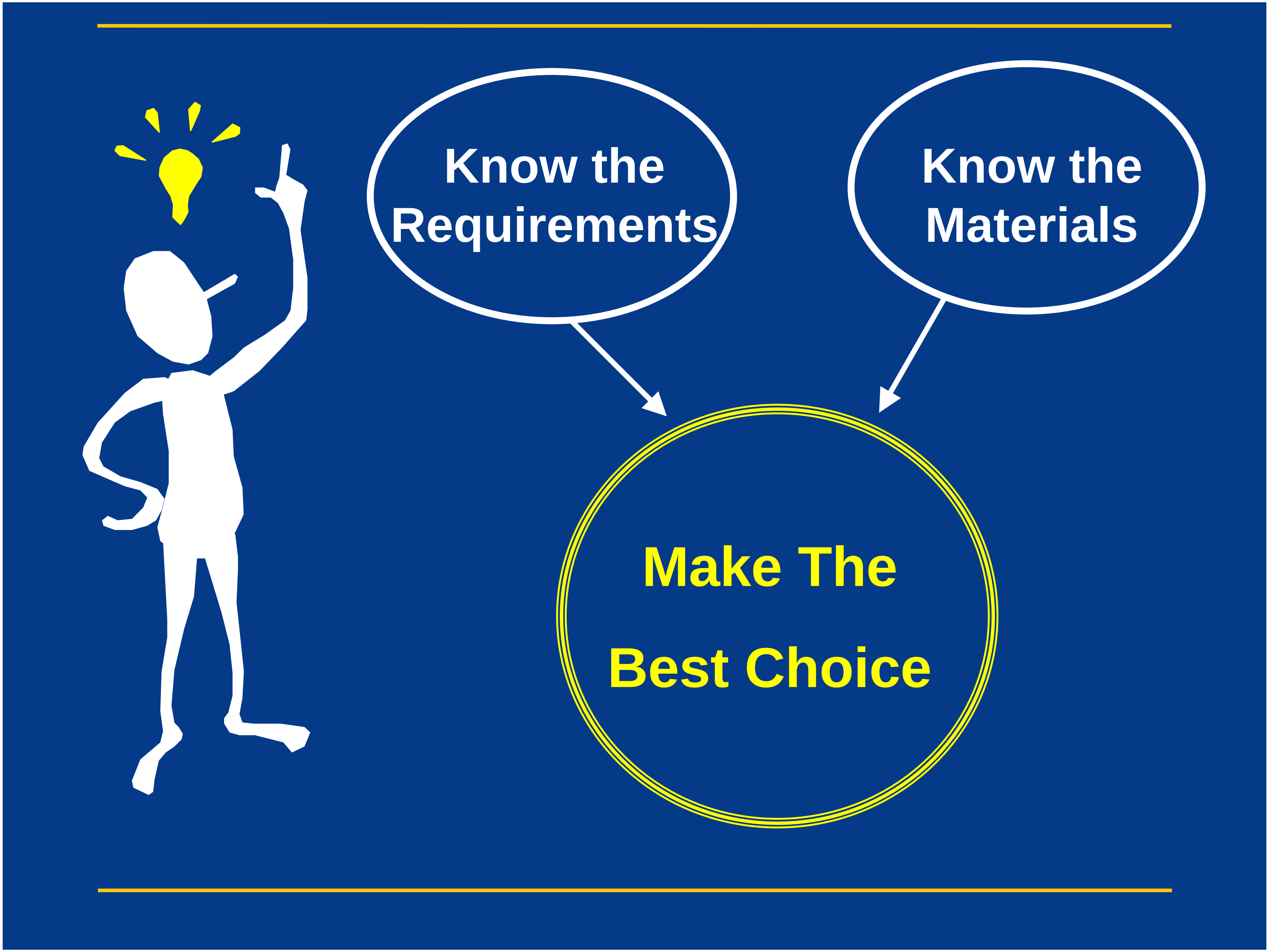
# *Extruded or Compression Molded ?*

**Extruded**

- Higher Volume Production Runs
- Higher Stresses in Fiber Filled Materials
- Mostly Available to 4” Diameter Rods; to 2” Thick Plate; and 4” OD Tubes
- Longer Lengths (48”) for All Geometries

**Compression Molded**

- Lower Volumes
- Lowest Stress Levels
- Best Dimensional Stability
- Larger Diameter Rods or OD/ID Tubes, but $\leq$12” in Length
- Non-Melt Processable Materials Feasible
- Specialty Formulations Easier to Evaluate


Know the Requirements
Know the Materials
Make The Best Choice

EVERETT CHARLES TECHNOLOGIES
Testing the Limits

# *Permittivity Determination of Contactor Dielectrics at RF Frequencies*

**Jason Mroczkowski**
**Everett Charles Technologies**
**March, 2003**

BiTS BURN-IN & TEST SOCKET WORKSHOP

## *Presentation Topics*

- STG's Need
  - To understand contactor material electrical properties in the GHz Frequency Range
- Our Goal
  - Complex permittivity at high frequencies
- The Problem
  - No Published Data at High Frequencies for contactor materials
- Our Solution
  - Measure properties using Vector Network Analyzer
- Some Data
  - Dielectric constant, loss versus frequency
- The Future
- Summary and Conclusion

## *Our Need*

- ECT-STG needed to understand effects of high frequency signals on contactor dielectric materials
  - Increasing operating frequencies of semiconductor devices
    - 10 to 20 times bps needed for bandwidth
    - 500 mbps $\rightarrow$ 5 – 10 GHz bandwidth needed
  - **Known:** low frequency properties (MHz)
  - **Unknown:** high frequency properties (GHz)
    - do properties diverge from low frequency values?
  - If properties do not match published values at High frequencies transmission characteristics will change
    - designed in MHz used at GHz may lead to disaster

# *The Problem*

- **There is little published data for test contactor material permittivity characteristics in the GHz range**

  - Current publications specify material properties at low frequencies (e.g.10Mhz or so)

  - Manufacturer material specifications vary

## *Our Goal*

- Determine dielectric properties of contactor materials in the GHz range
  - Measure permittivity as function of frequency
  - Use Software simulations to correlate measured data
- Do material properties change as frequency increases
  - Is there a trend as frequency increases?
  - Will material properties degrade at high frequency?
  - If so how will it affect transmission characteristics?

# *Intro To Permittivity*

- **What is permittivity?**
  - Ability of material to resist alignment of electron
- **What is complex permittivity?**
  - Complex number
  - Real part - relative permittivity
  - Imaginary part - attenuation constant (loss)
- **What is relative permittivity?**
  - Ratio of  material permittivity to that of a vacuum
  - Dielectric constant
- **Why is permittivity important?**
  - Permittivity describes a materials insulating properties
  - Affects characteristic impedance of transmission lines

## *Theory*

- ***General permittivity***
  - **Complex permittivity** $\varepsilon = \varepsilon_o(\varepsilon_r' - \varepsilon_r'')$
  - **Dielectric constant** (capacity to hold charge) $\varepsilon_r'$
    - – Free space $\varepsilon_r' = 1$
  - **Dielectric and conductor loss** (energy dissipation) $\varepsilon_r''$
    - – Free space $\varepsilon_r'' = 0$
  - **Loss tangent** $\tan\delta = \varepsilon_r'' / \varepsilon_r'$
  - **Characteristic impedance** $Zo \propto 1/\left(\sqrt{\varepsilon_r}\right)$
    - – ***change in Zo changes $\varepsilon_r$'*** may cause mismatch

# *Measurement* (Obstacles)

- **Equipment costs**
  - Off the shelf measurement units - mucho denero

  - Only measure to 1GHz

- **Sample Fabrication**
  - Milling, etching, polishing, assembly
  - technique dependent

# *Obstacles (cont…)*

- Accuracy and precision of technique
  - Error introduced by non-idealities
  - More sensitive at high frequency
  - Frequency range - varies dependent upon technique

- Time and RedBull(energy)
  - Fabrication of samples
  - Measurement tools needed
  - Measurement setup
  - Data acquisition
  - Extraction of properties from data

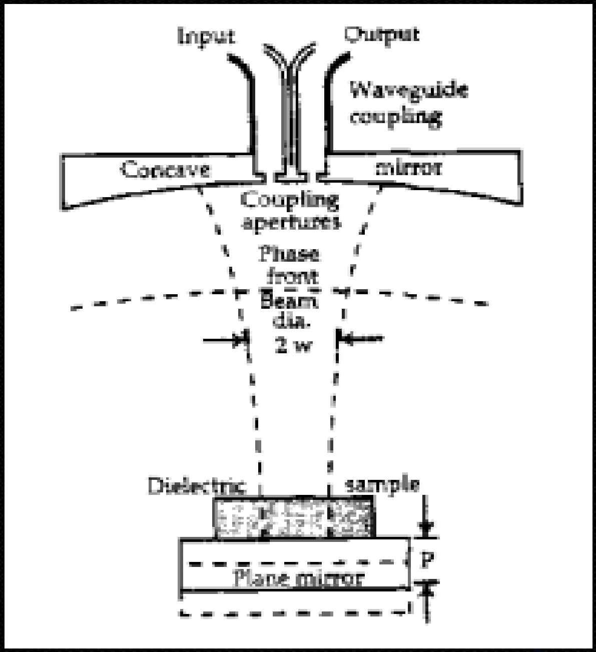
# *The Solution*

- **Measurement technique**
  - Many solution procedures
  - Each technique has advantages and disadvantages

| Technique | Field | Advantages | Disadvantages | $\Delta\varepsilon'_r$ | $\Delta\tan\delta_r$ |
|---|---|---|---|---|---|
| **Transmission-line** | TEM,$TE_{10}$ | Broadband | Precision machining of specimen | ±2% | ±0.01 |
| **Cavity** | $TE_{011}$ | Very Accurate | Low Loss | ±0.5% | $\pm 5x10^{-4}$ |
| **Dielectric Resonator** | $TM_{110}$ | Very Accurate | Low Loss | ±.05% | $\pm 5x10^{-4}$ |
| **Whispering Gallery** | Hybrid | Very Accurate | High Frequency | ±1% | $\pm 5x10^{-6}$ |
| **Fabry Perot** | $TE_{01}$ | Very Accurate | Low Loss | ±1% | $\pm 5x10^{-5}$ |

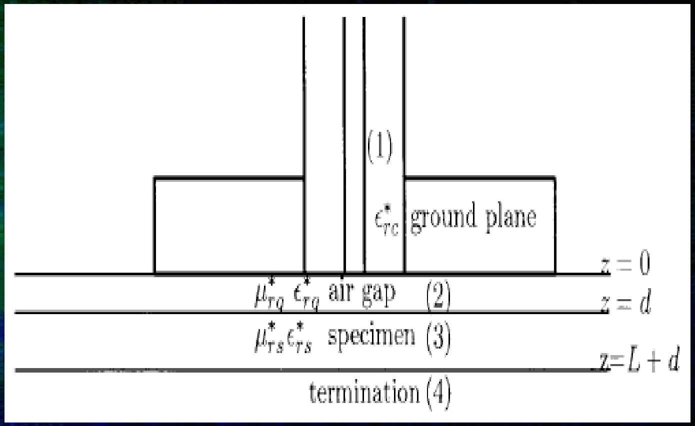
# *The Solution (Methods)*

## Fabry Perot

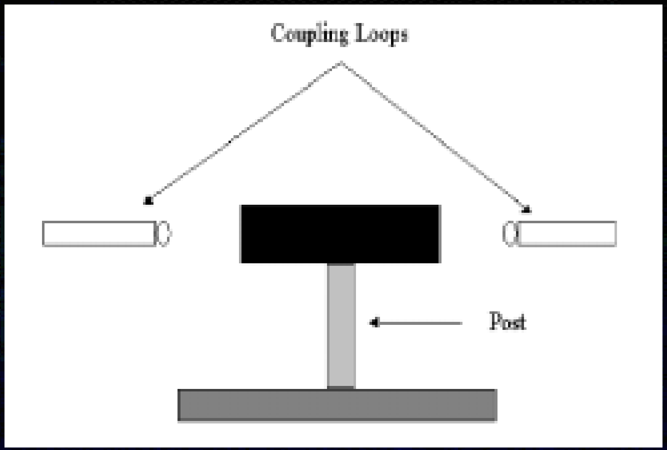



## Resonant Cavity


## Open Ended Coax

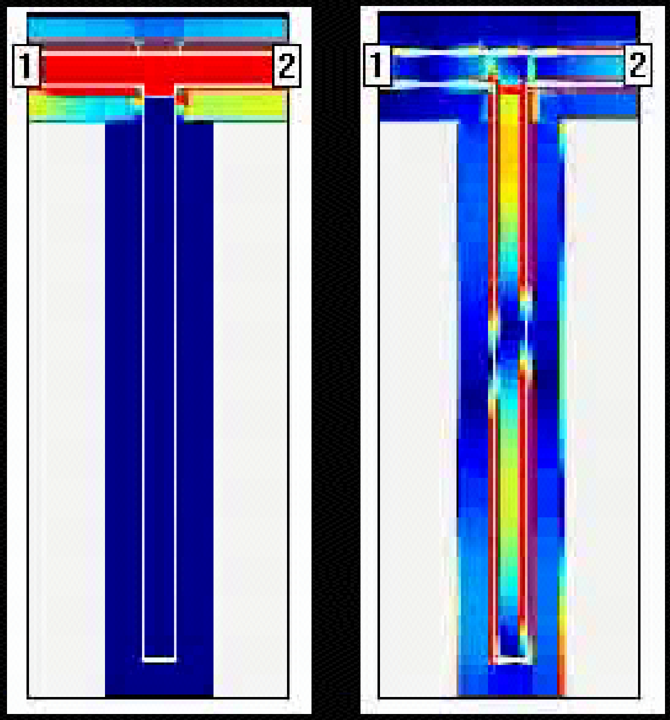


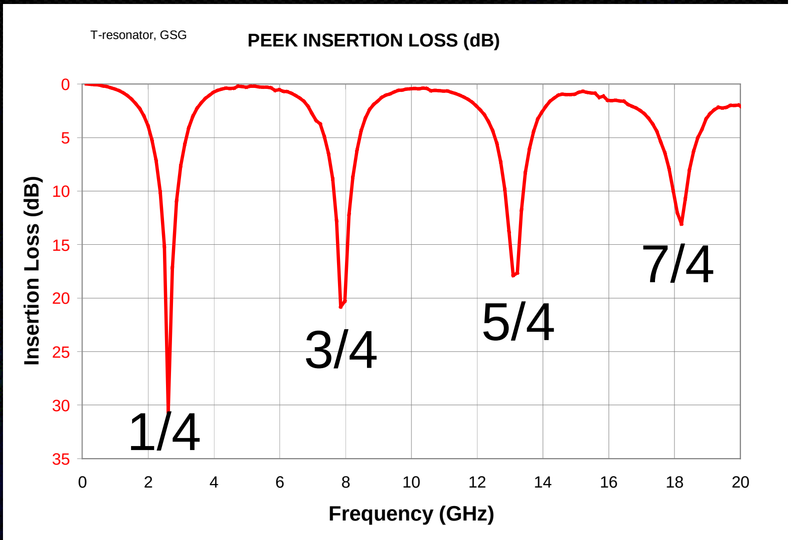

## Whispering Gallery



# *The Solution (Method)*

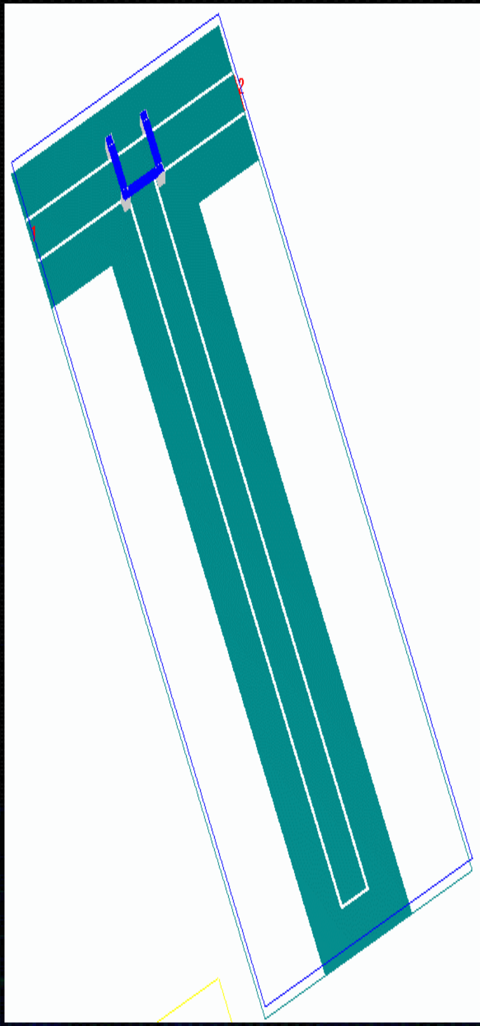
- **Coplanar Waveguide T-Resonator**
  - Resonates at odd-quarter wavelengths
  - Impedance independent
  - Easy to fabricate samples with scrap material
  - Can use air-coplanar microwave probes for testing
  - Multiple resonances allow broadband frequency range
  - Scalable
  - known equations for $\varepsilon_{eff}$ ***and*** $\alpha_t$
- ***Cost efficient, simple, accurate***



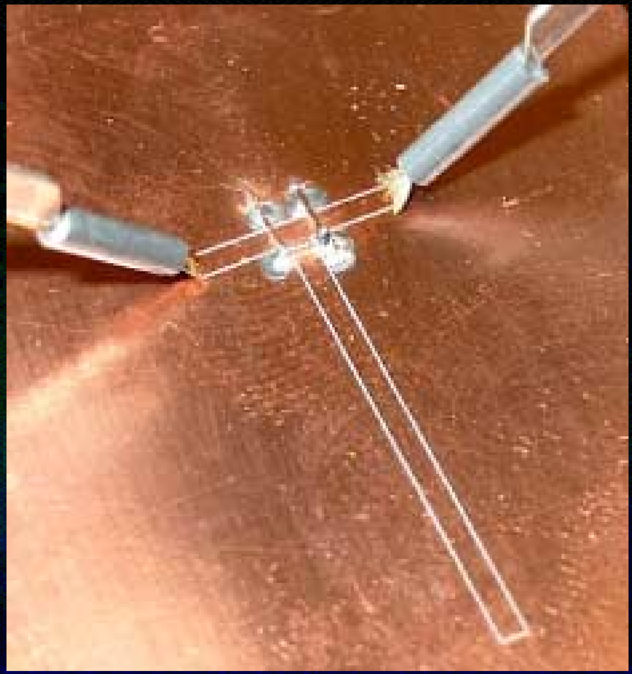
# *The Solution (Method)*

- Laminate .5oz. copper to material samples
- Fabricate CPW tee shape to approximate 50ohm impedance
  - .005” (.127mm) slot machined in with very good results
- Add air bridges to reduce slot line resonance
  - Connect grounds to ensure equal potential
  - Eliminate resonance due to stub transition



# *The Solution (Methods)*

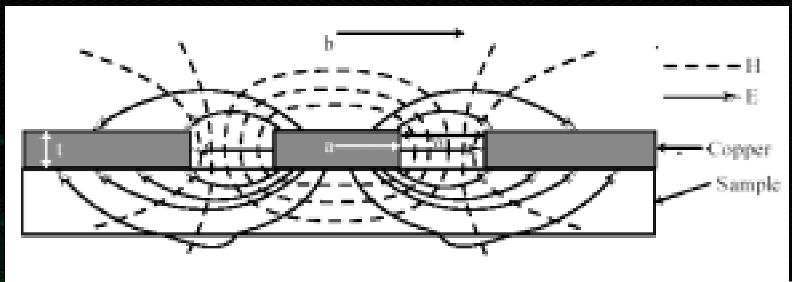
- Extract S-Parameters with Vector Network Analyzer
  - HP8510C network analyzer
  - Picoprobe 40A-GSG-1000-DS 1mm pitch probes
  - Probes calibrated using full two port SOLT (Short-Open-Load-Thru) technique
  - Save $S_{21}$ (transmission) data

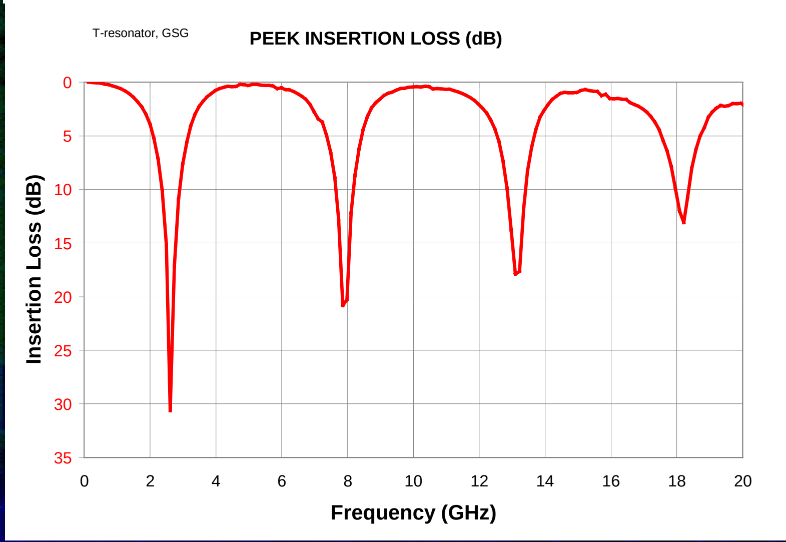


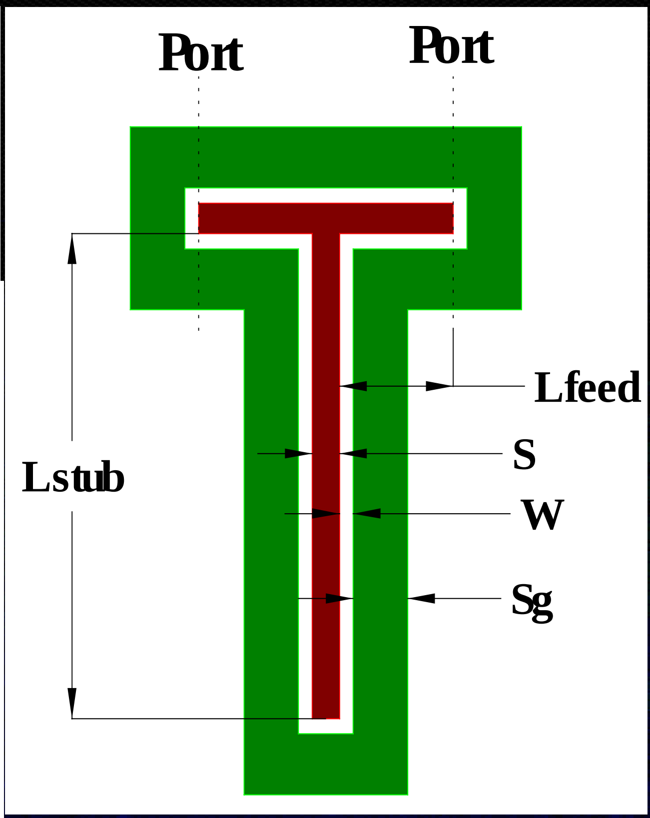
# *The Solution (Theory)*

- T-resonator theory
  - ➤ $\varepsilon_{eff} = ((n \cdot c)/(4 \cdot L_{stub} \cdot f_n))^2$
  - ➤ $\alpha_{tot,n} = 8.686\ ((\pi \cdot n \cdot BW_n)/(4 \cdot L_{stub} \cdot f_n))$ [dB/length]

    (n=resonance index, c=speed of light, $F_n$=resonant frequency, $BW_n$=local 3dB point frequency)



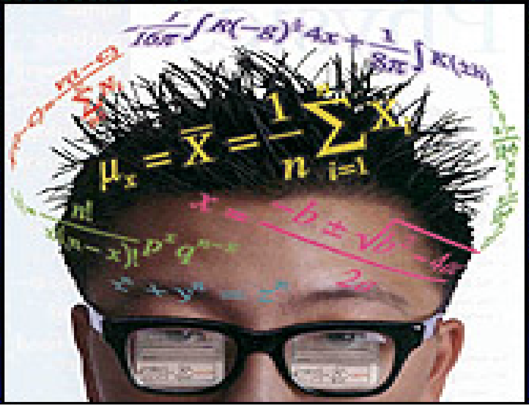
# *The Solution (Theory)*

- Dielectric constant and Loss tangent calculation
  - ***$\varepsilon_r$' and $\varepsilon_r$'' found by solving elliptic integral***

$$K\left(k\right)=\int_0^1 \frac{dx}{\sqrt{(1-x^2)(1-k^2x^2)}}$$

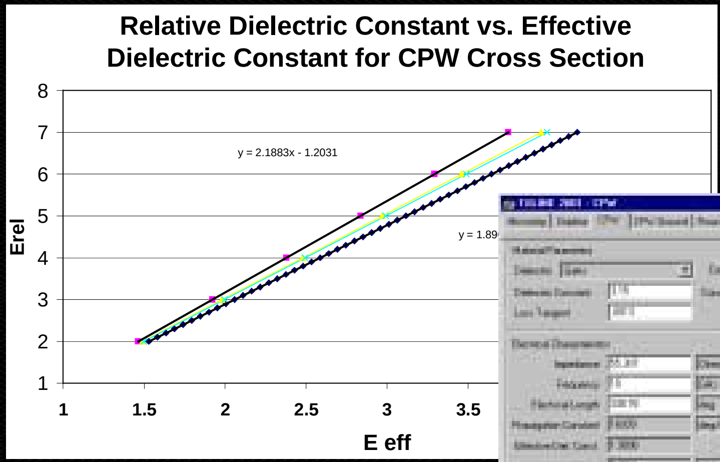
$$\varepsilon_{eff}=\frac{\varepsilon_r-1.0}{2.0}\frac{K(k_2')}{K(k_2)}\frac{K(k_1)}{K(k_1')}+\frac{\varepsilon_r-1.0}{2.0}\frac{K(k_2')}{K(k_2)}\left[\frac{K(k_1)}{K(k_1')}\right]^2\left(\frac{t}{b-a}\right)+\frac{2.0t}{b-a}\frac{K(k_1)}{K(k_1')}+\left[\frac{t}{b-a}\frac{K(k_1)}{K(k_1')}\right]^2$$

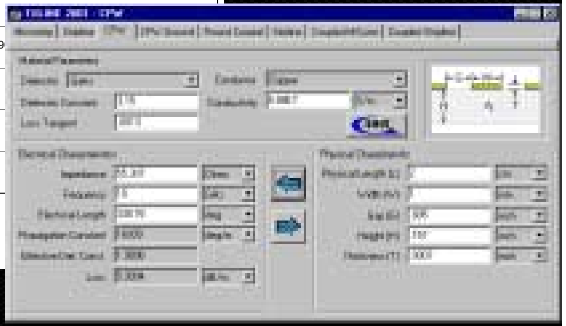
  - ***Requires too much brain power***
    - ***May cause nervous breakdown if calculated manually***



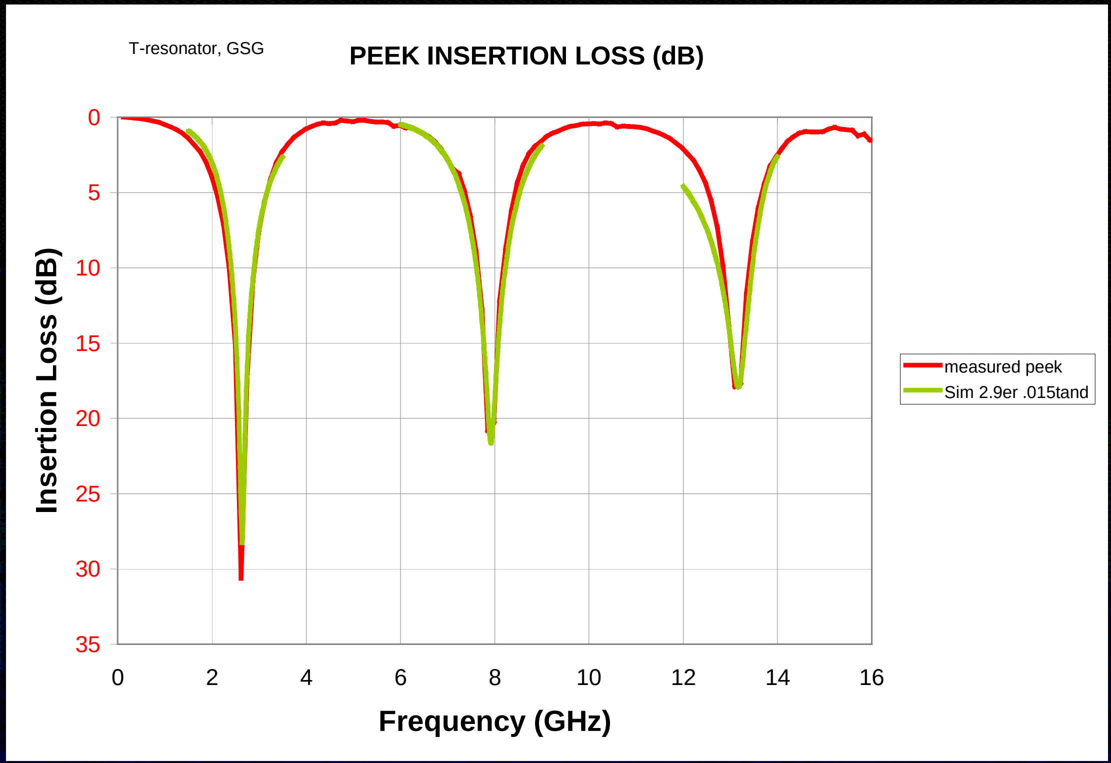
# *Solution - Theory*

- Match measured effective dielectric constant to relative dielectric



- Match planar-EM simulation to measured resonance to determine loss tangent

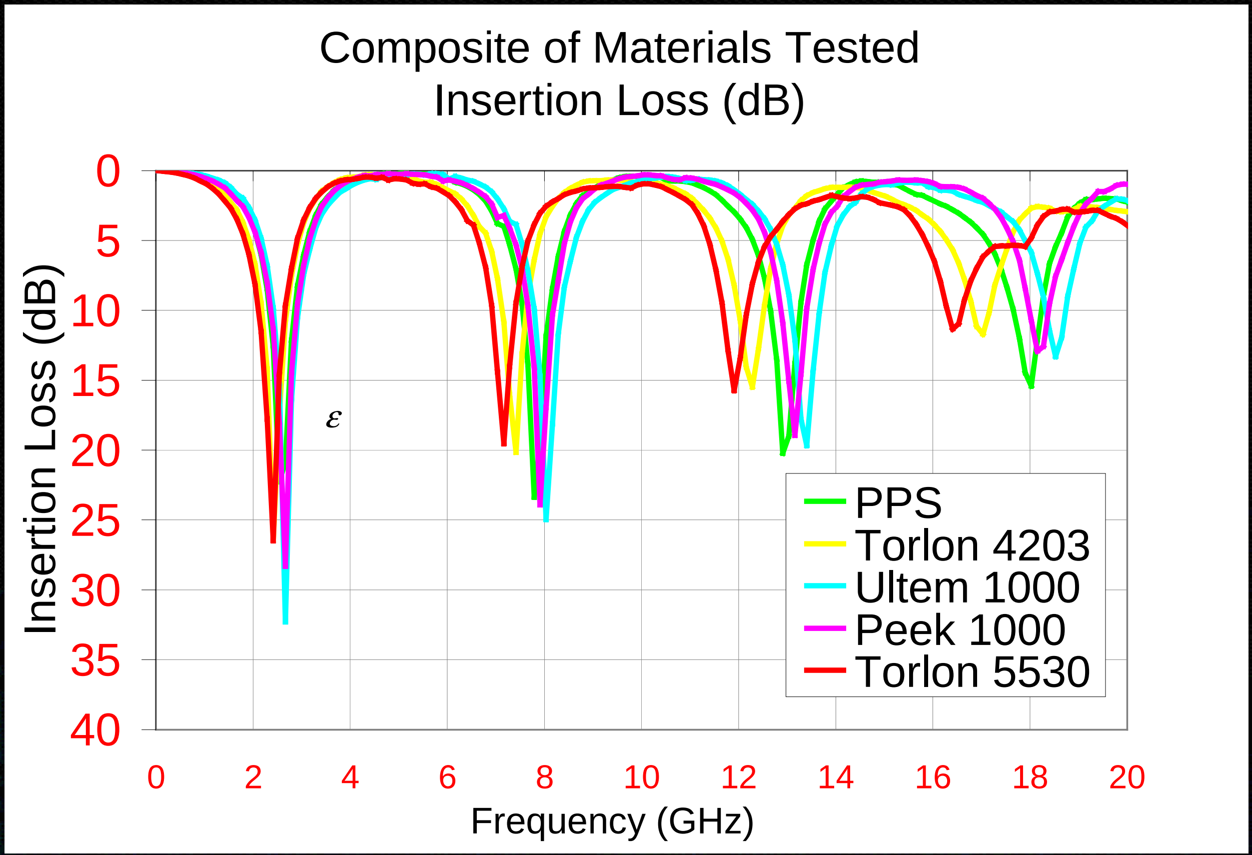


## *Results -*

- Plot measured insertion loss

$$\varepsilon_{eff} = \left( \frac{n \cdot c}{4 \cdot L_{stub} \cdot f_n} \right)^2$$

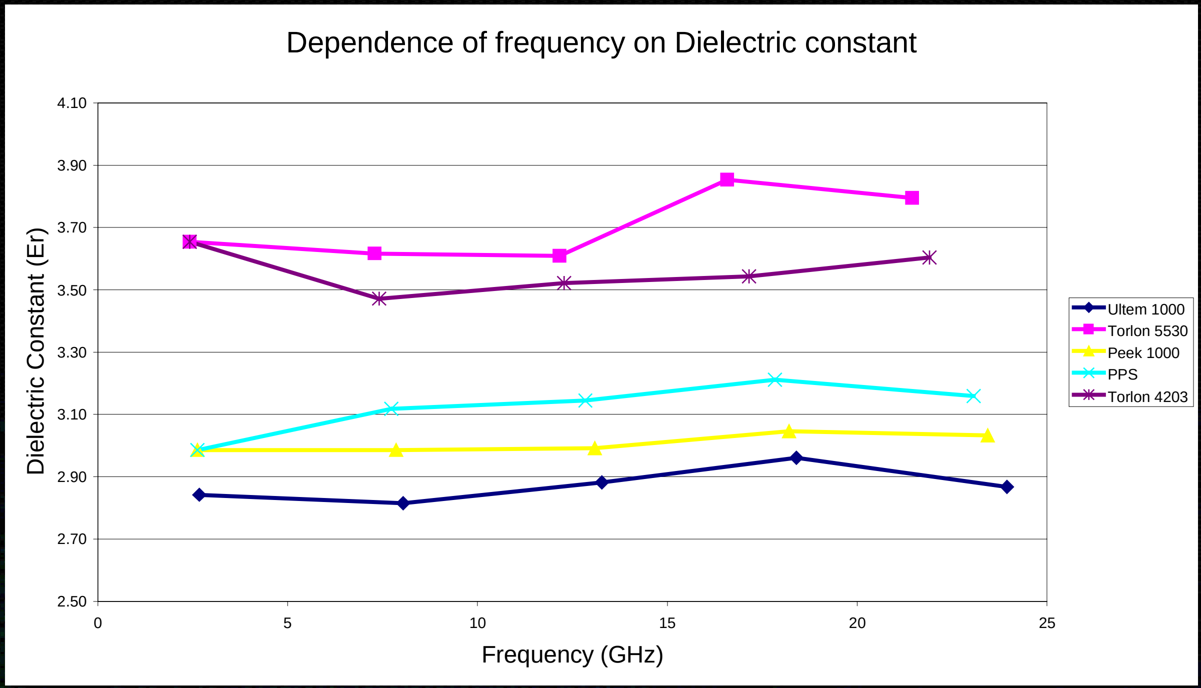
$$\alpha_t = 8.686 \cdot \frac{\pi \cdot n \cdot BW_n}{4 \cdot L_{stub} \cdot f}$$




- Extract resonant frequencies and 3dB points from insertion loss plot

# Results

- Determine relative dielectric using CPW transmission line software

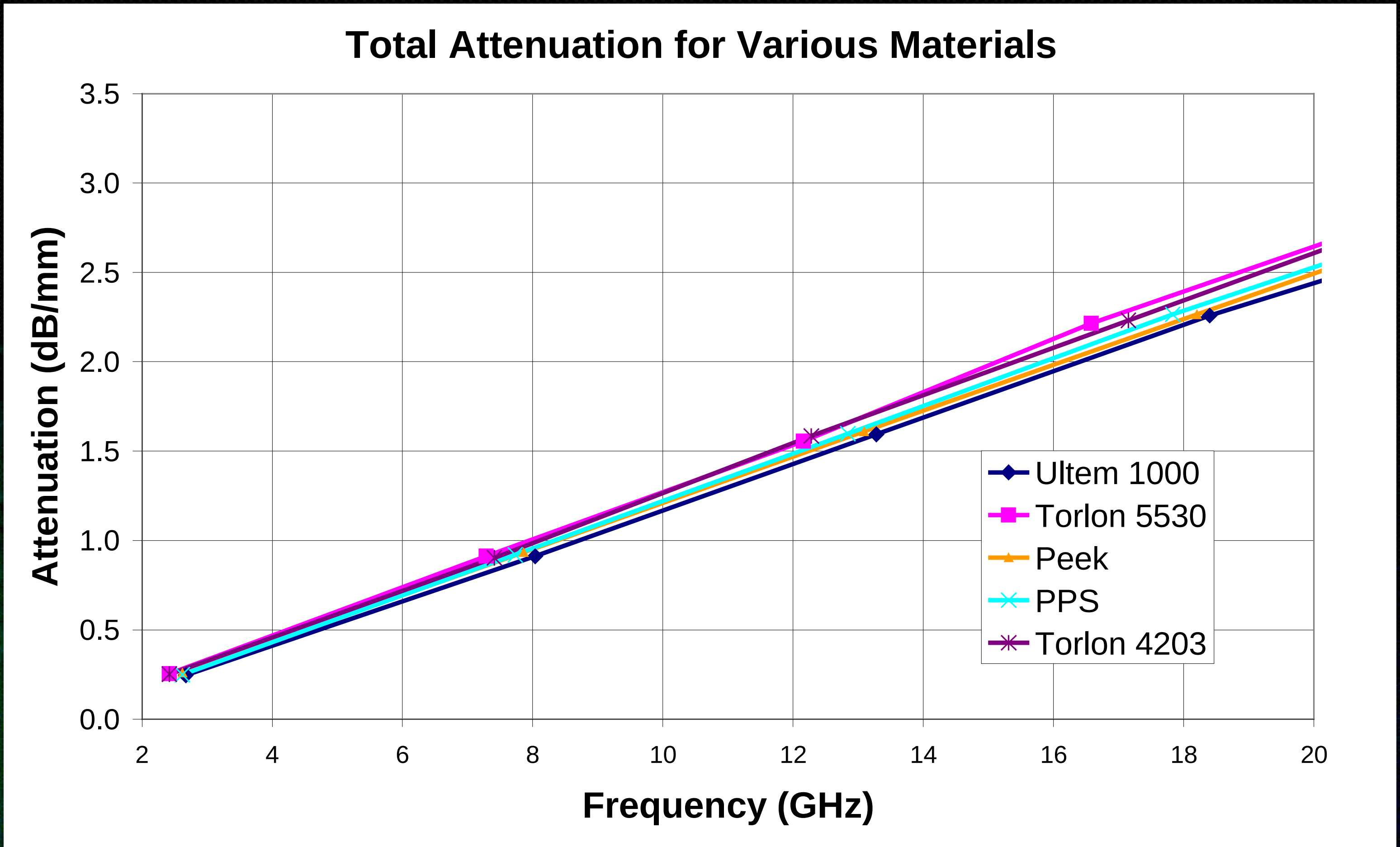



- Plot relative dielectric vs. frequency
- Compare to published (1MHz) data

| Material | Ultem 1000 | Torlon 5530 | Torlon 4203 | Peek 1000 | PPS |
|---|---|---|---|---|---|
| Published Dielectric constant | 3.15 | 6.3 | 4.2 | 3.3 | 3 |

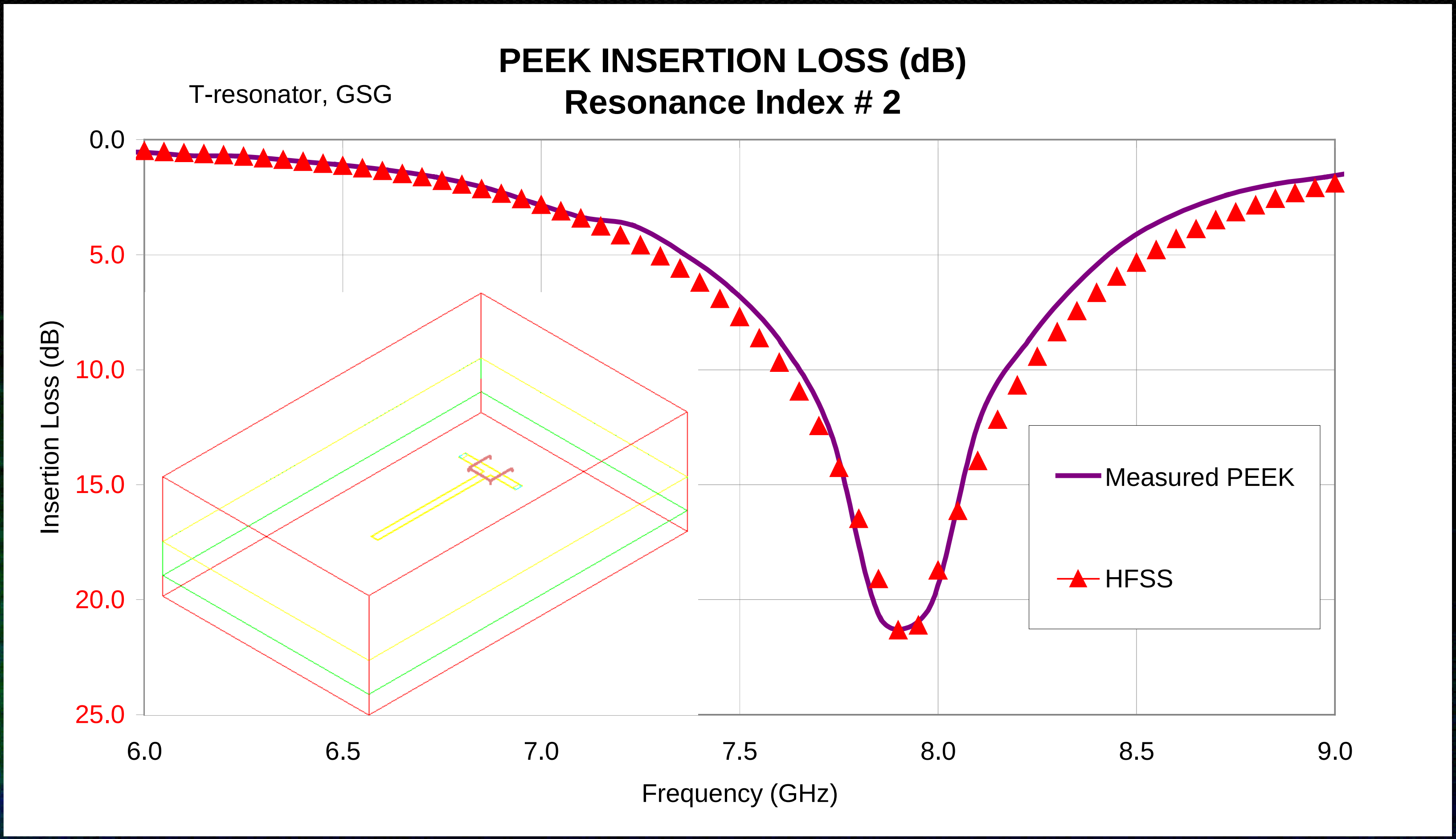
# *Results*

- Plot total attenuation vs. frequency



# Results: PEEK - Measured vs. Simulated

- Compare Measured and Simulated Results



# *The Future*

- Testing procedure
  - Reduce uncertainties - roughness, dispersion
  - Improve fabrication techniques of samples - airbridges
  - Test other contactor materials
  - Verify impedance independence - test @ 25ohms
  - Compare to other measurement techniques
  - Increase number of resonant frequencies by building a longer stub in ‘Tee’ structure – more data points
  - Stock up on RedBull and…..
    Find theoretical property values by computing elliptical integral
- Data
  - Use findings to more accurately create matched transmission through contactors at high frequencies

# Conclusion

- Verified T-Resonator as method for determination of dielectric constant and loss
- Found material properties of Torlon ®, PEEK, Ultem® and PPS at high frequency
- Found published data diverges from measured material properties at RF frequencies
- Successfully correlated 2D and 3D simulations to measured data
  - Ansoft HFSS (3D simulator) and Ensemble® (2D MoM planar EM simulator)
  - Sonnet® (2D MoM planar EM simulator)

# References


- Rhonda Franklin Drayton and Rebecca Lorenz Peterson, “A CPW T-Resonator Technique for Electrical Characterization of Microwave Substrates”, IEEE Microwave and Wireless Components Letters, Vol. 12, No. 3, March 2002
- Brian Frank, “Transmission line Examples”, Transmission lines and Microwave Networks, Sept. 2002
- James Baker-Jarvis, Michael D. Janezic, Bill Riddle, Christopher l. Holloway, N.G. Paulter, J.E. Blendell, “Dielectric and Conductor-Loss Characterization and Measurements on Electronic Packaging Materials”, NIST Technical Note 1520, July 2001
- Matt Commens, Applications Engineer, Ansoft Corporation, HFSS
- James Baker-Jarvis, Richard G. Geyer, John H. Grosvenor, Jr., Michael D. Janezic, Chriss A. Jones, Bill Riddle, Claude M. Weill, “Dielectric Characterization of Low-loss Materials”, Electromagnetic Fields Division, National Institute of Standards and Technology, Boulder CO, Vol. 5 No. 4, August 1998
- Daniel I. Amey and Samuel J. Horowitz, “Tests Characterize High-Frequecny Material Properties”, DuPont Photopolymer & Electronic Materials, Penton Publishing Inc. Cleveland Ohio 44114, 1997
- Material data from: Phillips 66, GE Plastics, Amoco and Quadrant Engineering Plastic Products. Material names used in this presentation are registered trademarks of their manufacturers

GE Plastics

# High Flow Glass Filled Polyetherimide Resins for Burn-in Test Sockets

**2003 Burn-in and Test Socket Workshop**

**March 2 - 5, 2003**


**Ken Rudolph**
**Robert Gallucci**
**Chisato Suganuma**
**GE Plastics**

# Contents

- Test Socket Requirements
- Common BiTS Materials
- BiTS Materials Performance Properties
- ULTEM Resin Grades
- BiTS Trends
- ULTEM EPR Technology
- ULTEM Higher Heat Resins
- ESD Considerations
- Conclusions

Courtesy of Aries Electronics, Inc.

# Test Socket Requirements I

## Critical to Quality

- Heat Performance: -55 to 170°C
- Dimensional Stability:
  - Isotropic Properties, Low CTE
- Flex & Tensile Strength & Stiffness:
  - Reduce twisting during assembly
  - Knit-line Strength, No Brittle failure
- Flame Retardancy: UL 94 V-0

Courtesy of Texas Instruments Incorporated

# Test Socket Requirements II

## Critical to Quality

- Processability: Shrinkage, Regrind, Release
- Thin-wall Molding
- Chemical Resistance to Solvents
- Low Out-gassing, Low Contamination
- Lubricity / Wear Resistance

Courtesy of Yamaichi Electronics

# Common BiTS Materials

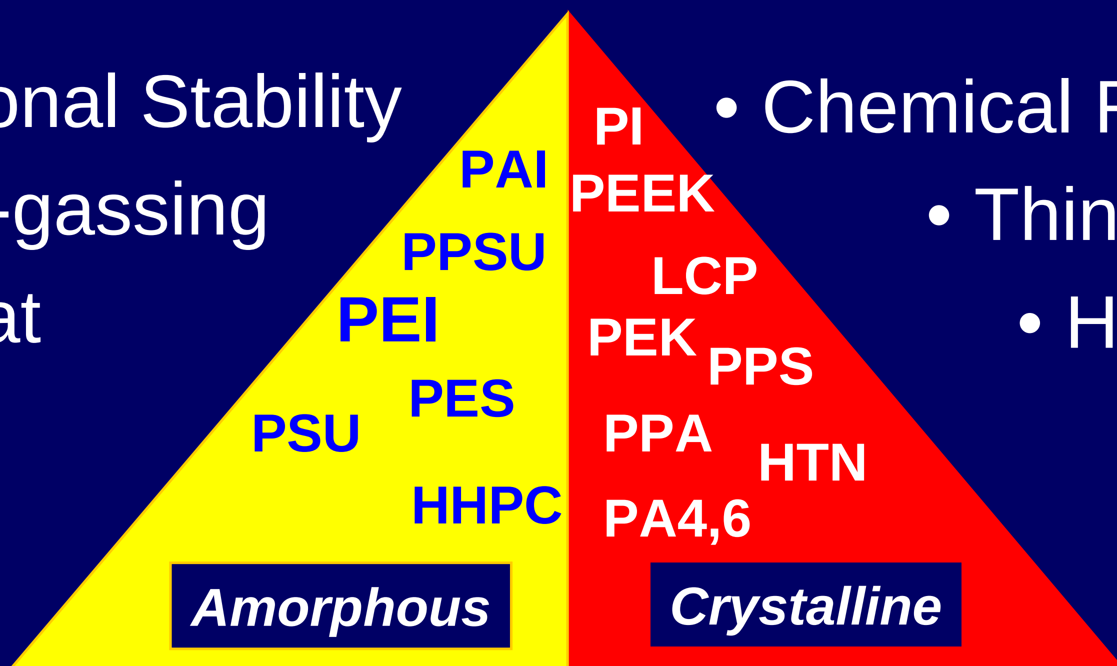
<u>Amorphous Thermoplastics</u>

**PEI PES PAI**

<u>Crystalline Thermoplastics</u>

**PEEK PPS PI LCP**

- Dimensional Stability
- Low Out-gassing
- High Heat
- Ductility

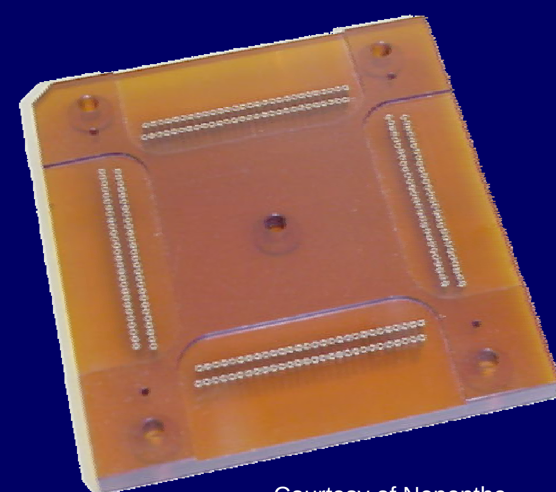



- Chemical Resistance
- Thin Wall Flow
- Higher Heat
- Lubricity

# ULTEM® Resin Benefits

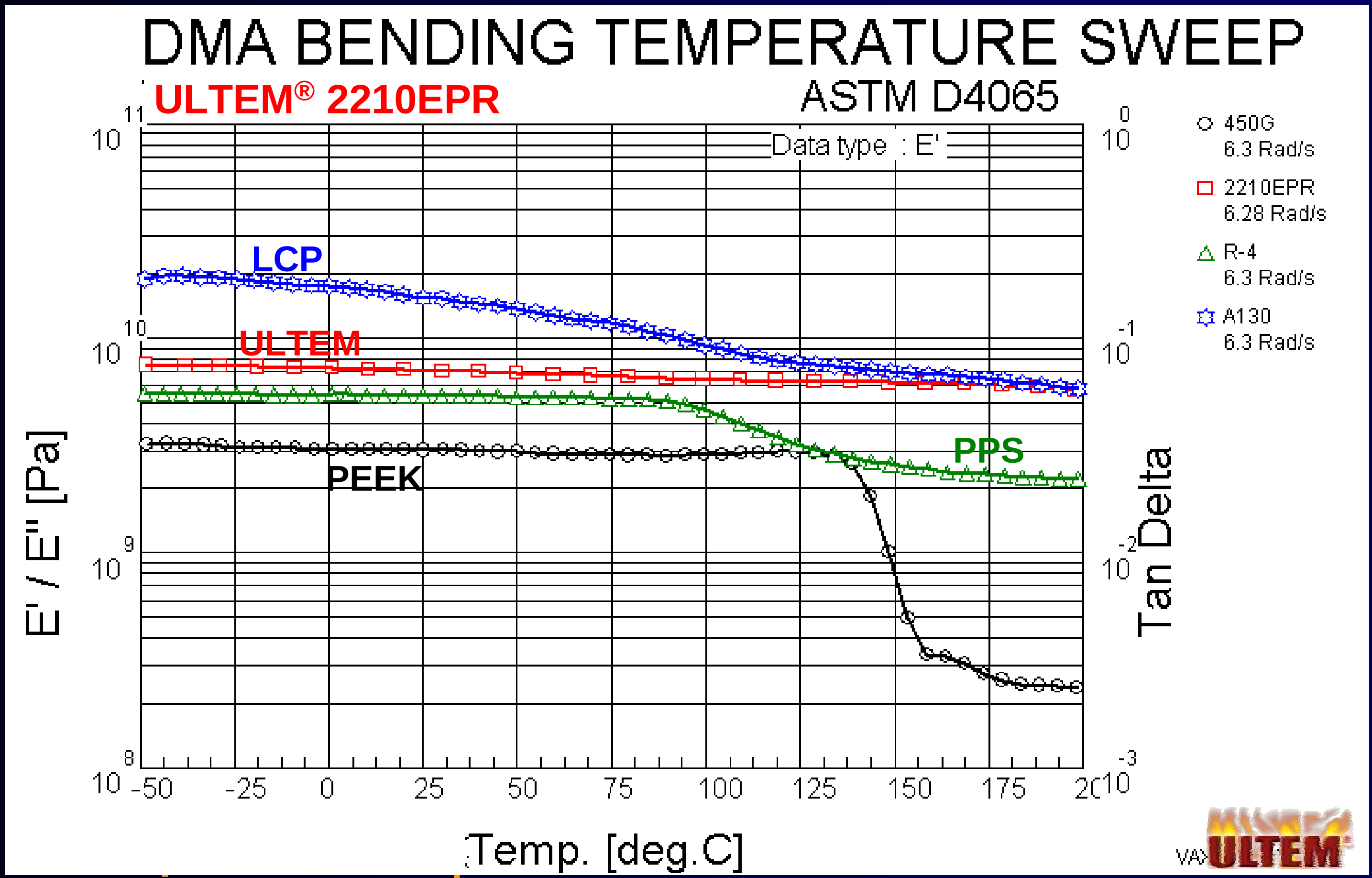
- High Temperature Modulus & Creep Resistance
- Flexural Strength & Stiffness
- Knit-line Strength & Elongation
- Resistance to Cleaners / Solvents
- Dimensional Stability, Low CTE
- Thin-Wall Flame Retardancy
- Ionic Purity
- Injection Moldable w/ Low Flash
- Extrudable & Machinable
- Lower Specific Gravity

Polyetherimide



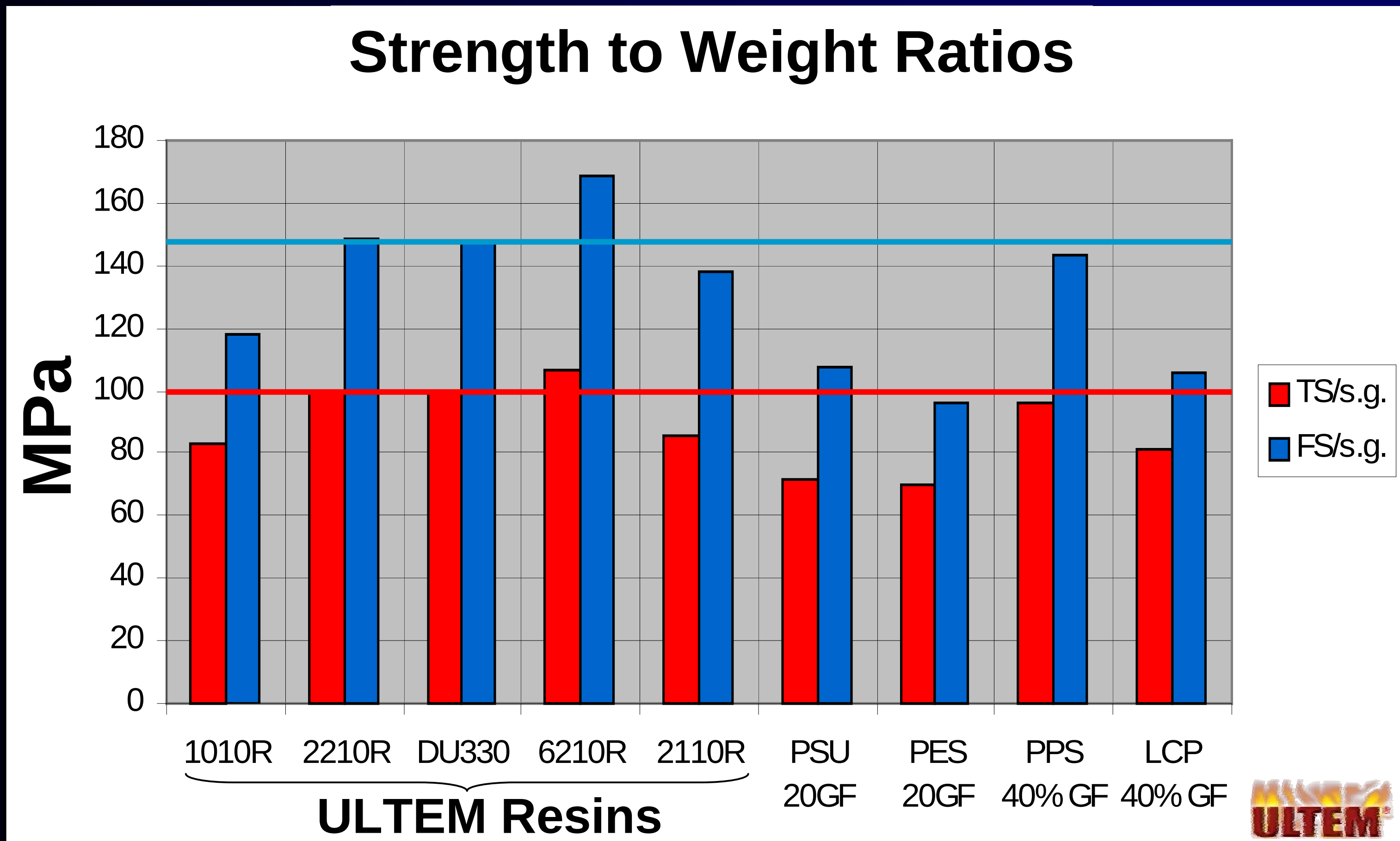
Courtesy of Nepenthe

# Flex Modulus vs. Temperature



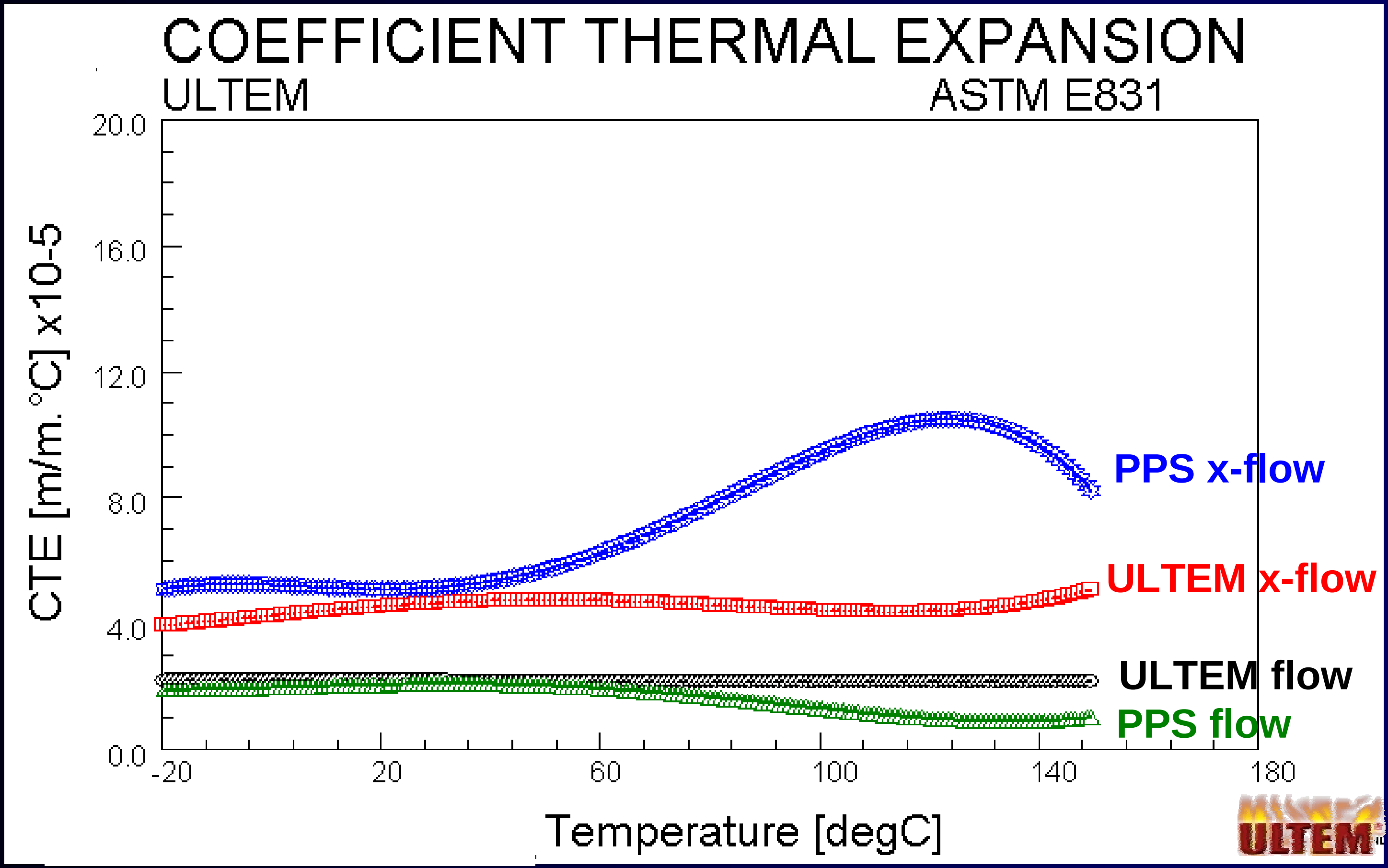

**Constant Modulus over BiTS Operating Temps**

# Tensile & Flex Strength



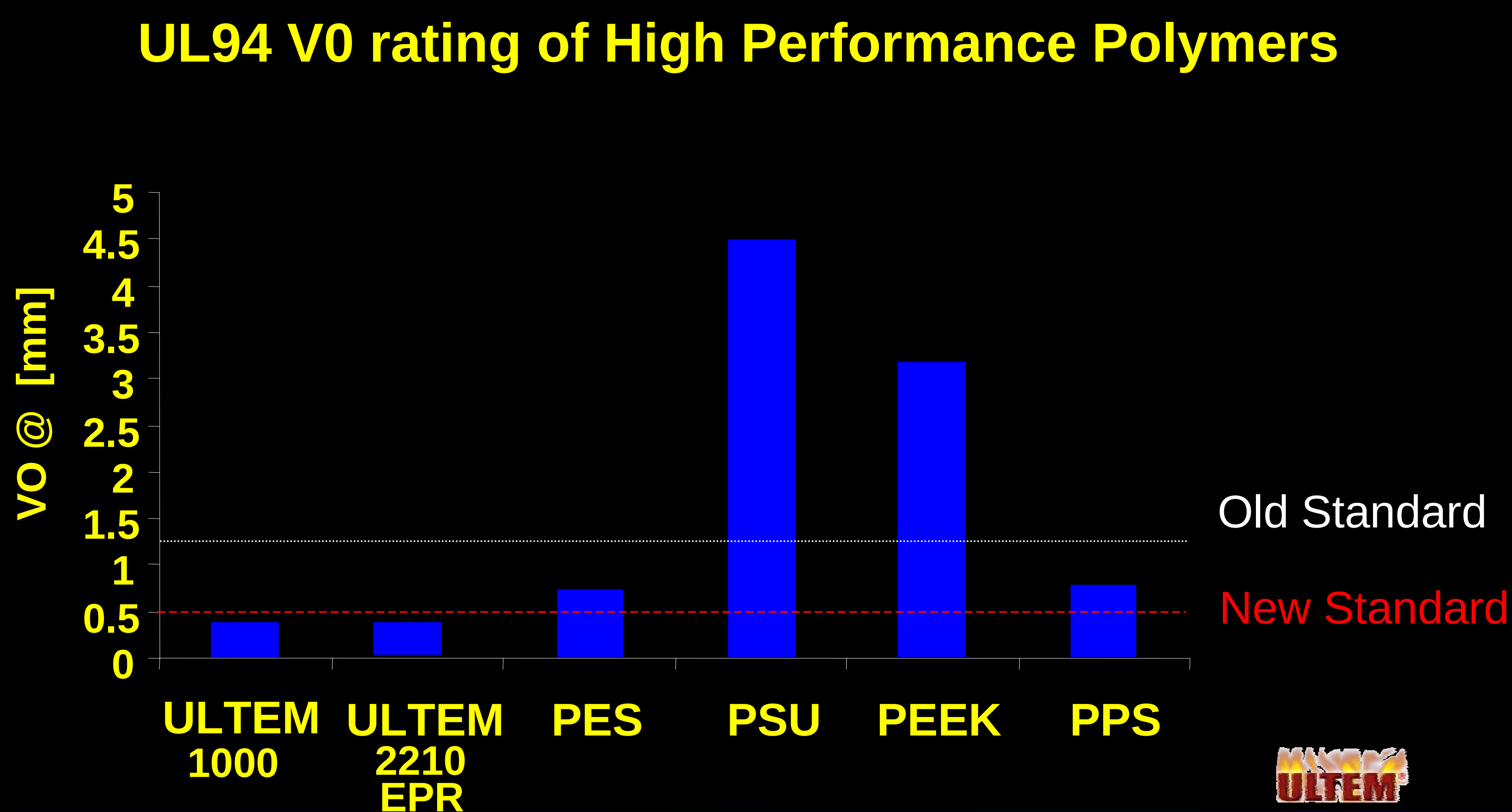

**Highest Strength to Weight for Resin < $15 / #**

# Dimensional Stability




**Low Isotropic Thermal Expansion**

# Thin Wall Flame Retardance

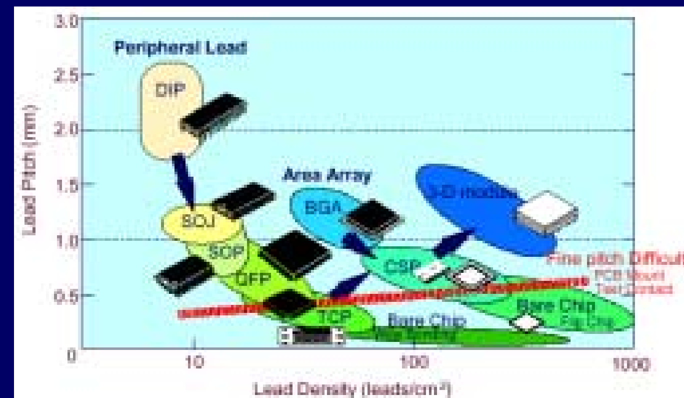



**ULTEM Resins Deliver Thin Wall V-0**

# ULTEM Resin Grades


- **ULTEM® PEI Resin**
  - **Un-reinforced**
    - Base — 1000
    - Easy Flow — 1010R
  - **Glass Filled**
    - 10 % GF — 2110R, 2110EPR
    - 20 % GF — 2210R, 2210EPR
  - **Wear Resistant**
    - Easy Flow — 4001
    - 20 % GF — 4211
  - **Copolymer**
    - Easy Flow — 6010R
    - 20 % GF — 6210R

# BiTS Trends



Courtesy of Hitachi, Ltd. & Enplas Corp.

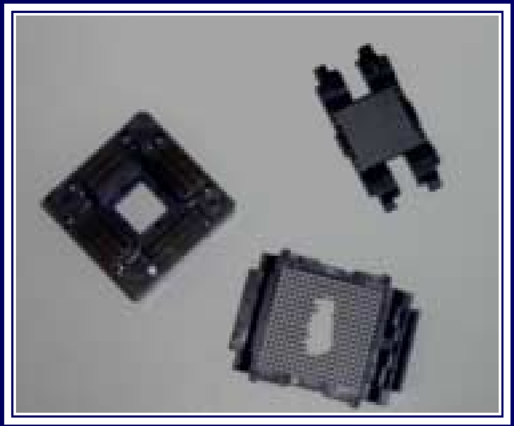
- Larger Geometries:
  - Full Surfaces, Larger Size
  - Increased Pin Counts
- Tighter Pitch:
  - 1.27→ 1.0 → 0.8 → 0.65 → 0.5 mm
- Higher Heat Requirements
- Electro-Static Dissipative Materials:
  - $10^6$ –$10^8$ ohm-cm$^2$
- Reduced Time for Tool Build & Modifications
- Color Coded Guide Rings

**Improved Thin Wall Flow; Material Development**

# Flow Challenges for PEI Resins

- Amorphous Resins Have Broad Softening Range
- Addition of chopped fiberglass (10-40%) to PEI
  + Increase Modulus, Strength, HDT, FR
  – Decreases Elongation & Melt Flow
- Improved Flow Typically Achieved Through Lower Molecular Weight Polymer or Plasticizers
  – Ductility, Knit-line Strength Sacrificed
  – More Susceptible to Degradation
  – Reduction of Tg & HDT

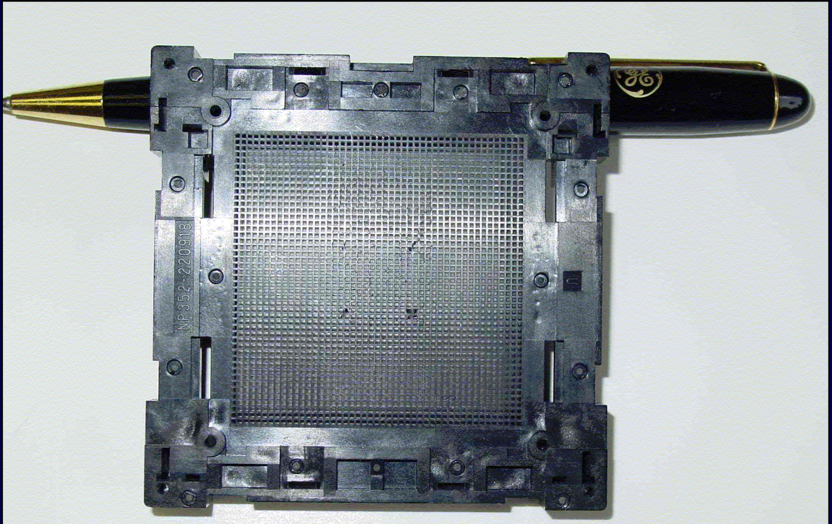
**Existing PEI Flow Limited Use in Tighter Pitch BiTS**



# ULTEM EPR Technology

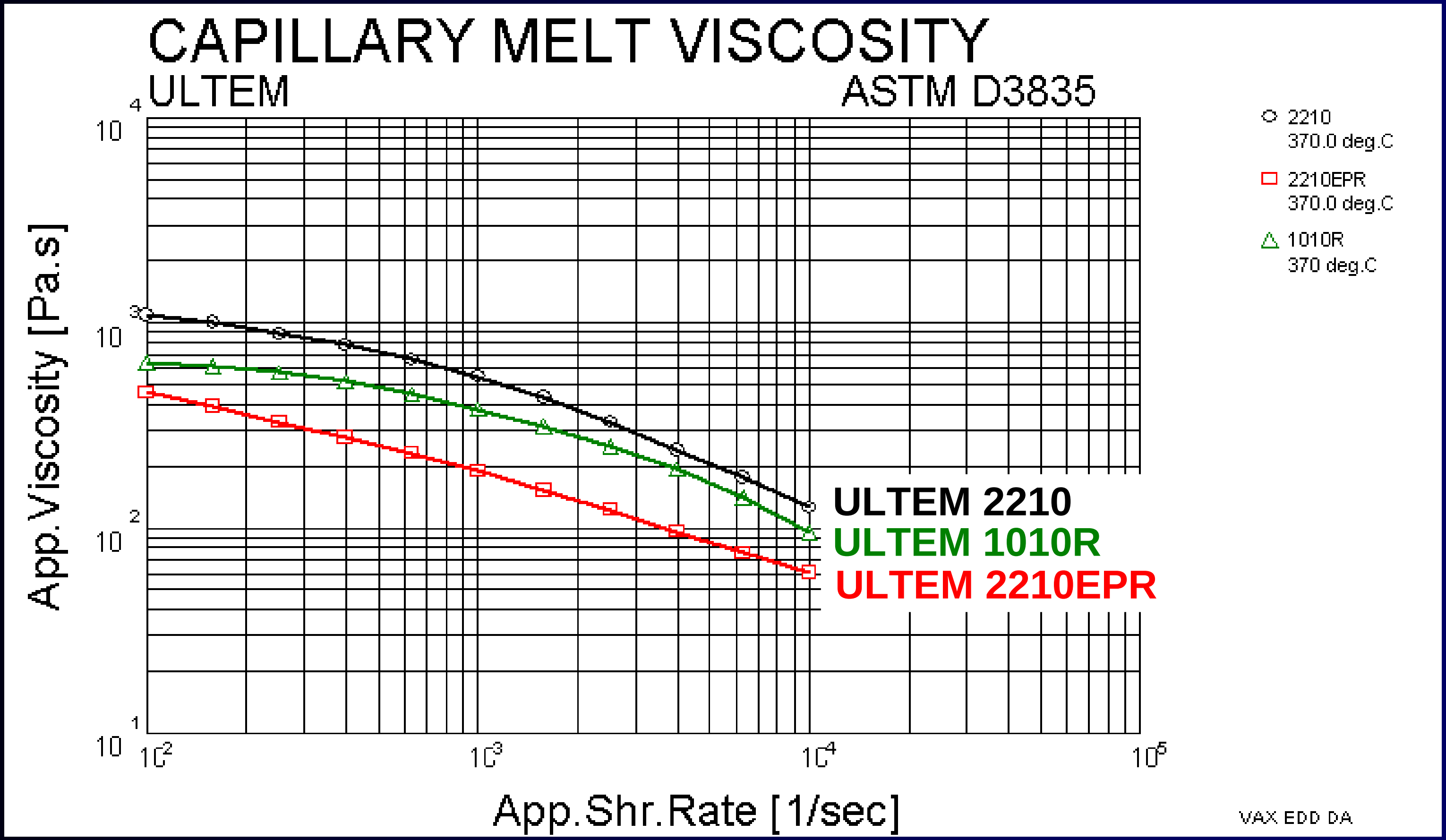
- Proprietary High Flow Additive Compatible with Glass Reinforced Polyetherimide (10-40% GF)
  - + Flow Enhanced by 30%, Improved Release
  - + Tensile & Flexural Strength Maintained
  - + HDT, CTE & Thermal Aging Maintained
  - + UL94-V0 Rating Maintained at 0.4mm

| Properties | ULTEM 1000 | ULTEM 2210 | ULTEM 2210EPR |
|---|---|---|---|
| HDT @1.8MPa | 201 | 211 | 209 |
| T Str. Mpa | 110 | 140 | 138 |
| T Mod. Mpa | 3600 | 6900 | 6900 |
| % Elong. | 7% | 4% | 3% |
| Flex Mod Mpa | 3600 | 6900 | 6900 |
| Flex Str Mpa | 166 | 228 | 207 |
| N. Izod J/m | 53 | 75 | 80 |
| % Ash | 0% | 20% | 20% |
| Sp. Gravity | 1.27 | 1.42 | 1.39 |
| Melt Flow @337C | 9.0 | 9.0 | 13.0 |
| UL 94-V0 (mm) | 0.4 | 0.4 | 0.4 |



ULTEM 2210EPR Success !

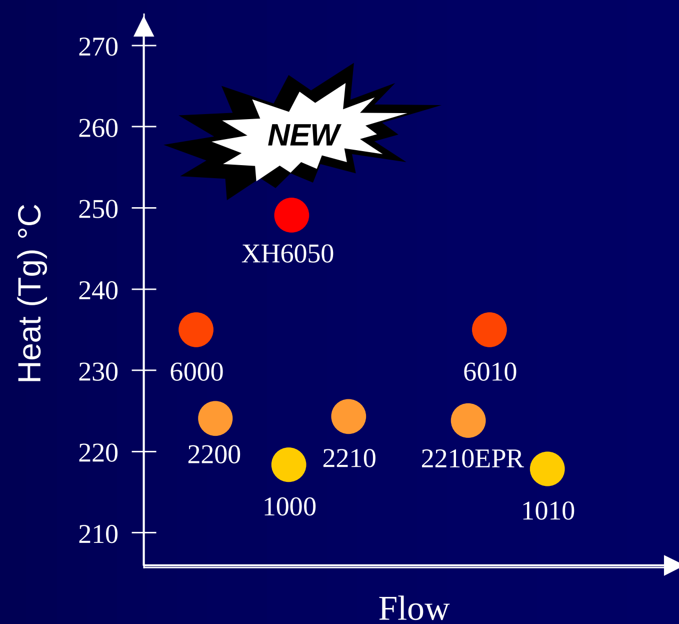
# ULTEM EPR Technology




**ULTEM 2210EPR Melt Processability: 30% Improvement over ULTEM 2210**

# ULTEM Higher Heat Resins

- High Heat ULTEM Resin Program
  - 230 °C HDT Capable
  - Optimization of MW & Flow
- Addresses Higher Heat Needs for Electronics Market
  - SMT Connector Technology
  - ULTEM-like Properties
  - More Cost Effective than PAI and PEEK
- Commercializing 3Q 2003
  - Unfilled XH6050 Available
  - 10% GF Available for Sampling

# ESD Considerations

Stat-Kon®

- Electrostatic Discharges can:
  - Ground to humans causing a shock
  - Destroy ICs; Effect Component Operation
- Stat-Kon Dissipative Additives ($10^6$-$10^9$)
  - Carbon Powder (10-20%, improves wear)
  - Carbon Fiber (~10%, wear, HDT, warp)

- Performance & Metrics
  - No initial charge; Prevents ESD
  - Insulates against high leakage currents
  - Volume & Surface Resistivity; Static Decay

# Conclusions

- ULTEM Resins May Satisfy Many Critical To Quality Requirements for Test Sockets
- Thin Wall Flow Needs Are Addressed by ULTEM EPR Technology – 30% Improvement
- Higher Heat ULTEM Resins Can Provide For Max Use Temperatures up to 230 °C
- Custom Compound Resins Can be Formulated to Address ESD, Wear, Flow and Color Requirements