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Reliability and Key Properties of RT/duroid® 6002

RT/duroid® 6002 PTFE composite circuit board materials for microwave applications are designed for high reliability multilayer stripline and microstrip printed circuits. RT/duroid 6002 not only maintains the superior electrical properties characteristic of PTFE composites, but also has improved thermomechanical reliability. In fact, the thermal coefficient of expansion in the Z-direction is the lowest of all commercially available PWB materials, which results in excellent plated-thru hole (PTH) reliability.

Product Features	Benefits	Comments/References
Low dielectric constant and loss tangent	Ideally suited for microwave and high speed digital applications	εr = 2.94 ±0.04 at 10GHz, 23°C tan δ = 0.0012 at 10 GHz, 23°C
Low thermal coefficient of dielectric constant (Fig 1)	Temperature excursions do not affect performance	Thermal coefficient of εr = 0 at 10 GHz between -55 and 100°C
Coefficient of thermal expansion (CTE) in Z-direction is close match to copper.	Excellent plated-thru hole (PTH) reliability	Typical aspect ration PTH's subjected to MIL-P-55110 thermal shock and thermal cycling pass without failure (>1,000 cycles, -55 to +125°C), even with CIC constraint (Fig.2)
Combination of low modulus and X-Y direction coefficient of thermal expansion	Affords surface mount reliability (Fig. 3)	Combination of RT/duroid 6002 with constraining CIC-foils allow ultilization of large LCCC devices (up to 84 I/Os) for programs requiring all interconnects to survive 1,000 cycles from -55 to +125°C.
Passes ALL MIL-P-55110 Tests	Ideally suited for demanding military and other applications	Only PTFE material on the market that satisfies all the MIL-P-55110 Tests.

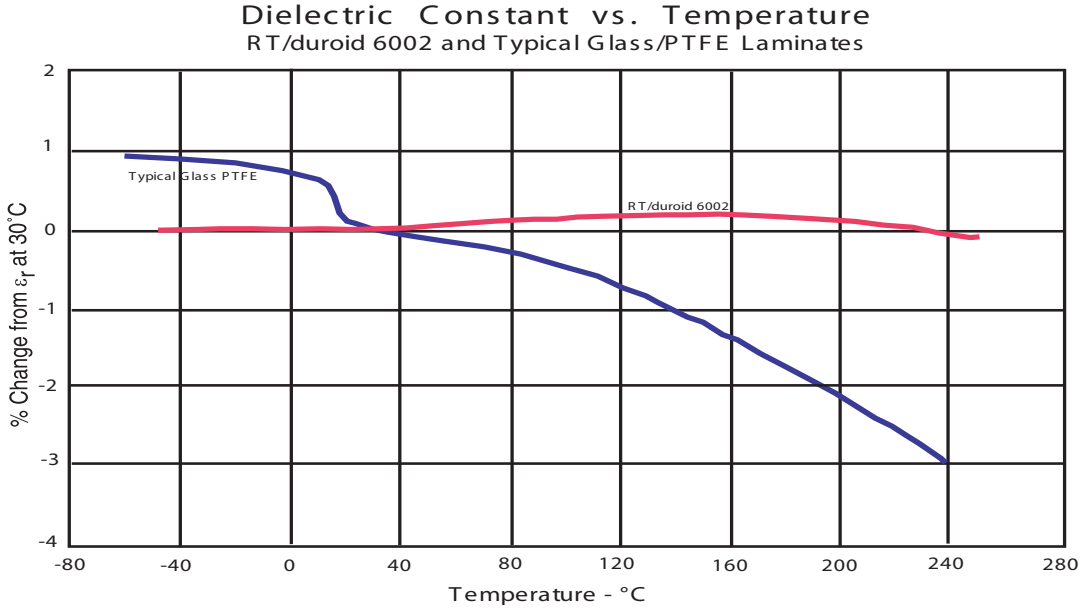

Figure 1: *RT/duroid 6002 Dielectric Constant vs. Temperature.*

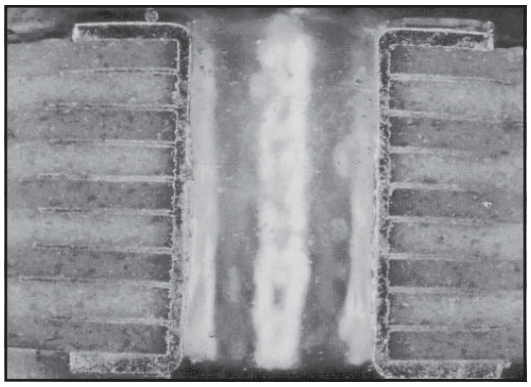

Figure 2: *Cross section of 9-layer dual stripline board showing plated thru hole and layer-to-layer registration.*

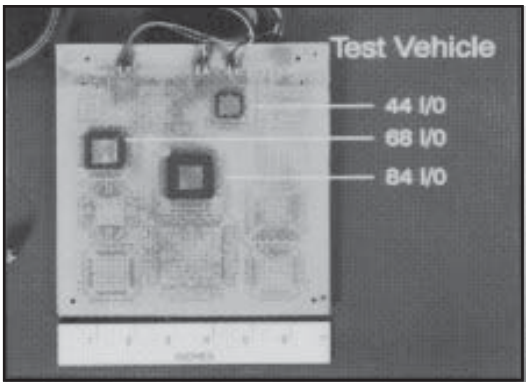

Figure 3: *LCCCs mounted on RT/duroid 6002 multilayer board.*

In 1987 Rogers Corporation recognized the need for a rigorous and comprehensive analysis of the "real life" performance of RT/duroid 6002 (*). A decision was then made to privately fund a separate, parallel effort along with the Air Force program for the development of Manufacturing Technology for Advanced Data/Signal Processing (Mantech AD/SP). The primary objectives of the contractees, Martin-Marietta, General Electric and Westinghouse, was to establish the manufacturing techniques, processes and controls to produce the next generation of VHSIC assemblies. During the course of this program, RT/duroid 6002 (*) was tested side by side with PWB materials identified as being the most likely candidates for these military assemblies.

The results from this program confirmed Rogers high expectations, as shown in Table 2 below.

(*) At the time of the Mantech program testing, the material was still named RO2800®, rather than

Material	ε_r effective		Loss Tangent tan δ	CTE Z-Dir (ppm/°C)	PTH Reliability (Cycle to failure)	Peel Strength (lb/in)	Arc Resistance (sec.)	CAF (ohms)
	Buried Stripline	Dual Stripline						
	(1)		(2)	(3)	(4)	(5)	(6)	(7)
RT/duroid 6002	2.79	2.95	0.001	29.8	>1000	4.8	252.0	7.7×10^4
BT Epoxy Kevlar® 120	3.46	3.56	0.011	73.7	159	4.3	123.8	2.1×10^3
PI/Kevlar 108	3.79	4.15	0.017	84.8	929	3.2	125.8	8.3×10^3
Quartrex/™ Kevlar 108	3.74	3.95	0.022	89.3	201	3.7	123.8	3.6×10^3
Quartrex/™ Quartrex 525	3.72	3.81	0.013	64.8	701	5.2	127.5	5.6×10^2

(1) Measured with Time Domain Reflectometry (Mantech test method 24)
(2) 1 MHz, 25°C - Resselaer Polytechnic Institute (Mantech test method 58)
(3) 0.100" laminate, - 55°C to 125°C - Martin Marietta (IPC-TM-650, 2.4.4.1)
(4) With standard copper plating, cycles to first electrical failure (Mantech test method 25)
(5) 1 oz. cu. as received - Trace Laboratory (IPC-TM-650, 2.4.8)
(6) Trace Laboratory (MIL-P-13949G, 4.8.3.16)
(7) Conductive Anodic Filament (CAF): Hole to hole, 10 volt bias 200 hrs. - Martin Marietta (Mantech test method 9)

RT/duroid 6002. Today RO2800 and RT/duroid 6002 are two distinct products: RO2800, part of the ROHSI-program, addresses the needs of the high performance commercial market which typically require very thin dielectric layers (2 mils and less) for very high layer count boards, whereas the properties of RT/duroid 6002 have been tailored to match the needs of the commercial microwave and military (both digital and microwave) markets through tight tolerances of its dielectric constant and dissipation factor, as well as through the availaibility of thicker sheets and various claddings. Today's RT/duroid 6002 is the same product as the RO2800 material that has been tested in the Mantech program.

Tables 3, 4, and 5 highlight additional features of RT/duroid 6002.

Table 3: RT/duroid 6002 Test Results

Thermal Stress (10 sec. 550°F(288°C):	PASS		
Volume Resistivity (MOhm-cm) - Tested as received	Average = $6x10^7$		
Surface Resistivity (MOhm) - Test as received:	Average = $9x10^7$		
Electrical Strength (Volts/mil @ 5.6 mil thickness):	Average = 859		
Arc Resistance (seconds):	Average = 252		
Water Absorption (ASTM D570, D48/50):	0.13% maximum		
Dimensional Stability:	Afteretch:	MD:	+0.07%
		TD:	+0.06%
MD: Machine Direction	After etch:	MD:	+0.08%
TD: Transverse Direction		TD:	-0.02%

Table 4: RT/duroid 6002 Passed All MIL-P-55110 Tests (**).

Moisture and Insulation Resistance (Specification: >500 MOhm):	
Before temperature/humidity cycling:	Average = 107 MOhm
After temperature/humidy cycling:	Average = 107 MOhm
Thermal Shock and Thermal Stress (100 cycles, -65°C to 150°C - 10 seconds, 288°C):	
All traces and plated-thru holes survived (no cracks/opens)	
Layer to Layer registration (Specification: should be less than or equal to 0.014" misregistration):	
Less than 0.0024" misregistration	

(**) Minimum etchback of 0.0002" is not necessary since smear does not occur while drilling RT/duroid 6002.

PROPERTY	TYPICAL VALUE[2]	DIRECTION	UNITS[1]	CONDITIONS	TEST METHOD
Dielectric Constant, ε_r	2.94 ± 0.04	Z	--	10 GHz/23°C	IPC-TM-650, 2.5.5.5
Dissipation Factor, Tan δ	0.0012	Z	--	10 GHz/23°C	IPC-TM-650, 2.5.5.5
Thermal Coefficient of ε_r	+12	Z	ppm/°C	10 GHz/1-100°C	IPC-TM-650, 2.5.5.5
Volume Resistivity	10^6	Z	Mohm cm	A	ASTM D257
Surface Resistivity	10^7	Z	Mohm	A	ASTM D257
Tensile Modulus Ultimate Stress Ultimate Strain	828 (120) 6.9 (1.0) 7.3	X,Y X,Y X,Y	MPa (kpsi) MPa (kpsi) %	23°C	ASTM D638
Compressive Modulus	2482 (360)	Z	MPa (kpsi)		ASTM D638
Moisture Absorption	0.1 0.13 max	---	%	D23/24 D48/50	IPC-TM-650 2.6.2.1 ASTM D570
Thermal Conductivity	0.60	---	W/m/K	80°C	ASTM C518
Coefficient of Thermal Expansion	16 24	X,Y Z	ppm/°C	(10K/min)	ASTM D3386
Density	2.1		gm/cm^3		ASTM D792
Specific Heat	0.93 (0.22)	---	J/g/K (BTU/lb/°F)	----	Calculated
Copper Peel	8.9 (1.6)		lbs/in (N/mm)		IPC-TM-650, 2.4.8
Flammability	94V-0				UL

[1] S1 units given first, with other frequently used units in parentheses.

[2] References: Internal TRs 3824, 5016, 5017, 5035. Tests were at 23°C unless otherwise noted.

Typical Values should not be used for specification limits.

Circuit Board Fabrication with PTFE/Ceramic Composites

The fabrication methods used to produce RT/duroid 6002 (multilayer) boards are described in David B. Noddins paper entitled "Fabrication of High Performance Multilayer Boards for Fluoropolymer Materials". Reprints are available from Rogers Corporation.

Other Available Literature:

"PTH Reliability of High Performance PWB Material" *by David J. Arthur and Elizabeth Kozij, Rogers Corporation.*

"Engineering Printed Wiring Boards for Enhanced Surface Mount Reliability" *by Robert C. Daigle, Kathleen Senkewitcz and David J. Arthur, Rogers Corporation.*

"Multilayer Microwave Boards Manufacturability and Design Issues" *by Robert C. Daigle, Greg W.Bull and Dale J. Doyle, Rogers Corporation.*

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