ROGERS CORPORATION
Advanced Circuit Materials

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Data Sheet

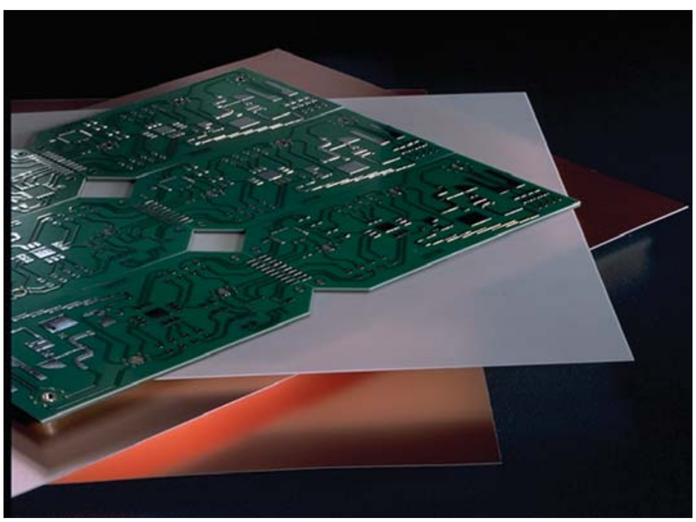
RO4000® Series High Frequency Circuit Materials

Features:

- Not-PTFE
- Excellent high frequency performance due to low dielectric tolerance and loss
- Stable electrical properties versus frequency
- Low thermal coefficient of dielectric constant
- Low Z-Axis expansion
- Low in-plane expansion coefficient
- Excellent dimensional stability
- Volume manufacturing process

Some Typical Applications:

- LNB's for Direct Broadcast Satellites
- Microstrip and Cellular Base Station Antennas and Power Amplifiers
- Spread Spectrum Communications Systems
- RF Identifications Tags



RO4000® Series High Frequency Circuit Materials are glass reinforced hydrocarbon/ceramic laminates (**Not PTFE**) designed for performance sensitive, high volume commercial applications.

RO4000 laminates are designed to offer superior high frequency performance and low cost circuit fabrication. The result is a low loss material which can be fabricated using standard epoxy/glass (FR4) processes offered at competitive prices.

The selection of laminates typically available to designers is significantly reduced once operational frequencies increase to 500 MHz and above. RO4000 material possesses the properties needed by designers of RF microwave circuits and allows for repeatable design of filters, matching networks and controlled impedance transmission lines. Low dielectric loss allows RO4000 series material to be used in many applications where higher operating frequencies limit the use of conventional circuit board laminates. The temperature coefficient of dielectric constant is among the lowest of any circuit board material (Chart 1), and the dielectric constant is stable over a broad frequency range (Chart 2). This makes it an ideal substrate for broadband applications.

RO4000 material's thermal coefficient of expansion (CTE) provides several key benefits to the circuit designer. The expansion coefficient of RO4000 material is similar to that of copper which allows the material to exhibit excellent dimensional stability, a property needed for mixed dielectric multilayer boards constructions. The low Z-axis CTE of RO4000 laminates provides reliable plated through-hole quality, even in severe thermal shock applications. RO4000 series material has a Tg of >280°C (536°F) so its expansion characteristics remain stable over the entire range of circuit processing temperatures.

RO4000 series laminates can easily be fabricated into printed circuit boards using standard FR4 circuit board processing techniques. Unlike PTFE based high performance materials, RO4000 series laminates do not require specialized via preparation processes such as sodium etch. This material is a rigid, thermoset laminate that is capable of being processed by automated handling systems and scrubbing equipment used for copper surface preparation.

RO4003™ laminates are currently offered in various configurations utilizing both 1080 and 1674 glass fabric styles, with all configurations meeting the same laminate electrical performance specification. Specifically designed as a drop-in replacement for the RO4350 material, RO4350B laminates utilize RoHS compliant flame-retardant technology for applications requiring UL 94V-0 certification. These materials conform to the requirements of IPC-4103, slash sheet /10 for RO4003C and /11 for RO4350B.

Chart 1: RO4000 Series Materials
Dielectric Constant vs. Temperature

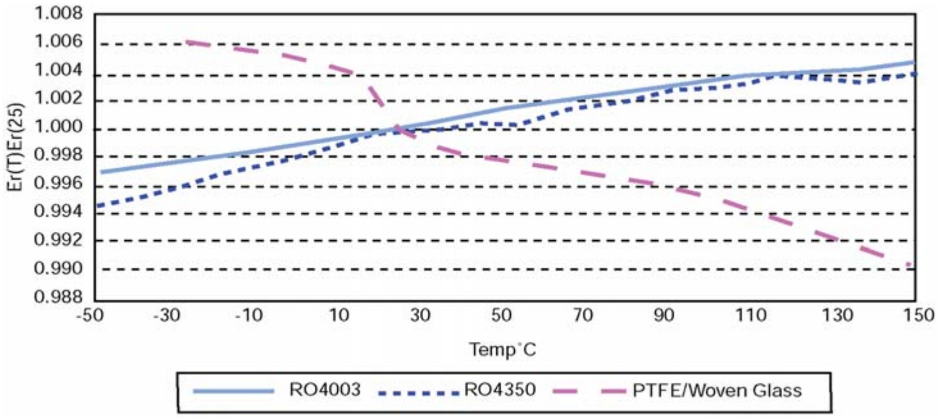


Chart 2: RO4000 Series Materials
Dielectric Constant vs. Frequency

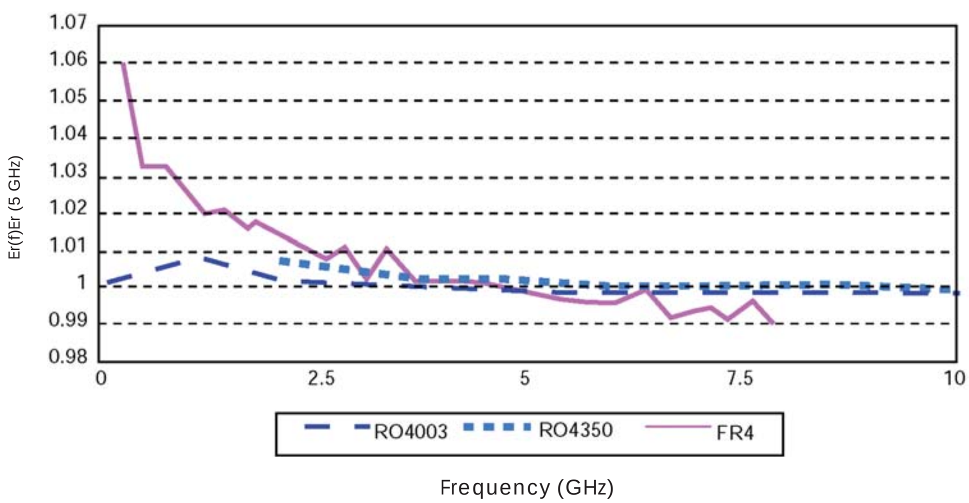
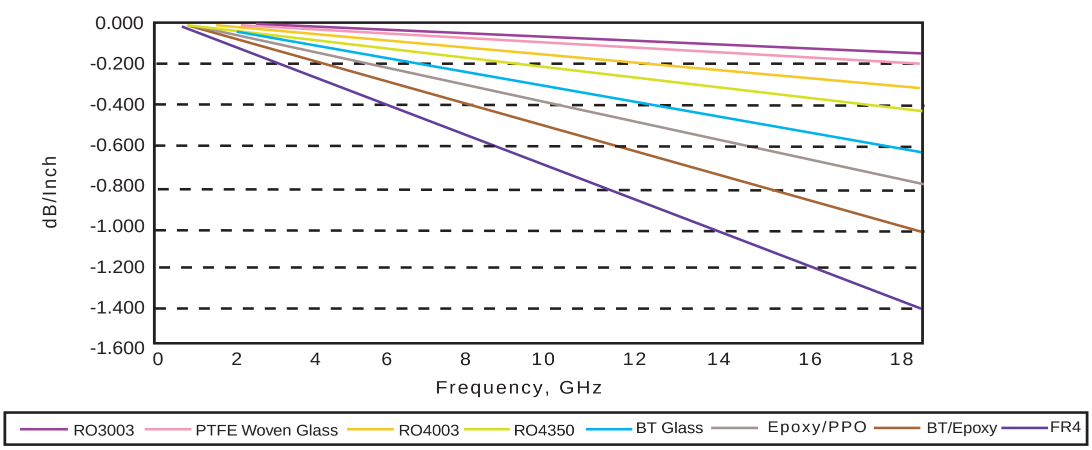


Chart 3: Microstrip Insertion Loss
(0.030” Dielectric Thickness)



Property	Typical Value		Direction	Units	Condition	Test Method
	RO4003C™	**RO4350B™**				
Dielectric Constant, ε_r (Process specification)	3.38 ± 0.05	(1) 3.48 ± 0.05	Z	--	10 GHz/23°C	IPC-TM-650 2.5.5.5 (2) Clamped Stripline
(3) Dielectric Constant, ε_r (Recommended for use in circuit design)	3.55	3.66	Z	--	FSR/23°C	IPC-TM-650 2.5.5.6 Full Sheet Resonance
Dissipation Factor tan, δ	0.0027 0.0021	0.0037 0.0031	Z	--	10 GHz/23°C 2.5 GHz/23°C	IPC-TM-650 2.5.5.5
Thermal Coefficient of ε_r	+40	+50	Z	ppm/°C	-50°C to 150°C	IPC-TM-650 2.5.5.5
Volume Resistivity	1.7 X 10^{10}	1.2 X 10^{10}		MΩ•cm	COND A	IPC-TM-650 2.5.17.1
Surface Resistivity	4.2 X 10^{9}	5.7 X 10^{9}		MΩ	COND A	IPC-TM-650 2.5.17.1
Electrical Strength	31.2 (780)	31.2 (780)	Z	KV/mm (V/mil)	0.51mm (0.020")	IPC-TM-650 2.5.6.2
Tensile Modulus	26,889 (3900)	11,473 (1664)	Y	MPa (kpsi)	RT	ASTM D638
Tensile Strength	141 (20.4)	175 (25.4)	Y	MPa (kpsi)	RT	ASTM D638
Flexural Strength	276 (40)	255 (37)		MPa (kpsi)		IPC-TM-650 2.4.4
Dimensional Stability	<0.3	<0.5	X,Y	mm/m (mils/inch)	after etch +E2/150°C	IPC-TM-650 2.4.39A
Coefficient of Thermal Expansion	11 14 46	14 16 35	X Y Z	ppm/°C	-55 to 288°C	IPC-TM-650 2.1.41
Tg	>280	>280		°C DSC	A	IPC-TM-650 2.4.24
Td	425	390		°C TGA		ASTM D3850
Thermal Conductivity	0.64	0.62		W/m/°K	100°C	ASTM F433
Moisture Absorption	0.06	0.06		%	48 hrs immersion 0.060" sample Temperature 50°C	ASTM D570
Density	1.79	1.86		gm/cm^3	23°C	ASTM D792
Copper Peel Strength	1.05 (6.0)	0.88 (5.0)		N/mm (pli)	after solder float 1 oz. EDC Foil	IPC-TM-650 2.4.8
Flammability	N/A	94V-0				UL
Lead-Free Process Compatible	Yes	Yes				

(1) Dielectric constant typical value does not apply to 0.004" (0.101mm) laminates. Dielectric constant specification value for 0.004 RO4350B material is 3.36.
(2) Clamped stripline method can potentially lower the actual dielectric constant due to presence of airgap. Dielectric constant in practice may be higher than the values listed.
(3) Typical values are a representation of an average value for the population of the property. For specification values contact Rogers Corporation.

Prolonged exposure in an oxidative environment may cause changes to the dielectric properties of hydrocarbon based materials. The rate of change increases at higher temperatures and is highly dependent on the circuit design. Although Rogers' high frequency materials have been used successfully in innumerable applications and reports of oxidation resulting in performance problems are extremely rare, Rogers recommends that the customer evaluate each material and design combination to determine fitness for use over the entire life of the end product.

Standard Thickness	Standard Panel Size	Standard Copper Cladding
RO4003C: 0.008" (0.203mm), 0.012 (0.305mm), 0.016" (0.406mm), 0.020" (0.508mm) 0.032" (0.813mm), 0.060" (1.524mm) **RO4350B**: *0.004" (0.101mm), 0.0066" (0.168mm) 0.010" (0.254mm), 0.0133 (0.338mm), 0.0166 (0.422mm), 0.020" (0.508mm) 0.030" (0.762mm), 0.060" (1.524mm)	12" X 18" (305 X457 mm) 24" X 18" (610 X 457 mm) 24" X 36" (610 X 915 mm) 48" X 36" (1.224 m X 915 mm) *0. 004" material in not available in panel sizes larger than 24"x18" (610 X 457mm).	½ oz. (17µm), 1 oz. (35µm) and 2 oz. (70µm) electrodeposited copper foil . **LoPro™ Reverse Treated EDC for PIM Sensitive Applications:** ½ oz (17mm), 1 oz (35 µm)

Fabrication Guidelines for RO4000® Series High Frequency Circuit Materials

RO4000® High Frequency Circuit Materials were developed to provide high frequency performance comparable to woven glass PTFE substrates with the ease of fabrication associated with epoxy/glass laminates. RO4000 material is a glass reinforced hydrocarbon/ceramic filled thermoset material with a very high glass transition temperature (Tg >280°C). Unlike PTFE based microwave materials, no special through-hole treatments or handling procedures are required. Therefore, RO4000 material circuit processing and assembly costs are comparable to epoxy/glass laminates.

Some basic guidelines for processing double sided RO4000 panels are provided below. In general, process parameters and procedures used for epoxy/glass boards can be used to process RO4000 boards.

DRILLING:

ENTRY/EXIT MATERIAL:

Entry and exit materials should be flat and rigid to minimize copper burrs. Recommended entry materials include aluminum and rigid composite board (0.010” to 0.025” (0.254 0.635mm)). Most conventional exit materials with or without aluminum cladding are suitable.

MAXIMUM STACK HEIGHT:

The thickness of material being drilled should not be greater than 70% of the flute length. This includes the thickness of entry material and penetration into the backer material.
For example:

Flute Length:	0.300” (7.62mm)
Entry Material:	0.015” (0.381mm)
Backer Penetration:	0.030” (0.762mm)
Material Thickness:	0.020” (0.508mm)⇒(0.023”(0.584mm) with 1 oz Cu on 2 sides)

Maximum Stack Height = 0.70 x 0.300”(7.62mm) = 0.210” (5.33mm) (available flute length)
-0.015” (0.381mm) (entry)
-0.030” (0.762mm) (backer penetration)
0.165”(4.19mm) (available for PCBs)

$$\text{Maximum Boards per Stack} = \frac{0.165\text{” (4.19mm) (available for PCBs)}}{0.023\text{” (0.58mm) (thickness per board)}} = 7.2 = 7 \text{ boards/stack (round down)}$$

DRILLING CONDITIONS:

Surface speeds greater than 500 SFM and chip loads less than 0.002” (0.05mm) should be avoided, whenever possible.

Recommended Ranges:

Surface Speed:	300 - 500 SFM (90 to 150 m/mm)
Chip Load:	0.002” - 0.004”/rev. (0.05-0.10 mm/rev)
Retract Rate:	500 - 1000 IPM 500 IPM (12.7 m/min) for tool less than 0.0135" (0.343 mm),1000 IPM (25.4 m/min) for all others.
Tool Type:	Standard Carbide
Tool life:	2000-3000 hits

Hole quality should be used to determine the effective tool life rather than tool wear. The RO4003™ material will yield good hole quality when drilled with bits which are considered worn by epoxy/glass standards. Unlike epoxy/glass, RO4003 material hole roughness does not increase significantly with tool wear. Typical values range from 8-25 um regardless of hit count (evaluated up to 8000 hits). The roughness is directly related to the ceramic filler size and provides topography that is beneficial for hole-wall adhesion. Drilling conditions used for epoxy/glass boards have been found to yield good hole quality with hit counts in excess of 2000.

CALCULATING SPINDLE SPEED AND INFEED:

$$\text{Spindle Speed (RPM)} = \frac{12 \times [\text{Surface Speed (SFM)}]}{\pi \times [\text{Tool Diam. (in.)}]}$$

Feed Rate (IPM) = [Spindle Speed (RPM)] x [Chip Load (in/rev.)]

<u>Example</u>:

Desired Surface Speed:	400 SFM
Desired Chip Load:	0.003”(0.08 mm)/rev.
Tool Diameter:	0.0295”(0.75 mm)

$$\text{Spindle Speed} = \frac{12 \times [400]}{3.14 \times [0.0295]} = 51{,}800 \text{ RPM}$$

Infeed Rate = [51,800] x [0.003] = 155 IPM

***QUICK REFERENCE TABLE*:**

Tool Diameter	Spindle Speed (kRPM)	Infeed Rate (IPM)
0.0100” (0.254mm)*	95.5	190
0.0135” (0.343mm)*	70.7	141
0.0160” (0.406mm)*	95.5	190
0.0197” (0.500mm)*	77.6	190
0.0256” (0.650mm)	60.0	180
0.0258” (0.655mm)	60.0	180
0.0295” (0.749mm)	51.8	155
0.0354” (0.899mm)	43.2	130
0.0394” (1.001mm)	38.8	116
0.0453” (1.151mm)	33.7	101
0.0492” (1.257mm)	31.1	93
0.0531” (1.349mm)	28.8	86
0.0625” (1.588mm)	24.5	74
0.0925” (2.350mm)	16.5	50
0.1250” (3.175mm)	15.0	45

* *Conditions stated are tapered from 200SFM and 0.002 chip load up to 400 SFM and 0.003" chip.*

DEBURRING:

RO4000 material can be deburred using conventional nylon brush scrubbers.

COPPER PLATING:

No special treatments are required prior to electroless copper plating. Board should be processed using conventional epoxy/glass procedures. Desmear of drilled holes is not typically required, as the high Tg (280°C+ [536°F]) resin system is not prone to smearing during drill. Resin can be removed using a standard CF4/O2 plasma cycle or a double pass through an alkaline permanganate process should smear result from aggressive drilling practices.

IMAGING/ETCHING:

Panel surfaces may be mechanically and/or chemically prepared for photoresist. Standard aqueous or semi-aqueous photoresists are recommended. Any of the commercially available copper etchants can be used.

SOLDERMASK:

Any screenable or photoimageable solder masks typically used on epoxy/glass laminates bond very well to the surface of RO4003. Mechanical scrubbing of the exposed dielectric surface prior to solder mask application should be avoided as an "as etched" surface provides for optimum bonding.

HASL and REFLOW:

RO4000 material baking requirements are comparable to epoxy/glass. In general, facilities which do not bake epoxy/glass boards will not need to bake RO4000 boards. For facilities that do bake epoxy/glass as part of their normal process, we recommend at 1-2 hour bake at 250°F-300°F (121°C-149°C).

***Warning*: RO4003** *does not contain fire retardant(s). We understand boards trapped in an infrared (IR) unit or run at very slow conveyor speeds can reach temperatures well in excess of 700°F (371°C). RO4003 may begin to burn at these high temperatures. Facilities which still use IR reflow units or other equipment which can reach these high temperatures should take the necessary precautions to assure that there are no hazards.*

SHELF LIFE:

Rogers' High Frequency laminates can be stored indefinitely under ambient room temperatures (55-85°F, 13-30°C) and humidity levels. At room temperature, the dielectric materials are inert to high humidity. However, metal claddings such as copper can be oxidized during exposure to high humidity. Standard PWB pre-exposure cleaning procedures can readily remove traces of corrosion from properly stored materials.

ROUTING:

RO4000 material can be machined using carbide tools and conditions typically used for epoxy/glass. Copper foil should be etched away from the routing channels to prevent burring.

MAXIMUM STACK HEIGHT:

The maximum stack height should be based on 70% of the actual flute length to allow for debris removal.

Example:

Flute Length:	0.300” x 0.70 =	0.210”(5.33 mm)
Backer Penetration:		– 0.030”(0.762mm)
Max. Stack Height:		0.180”(4.572mm)

TOOL TYPE:

Carbide multifluted spiral chip breakers or diamond cut router bits.

ROUTING CONDITIONS:

Surface speeds below 500 SFM should be used whenever possible to maximize tool life. Tool life is generally greater than 50 linear feet when routing the maximum allowable stack height.

Chip Load:	0.0010-0.0015”(0.0254-0.0381mm)/rev
Surface Speed:	300 - SFM

QUICK REFERENCE TABLE:

Tool Diameter	Spindle Speed	Lateral Feed Rate
1/32	40 k RPM	50 IPM
1/16	25 k RPM	31 IPM
3/32	20 k RPM	25 IPM
1/8	15 k RPM	19 IPM

World Class Performance

Rogers Corporation (NYSE:ROG), headquartered in Rogers, Conn., is a global technology leader in the development and manufacture of high performance, specialty material-based products for a variety of applications in diverse markets including: portable communications, communications infrastructure, computer and office equipment, consumer products, ground transportation, aerospace and defense. In an ever-changing world, where product design and manufacturing often take place on different sides of the planet, Rogers has the global reach to meet customer needs. Rogers operates facilities in the United States, Europe and Asia. The world runs better with Rogers.®

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