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Why Do Different Test Methods Yield Different Electrical Values?

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A variety of different test methods may be used for any one electrical concern. This article will discuss the issues related to determining the dielectric constant (Dk) and dissipation factor (Df or Tan-Delta). On a data sheet, a designer may see a Dk value for a material to be 3.5, as an example. Once the designer buys the material and performs necessary evaluations, it may be found that the Dk of the material is 3.8. In some applications this difference in Dk is probably not meaningful; however, for many RF and high-speed digital applications, this difference could be very significant. What is really interesting about this example is that the two Dk values may both be correct, depending on the test methods used.

Most laminates used in the PCB industry are anisotropic and this means that the electrical properties are not the same on all three axes of the material. Typically the thickness (z-axis) of the material will have a different Dk value than the x or y axes of the material. The reasons for this depend on what type of material is being considered.

The laminates used in the PCB industry are typically woven-glass reinforced, however there are notable exceptions. The glass reinforcement layer typically has a different Dk and Df than does the raw substrate of the laminate. The standard E-glass most often used in PCB laminates has a typical Dk value of about 6 and a dissipation factor of around 0.004. The common FR-4 laminates use relatively simple resin systems and the resin itself has a Dk that is around 3 and a Df of about 0.03. Different ratios of resin to glass will cause the laminate to have a Dk that is somewhere between the value of the resin and that of the glass. However, the glass-resin ratio impact on Dk is usually considered when evaluating the material through the thickness axis and if the x- or y-axis is evaluated, the Dk value may be very different than the z-axis result.

A large number of test methods are available to evaluate materials for Dk and Df. The methods that are most often used in the PCB laminate industry for making these measurements are typically tailored to evaluating materials in very large volume. Because of this issue,



WHY DO DIFFERENT TEST METHODS YIELD DIFFERENT ELECTRICAL VALUES?

these test methods need to determine Dk and Df relatively fast, have good repeatability, and be used for quality control. A common test method used is the clamped stripline resonator, where a clamping fixture is used to form a stripline structure; the layer structure of a stripline is ground-signal-ground. This test method determines the Dk and Df of the material in the clamped fixture and more specifically, it is reporting these values related to the thickness axis of the material.

Other tests used in high-volume testing include SPDR (split-post dielectric resonator), rectangular cavity and open cavity resonance methods. All three of these methods have electric fields oriented perpendicular to the material, which means these test methods will evaluate the x-y plane of the material and not the z-axis. In the case of the common FR-4 material which is a resin-glass composite, the Dk number can be very different in the x-y plane than in the z-axis due to the impact of the glass.

Returning to the original example, where a material is tested and found to have a Dk of 3.5 and then another test is done on the same material and the Dk is found to be 3.8, both of these numbers can be correct when using two different test methods. These numbers are actually based on real life experience when testing high frequency laminates that are PTFE based with ceramic filler and have woven-glass reinforcement. With this type of material it is possible to have the same piece of material tested in the clamped stripline test and get a value of 3.5 and then tested in SPDR and obtain a result of 3.8. Since the clamped stripline test is evalu-

ating the z-axis of the material and the SPDR is evaluating the x-y plane of the material, both results are obviously different but still correct. Essentially these measurements show to some degree how anisotropic the material is, where the z-axis Dk of the material is 3.5 and the x-y plane Dk of the material is 3.8.

Knowing the anisotropic Dk values of a laminate is typically critical for RF applications with edge coupled features. In the case of high-speed digital circuits, these values can be important for differential pair structures. Having these values can be important, but also having a modeling software which can incorporate these values into predicted circuit performance is an important supplement to the design process.

It is always recommended to contact your material supplier if you have questions about the Dk or Df of a laminate. You should ask which test method is used and which axis or axes of the material is being evaluated. Another good question to ask your material supplier is the frequency at which these values are generated, because the Dk and Df of a material is frequency dependent. Having the most accurate laminate information for the design phase of a project is critical to its success. **PCBDISIGN**



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New Nanomanufacturing Technique Advances Imaging, Biosensing Technology

More than a decade ago, theorists predicted the possibility of a nanolens. But scientists had been unable to build and arrange many nanolenses over a large area.

"That's where we came in," said Xiaoying Liu, senior research scientist at the University of Chicago's Institute for Molecular Engineering.

They aligned three spherical gold nanoparticles of graduated sizes in the string-of-pearls arrangement predicted to produce the focusing effect.

The scientists are already exploring using this "hot spot" for high-resolution sensing using spectroscopy. "If you put a molecule there, it will interact with the focused light," said Liu.