MATERIAL SELECTION CRITERIA FOR PA and ANTENNA
We provide Materail Solutions For High Performance and High Reliability Circuits
1. About Rogers
2. Evaluation of Telecom technologies
3. Materials for PA and Subsystems
4. Materials for Broad Band Antennas
5. Conclusion
6. Q&A

“It is reliability that really sets them apart.”
Global Customer Survey, 2010
A global leader in material technologies that **Power, Protect and Connect** our world

- 2013 Sales of ~ $537.5M
- Headquarters: Rogers, CT, USA
- ~2400 employees worldwide
- Publicly held, ROG on NYSE
- Founded in 1832

Celebrating 180 Years of Reliability & Innovation
Our Solutions Segments

Powering
Power Electronic Solutions

Protecting
High Performance Foams

Connecting
Printed Circuit Materials

Powering, Protecting, Connecting Our World™
Megatrends Advancing Our Growth

INTERNET GROWTH
- Wireless Infrastructure
- Smart Antennas
- Wired Infrastructure
- Mobile Internet Devices

MASS TRANSIT
- Power Distribution
- Vibration management
- Passenger seating

CLEAN TECH
- Variable Frequency Motor Drives
- Vehicle Electrification, HEV/EV
- Wind & Solar
Mobile Communications Infrastructure

- Providing material solutions for the industry since 1993
  - GSM EDGE, CDMA, WDCMA, TD-SCDMA, LTE, TD-LTE, WiMAX
- Applications for RO3000 & RO4000
  - Power Amplifiers
  - PTP Microwave Radios
  - Base Station Antennas
Explosion in Mobile Data Demand
Cisco VNI Mobile Report February 2014

- **Current State of Mobile Data**
  - Global mobile devices grew to 7B in 2013, up from 6.5B in 2012, smartphones accounted for 77% of the growth.
  - Globally average mobile network speeds grew from 526kbps to 1387kbps in 2013.
  - Globally 45% of total mobile data traffic was offloaded to fixed network through WiFi or femtocell in 2013.

- **Mobile Forecast by 2018**
  - Mobile data growth in 2018 will exceed total data today 2 to 4X
  - Mobile connected devices will exceed world population by 2014
  - Average mobile connection speeds will exceed 2Mbps
  - 4G traffic will be more than half of the total mobile traffic by 2017
Drivers for BTS Market Growth

- Device diversification
- Growth in average traffic per device
- Mobile video
- Mobile cloud adoption
- Traffic offload from mobile to fixed networks
- Connection speeds to increase 9-fold, 4G impact by 2016
- The (mobile) internet of things

Source: Ericsson (Nov 2013)
Higher level of integration
- Greater MLB complexity due to multi function RF needs
- Reduction in size
- Increased thermal management
- Lower Cost

RO4000 MLB

RO4000 cap layer

FR4 MLB

Coin Heat Sink

RO4000 cap layer

FR4 MLB

RO4000 cap layer
Technology Drivers for Sophisticated RF Systems in Next Generation Smart Phones & Tablets

- Explosion of frequency bands worldwide ➔ higher frequency performance
- Carrier aggregation to obtain larger bandwidth needed for LTE Advanced (intra & inter band) ➔ stable broadband performance
- Future antenna technology challenges ➔ multiple antennas
  - LTE: 2x2MIMO & 4x4MIMO
  - Adoption of Semi-Active and Active Antennas
Mobile Evaluation
Mobile Standard Evaluation

- LTE (3.9G): 3GPP release 8~9
- LTE-Advanced: 3GPP release 10+
Rogers ACMD Global Footprint

USA:
- Custom Plant
- Commercial Plant
- PTFE raw dielectric in CT

Belgium:
- Commercial Plant

China:
- RO4000 lamination 2011
- Prepreg coating 2014

6/14/2014 SMTA, CHENNAI
Rogers ACMD Capabilities

- **Advanced materials development based on customer needs**
  - Expertise in polymers, fillers and metal claddings

- **Global manufacturing**
  - North America, China, Europe

- **Local application and PCB technical support**
  - Microwave engineers to provide material selection advise
  - Local material/PCB analysis testing lab (US & China) to support PCB facilities

- **Advanced electrical testing**
  - Property testing vs. frequency & environmental conditions
  - Problem solving support, modeling & testing
  - Internal Passive Intermodulation testing for antenna materials
Rogers ACMD Markets 2014
Market leader of high frequency PCB materials

Aerospace, Defense & High Reliability

Communications Infrastructure

Auto, Medical Security

DTH Satellite Services

High Speed Digital Chip Scale Packaging
Enabling technology through the use of advanced circuit materials for next generation mobile communication systems

- 45 years of experience in RF / microwave materials
- Brodest range of high frequency laminates
- Global presence, local supply
- Provide consistent, reliable circuit materials and services that enable our customers to succeed
Rogers has supplied a wide selection of quality HF laminates for both HIGH RELIABILITY APPLICATIONS and COMMERCIAL APPLICATIONS for decades!
# Proven History of PCB Material Development to Meet Challenges of Technology Evolution

<table>
<thead>
<tr>
<th>Generation</th>
<th>Year</th>
<th>Material Details</th>
<th>Technology Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1G</td>
<td>1993</td>
<td>RO3000 PTFE/ceramic</td>
<td>Increased mobile data rates</td>
</tr>
<tr>
<td>2G</td>
<td>1997</td>
<td>RO4350B Rigid RF</td>
<td>E-band PTP radios</td>
</tr>
<tr>
<td>3G</td>
<td>2002</td>
<td>RO4450B prepreg for MLB designs</td>
<td>Active antennas</td>
</tr>
<tr>
<td>4G</td>
<td>2009-2011</td>
<td>RO4450F prepreg for MLB designs</td>
<td>Green products</td>
</tr>
<tr>
<td>4G Advanced</td>
<td>2013-2014</td>
<td>RO4000LoPro RO4450F prepreg Antenna Grades RO4500 RO4730</td>
<td>Small cells</td>
</tr>
</tbody>
</table>

**Lower PCB costs**
- 1G
- 2G
- 3G
- 4G

**Lower material costs**
- 1G
- 2G
- 3G
- 4G

**RF performance**
- 1G
- 2G
- 3G
- 4G
# Brodest Product Portfolio in Industry

<table>
<thead>
<tr>
<th>Glass / PTFE</th>
<th>PTFE / Ceramic</th>
<th>PTFE / Ceramic Woven Glass</th>
<th>Ceramic Hydrocarbon (TMM)</th>
<th>Ceramic Hydrocarbon Woven Glass</th>
<th>Specialty Resins</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT/duroid® 5870</td>
<td>RO3003™ RO3006™ RO3010™ RO3035™ RO2800® RO2808™</td>
<td>RT/duroid 6202 6202PR</td>
<td>TMM® 3 4 6 10 10i 13i</td>
<td>RO4003C™ RO4233™ RO4350B™ RO4500™ RO4450B™ RO4450F™ RO4000® LoPro™ RO4725JXR™ RO4730JXR™ RO4360G2™ RO4835™</td>
<td>ULTRALAM® 3000 XT/duroid® High Performance Materials 2929 bondply Coolspan</td>
</tr>
<tr>
<td>RT/duroid® 5880 Microfiber</td>
<td>RO3003™ RO3006™ RO3010™ RO3035™ RO2800® RO2808™</td>
<td>RT/duroid 6010LM RT/duroid 6002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Laminates | Laminates | Laminates | Laminates | Laminates Bondply | Laminates Bondply |
Primary Material Selection Criteria

- **Performance**
  - Dk tolerance, variation, temp stability
  - Df, insertion loss, lab conditions

- **Design Considerations**
  - Operating temp
  - PTH
  - Environmental
  - Pb-free solder

- **Reliability**

- **Cost**
  - Material fabrication
  - Yield
  - Supply

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SMTA, CHENNAI 6/14/2014
PCB Losses

- Dielectric Losses
- Conductor Losses
- Radiation Losses
- Skin depth, Cu Foils and Gold plating
- Passive Inter Modulation (PIM)
## Rogers Connecting Materials Evaluation

<table>
<thead>
<tr>
<th>Material</th>
<th>Ease of Circuit Fabrication</th>
<th>Electrical Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTFE with micro glass fiber</td>
<td>Difficult</td>
<td>Excellent</td>
</tr>
<tr>
<td>PTFE with woven glass</td>
<td>Difficult</td>
<td>Good</td>
</tr>
<tr>
<td>Ceramic-filled PTFE</td>
<td>Moderate</td>
<td>Excellent</td>
</tr>
<tr>
<td>Ceramic-filled PTFE with woven glass</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>Ceramic-filled Hydrocarbon</td>
<td>Difficult</td>
<td>Good</td>
</tr>
<tr>
<td>Ceramic-filled Hydrocarbon with woven glass</td>
<td>Easy</td>
<td>Good</td>
</tr>
<tr>
<td>High Performance FR-4</td>
<td>Easy</td>
<td>Poor</td>
</tr>
</tbody>
</table>
## Break through in Power Savings

<table>
<thead>
<tr>
<th>BTS</th>
<th>dBm</th>
<th>Tx Watts</th>
<th>Eff</th>
<th>Loss In Watts/Wastage/Sector</th>
<th>Effective Power Radiated.</th>
<th>Total I/P Power Required Tx</th>
<th>Loss for 3Sectors</th>
<th>Average BTS/tower</th>
<th>Power Wastage of 400K Towers in MW</th>
<th>Savings (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro (LDMOS+F R4)</td>
<td>50</td>
<td>100</td>
<td>30</td>
<td>70</td>
<td>30</td>
<td>190</td>
<td>270</td>
<td>4</td>
<td>4</td>
<td>432</td>
</tr>
<tr>
<td>Macro (GaN+RO43 50B)</td>
<td>50</td>
<td>100</td>
<td>60</td>
<td>40</td>
<td>60</td>
<td>140</td>
<td>120</td>
<td>4</td>
<td>4</td>
<td>192</td>
</tr>
</tbody>
</table>

![Image of a circuit board]

![Diagram showing power components and their percentages]

- Power Amplifier: 22%
- Transceiver idling: 19%
- Power supply: 16%
- Cooling: 13%
- Transceiver power conversion: 9%
- Combining/Duplexing: 9%
- Central equipment: 8%
- Transmit power: 3%
- Cabling: 1%
# Material Sets for BTS Power Amplifiers

*Meeting the needs of designers since 1996*

<table>
<thead>
<tr>
<th>Material</th>
<th>Dk 10 GHz</th>
<th>Df 10 GHz</th>
<th>TC W/m/°K</th>
<th>Benefits</th>
</tr>
</thead>
</table>
| RO4350B   | 3.48±0.05 | 0.0037(0.0031*) | 0.69 | Low cost PCB manufacturing  
MLB & hybrid capable, w/ RO4400 prepreg  
Broadest material adoption in power amp’s |
| RO4835    | 3.48±0.05 | 0.0037(0.0031*) | 0.66 | Similar to RO4350B with improved anti oxidation performance |
| RO3035    | 3.5±0.05  | 0.0017     | 0.5      | Low loss PTFE based material |
| RO3006    | 6.15±0.15 | 0.0020     | 0.61     | Reduction in PCB size |
| RO3010    | 10.2±0.30 | 0.0023     | 0.66     | Highest dielectric constant of commercial products |

* Df measured at 2.5GHz

SMTA, CHENNAI  
6/14/2014
Recommended for LTE Designs

**RO4835™ & RO4350B™**

<table>
<thead>
<tr>
<th>Grade</th>
<th>RO4835 Laminate</th>
<th>RO4350B Laminate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dk (@ 10 GHz)</td>
<td>3.48 +/- 0.05</td>
<td>3.48 +/- 0.05</td>
</tr>
<tr>
<td>Design Dk 3.66</td>
<td>Design Dk 3.66</td>
<td></td>
</tr>
<tr>
<td>Df @ 10 GHz</td>
<td>0.0037</td>
<td>0.0037</td>
</tr>
<tr>
<td>2.5 GHz</td>
<td>0.0031</td>
<td>0.0031</td>
</tr>
<tr>
<td>CTE X/Y/Z (PPM/°C)</td>
<td>X = 10 / Y = 12</td>
<td>X = 10 / Y = 12</td>
</tr>
<tr>
<td>Typical Value</td>
<td>Z = 31</td>
<td>Z = 32</td>
</tr>
<tr>
<td>(From -55°C to 288°C)</td>
<td>(From -55°C to 288°C)</td>
<td></td>
</tr>
<tr>
<td>Moisture Absorption</td>
<td>0.05%</td>
<td>0.06%</td>
</tr>
<tr>
<td>TC (W/(m•K))</td>
<td>0.66</td>
<td>0.69</td>
</tr>
<tr>
<td>Thickness (Mils)</td>
<td>0.0066” / 0.010” / 0.0133” / 0.0166”</td>
<td>0.0066” / 0.010” / 0.0133” / 0.0166”</td>
</tr>
<tr>
<td></td>
<td>0.020” / 0.0233” / 0.030” / 0.040” / 0.060”</td>
<td>0.020” / 0.0233” / 0.030” / 0.040” / 0.060”</td>
</tr>
<tr>
<td>Flammability (UL)</td>
<td>94 V-0</td>
<td>94 V-0</td>
</tr>
</tbody>
</table>

**Hydrocarbon oxidation effect**

Maximum change in Dk is +0.15 & Df is 0.005
RO4835™ & RO4350B™ Materials: Dielectric Constant (Dk)

Stripline circuits will essentially never exhibit this change and microstrip circuits change at 1/10th to 1/100th the rate.

Accelerated aging testing of Rogers RO4350B and RO4835 laminates
Dk(T)/Dk(0) versus Time shifted to 25°C (fully etched samples)

Material property comparison and not a measure of circuit performance.

RO4350B laminate exhibits a 1% increase in Dk after about 70,000 hours (8 years).
RO4835 laminate exhibits an 1% increase in Dk after about 800,000 hours (91 years).
RO4835™ & RO4350B™ Materials: Loss Tangent (Df)

Accelerated aging testing of Rogers RO4350B and RO4835 laminates
Change in Df versus Time shifted to 25°C (fully etched samples)

RO4350B laminate exhibits a 0.001 increase in DF after about 70,000 hours (8 years).
RO4835 laminate exhibits an 0.001 increase in DF after about 800,000 hours (91 years)
Microstrip circuits
(RO4350B™ laminate, 0.5 mm thick)
Microstrip circuits

(RO4350B™ laminate, 0.5 mm thick)

RO4350B Accelerated aging - change in DK vs. Time
50 ohm TL lines and fully etched
Diffusion limited data removed
### Dk 6.15 Material for Size reduction
RO4360G2 & RO3006

<table>
<thead>
<tr>
<th></th>
<th>Rogers RO4360G2 Laminate Qualified</th>
<th>Rogers RO3006 Existing Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Constant @ 10 GHz</td>
<td>6.15 +/- 0.15 (6.6 Design)</td>
<td>6.15 +/- 0.15 (6.5 Design)</td>
</tr>
<tr>
<td>Loss Tangent (Df)</td>
<td>0.0038 @ 10 GHz</td>
<td>0.002 @ 10 GHz</td>
</tr>
<tr>
<td>CTE X/Y/Z PPM/°C</td>
<td>X = 13 / Y = 14</td>
<td>X = 17 / Y = 17</td>
</tr>
<tr>
<td></td>
<td>Z = 28</td>
<td>Z = 24</td>
</tr>
<tr>
<td></td>
<td>(From -55°C to 288°C)</td>
<td>(From -55°C to 288°C)</td>
</tr>
<tr>
<td>Cu Peel Strength Lbs/in</td>
<td>5.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Thermal Cond. W/m/K</td>
<td>0.75</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Reduce circuit size compared to RO4350B

Lower material cost than high Dk PTFE materials

Lower PCB processing costs than PTFE materials

RO4360G2 UL RTI testing completed
Bond Ply/Prepreg sampling in Q1 2014 (target Q3 launch)
Improving Thermal Management: High TC Materials

Thermal Conductivity (W/m/K)

Loss tangent @ 10GHz

- RO4350B: 0.0037
- RO3035: 0.0017
- RO3235HTC: 0.0017
- RO3035HTC: 0.0012
- RO4360G2: 0.0015
- RO3006: 0.002
- RO3006HTC: 0.0038
Power Handling Comparison

Higher thermal conductivity materials from Rogers have 3X more power capacity.

Theoretical calculations using Rogers MWI program found on website
Measured Effect of Improved Thermal Conductivity

RF Temperature rise vs. Input Power at 1.9 GHz
50 ohm microtrip lines on 0.5 mm laminates

- PTFE/WG/ceramic: 0.0018, 0.24
- RO3035: 0.0009, 0.5
- RO3035 HTC: 0.0009, 1.45
- RO4350B: 0.0031, 0.69

Input Power Watts

SMTA, CHENNAI 6/14/2014
Thick Metal Cladding on RO3000/RO4000

- Metal back currently offered on RO3000 materials (RO3003, 3035, 3006 and 3010)
- Metal back option on RO4350B possible through PCB facility
Technology Evolution: Thermal Management

- Thermal Vias
- Integrated heat sink
  - Pallet
  - Coin

Embedded Coin
1. flanged coin
2. laminate
3. Prepreg
4. Conductive adhesive

Courtesy of Viasystems

Solder Attached Coin

Coin Heat Sink

6/14/2014 SMTA, CHENNAI
Technology Evolution: Press Fit Coins

- Minimal extra processing costs
- Independent of material and prepreg choice
- Grounding is guaranteed if Cu-Coin is pressed into plated hole
- Can be located in principle beneath every SMT device
- Proven reliability
Thermal Management: COOLSPAN®
TECA Film

- Silver filled thermosetting conductive epoxy film
- Used to bond circuit boards to heavy clad metal backplanes, heat sink coins, and RF module pallets and housings
- Used as an alternative to fusion bonding, sweat soldering, mechanical, or press fit metal attachment
- Excellent high temperature performance and will survive lead-free solder processing
- Available in 2mil and 4mil thickness, 12” wide
- Volume resistivity 0.00038 Ohm-cm
- Thermal conductivity 6 W/m/°K
- Work life 3 months, Storage life 12 months

Product launched in December 2013
Effects of Plating on Insertion Loss @ 26.5 GHz testing

Insertion loss of 50 ohm lines on 0.020" RO4233 laminate clad with standard foil

Bare Cu IL = -0.0198(GHz)
ENIG IL = -0.0259(GHz)
HASL IL = -0.0243(GHz)
Silver IL = -0.0211(GHz)
Materials for Mobile Infrastructure

BTS Antennas
Technology Roadmap: Antennas

- Market Trends
  - Implementation of MIMO technology
  - Higher frequency bands (i.e., 2.6GHz)
  - Increased antenna complexity, multi-band antennas
  - Move towards integrated array & smart antennas
- Introduce RO4700JXR laminates with improved PIM performance
- RO4535 LoPro with RO4350B/RO4450F for integrated antenna/amplifier designs
  - Low cost of manufacture compared with PTFE solution
- Development of flame retardant versions of RO4700
- Implement PIM testing as in process test
Antenna material Considerations

- Design goals
  - Total Radiated Power, TRP (dBm)
  - Peak EIRP (dBm)
  - Directivity (dBi)
  - Efficiency (%)
  - Gain (dBi)
  - Beam tilt (Beam forming)
  - PIM (-dBc)
Antenna material Considerations

- Substrate Material Properties
  - Lowest Insertion Loss
    - Dielectric Loss
    - Radiation Loss
    - Conductor Loss
  - Lowest PIM
  - Highest linearity
  - Lowest phase delay (td).
  - Hi thermal dissipation (Tc)
  - Flammability.
New Technologies Driving Development of Antenna Grade Materials on RO4000

Use of Hollow Inorganic Microspheres on RO4700 materials to Obtain Dielectric Constants below 3.0

Developed LoPro™ Technology, Combining Reverse Treat Foil and Proprietary Adhesive for Improved PIM and Peel Strength
## Antenna Materials: Thermosets

<table>
<thead>
<tr>
<th>Laminates</th>
<th>Dk 10 GHz</th>
<th>Df (2.5/10) GHz</th>
<th>Thermal Conductivity (W/m/K)</th>
<th>PIM (dBc) Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO4533™ Laminates</td>
<td>3.3</td>
<td>0.0020</td>
<td>&gt; 0.60</td>
<td>-157*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO4534 ™ Laminates</td>
<td>3.4</td>
<td>0.0021</td>
<td>&gt; 0.60</td>
<td>-157*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0027</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO4535™ Laminates</td>
<td>3.5</td>
<td>0.0031</td>
<td>&gt; 0.60 UL 94V0**</td>
<td>-157*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0037</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO4725JXR™ Laminates</td>
<td>2.55</td>
<td>0.0023</td>
<td>&gt; 0.40</td>
<td>-166</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0033</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO4730JXR™ Laminates</td>
<td>3.0</td>
<td>0.0023</td>
<td>&gt; 0.40</td>
<td>-164</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0033</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*LoPro™ Resin Coated foil for lower PIM than traditional RO4500.

**Other Dk version in development.
RO4000 Materials Designed for MLB’s
Ideal for Smart Antennas

- CTE (Coefficient of Thermal Expansion)
  X,Y matched to copper
  - minimizes bow and twist of PCB
  - allows construction of hybrid MLB’s
- Low CTE Z and high Tg
  - plated through hole reliability
- Fabricate similar to conventional FR4
- Effect on electrical performance

- RO4000 materials are cost effective for
  multilayer power amplifier/transceiver units
  and integrated active antennas
  - Multilayer lamination at 175C, similar to FR4
### Features & Benefits of JXR

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
</table>
| RO4725JXR™ & RO4730JXR™ Laminates (Low Loss Dielectric Combined with LoPro™ Foil) | • Low PIM  
• Lower Insertion Loss than Standard RO4000® laminate  
• Match Dk to 2.55 & 3.0 Materials |
| Unique Filler / Closed Microspheres | • Low Density / Lightweight - ~30% Lighter Than PTFE / Glass  
• Design Flexibility  
• Automated Assembly Compatible  
• Consistent Circuit Performance |
| Low Z-Axis CTE <30 PPM/°C  
High Tg (Same as RO4000® Laminate - >280°C) | • Low TCDk  
• 2.55 & 3.0 Dk  
• Ease of Fabrication  
• PTH Process Capability  
• Processes Similar to FR-4  
• Halogen Free (non-flame retardant)  
• Lead Free Process Compatible  
• RoHS Compliant  
• Short Lead Times / Quick Inventory Turns  
• Efficient Supply Chain |
| Low TCDk <40 PPM/°C |  
Specially Formulated Thermoset Resin System / Filler |  
Environmentally Friendly |  
Regional FG Inventories |
### Features & Benefits Of RO4360G2

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO4000® Thermoset Resin System Specially Formulated To Meet 6.15 Dk</td>
<td>• Ease of Fabrication / Processes Similar to FR-4 (just like RO4350B™ laminate)</td>
</tr>
<tr>
<td></td>
<td>• RO4000 Material Repeatability</td>
</tr>
<tr>
<td></td>
<td>• PTH Capability / Reliability</td>
</tr>
<tr>
<td></td>
<td>• Low Dielectric Loss</td>
</tr>
<tr>
<td></td>
<td>• High Thermal Conductivity</td>
</tr>
<tr>
<td></td>
<td>• Lower Total PCB Cost Solution than Competing PTFE Products</td>
</tr>
<tr>
<td>Features</td>
<td>Benefits</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| Low Z-Axis CTE ~30 PPM/°C / High Tg (Same as RO4000® Laminate - >280°C) |  • Design Flexibility  
  • Automated Assembly Compatible |
| Environmentally Friendly |  • Lead Free Process Compatible  
  • RoHS Compliant |
| Regional Finished Goods Inventory |  • Short Lead Times / Quick Inventory Turns  
  • Efficient Supply Chain |
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Conclusion

- Rogers offers a wide variety of material to meet the needs of Telecom Network
- More than 85% of the world’s Power amplifiers are built using Rogers RO4000 Series materials
- Rogers is committed to invent newer material solutions to meet the needs of next generation networks
Questions?