

The Advantage of Nearly Isotropic Dielectric Constant for RT/duroid® 5870-5880 Glass Microfiber-PTFE Composite

The fine scale uniformity of glass microfibers in the PTFE matrix of the RT/duroid® high frequency laminates apparently accounts for a significant advantage in isotropy of dielectric constant compared with PTFE materials depending on a woven fabric for reinforcement.

Anisotropy, the condition in which the dielectric constant varies in value depending on the direction of the electric field with respect to the axis of the material, can be expected to lead to extra fringing capacitance, most evident in resonator elements, in narrow lines and in edgewise couplers where it impairs directivity. Localized variation in anisotropy, especially characteristic of woven fabric reinforced composites, can lead to degradation of performance. This is particularly true at higher frequencies in situations where a narrow coupling gap or very narrow lines are used.

To simplify circuit design computations, isotropy of the electrical properties of laminated materials for microstrip or stripline circuitry is usually assumed. The nominal dielectric constant value is obtained by test methods in which the electric field is predominantly in the Z (thickness) direction. Glass fiber reinforced PTFE laminates have fibers lying in the XY plane that have a dielectric constant nearly 3 times higher than the polymer matrix. The composite will be isotropic with $\epsilon_{p,x}$ and $\epsilon_{p,y}$ nearly equal but both greater than $\epsilon_{p,z}$.

TABLE 1 Test Data on a Block of RT/duroid® 5870 Glass Microfiber-PTFE Composite

Electric Field	X longitudinal	Y transverse	Z thickness
Thickness mm (in)	1.58 (0.0622)	1.53 (0.0604)	1.60 (0.0631)
Dielectric constant			
1 MHz (ASTM D1531)	2.428	2.430	2.330
10 GHz (ASTM D3380)	2.452	2.432	2.347
Dissipation Factor			
1 MHz (ASTM D1531)	0.0014	0.0009	0.0005
10 GHz (ASTM D3380)	0.0023	0.0024	0.0016

The experimental results are summarized in Table 1. The Z-direction results agree with accumulated QA test data on production laminates. The degree of anisotropy is expressed as the ratio of the average X,Y value to the Z value. For RT/duroid 5870, it is 1.040 by the 10 GHz stripline method and 1.042 by the 1 MHz fluid displacement method.

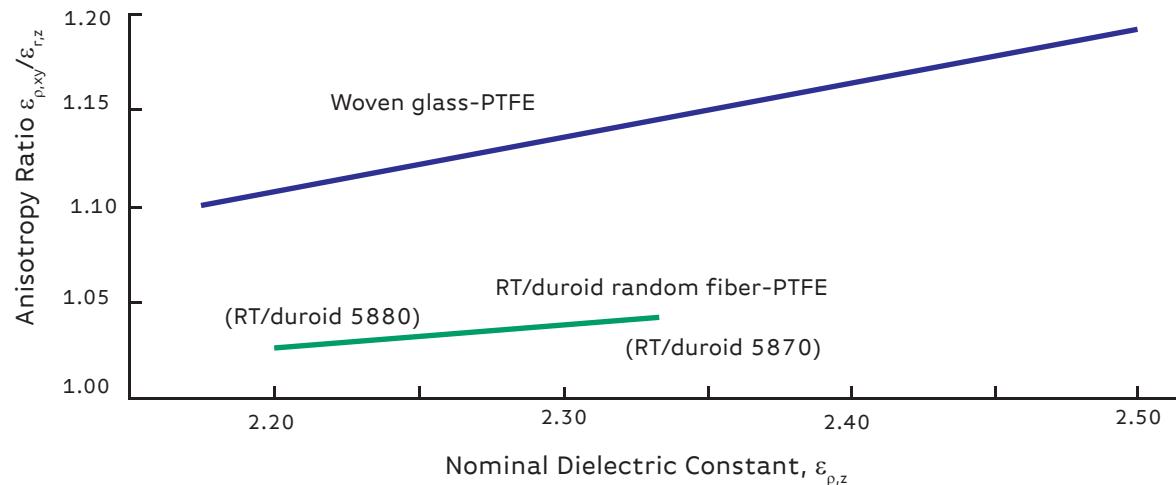


Figure 1: Anisotropy ratio of dielectric constant vs. nominal dielectric constant comparing woven glass-PTFE with random fiber-PTFE

Measuring the dielectric constant of a laminate for printed circuitry where the electric field is in each of the principal axis presented a problem. The identical method should be used for each axis to get directly comparable results. This was done for RT/duroid 5870 laminate by preparation of a thick block from thin layers of laminating stock. Pairs of slices were band-sawed from the block in planes perpendicular to each of the principal axis. These were surface ground on both sides to a thickness suitable for measurement by the stripline resonator test method at about 10 GHz¹ or by the fluid displacement method at 1 MHz². The electric field is essentially perpendicular to the plane of the specimen in both methods.

Since the only source of this anisotropy is the glass microfiber content, one would expect RT/duroid 5880 material—with about half as much volume fraction of fiber—to have an anisotropy ratio of about 1.02.

These results are compared in Figure 1 with published values for laminates based on woven glass³. They show that the RT/duroid random glass micro-fiber structure is less anisotropic than is a woven fabric structure.

This difference may possibly be explained by considering the woven fabric structure, especially at lower fiber content, to be a series of alternating polymer-rich and fiber-rich layers. The Z direction field in effect sees a series capacitor network while the X-Y fields see a parallel capacitor network. This layer effect is in addition to the fiber-orientation effect of the fiber-rich layers.

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