New Base Materials for Multilayer Applications in High-Speed Digital and RF Technology

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FR4 is the base material with which the overwhelming majority of all multilayer printed circuit boards can be manufactured. However, the number of applications is growing, for which base materials of a low dielectric constant (ε_R) and low dielectric loss factor (tan δ) have to be used.

High-Speed Digital

A low dielectric constant enables the use of (ultra) thin base materials for fast clocking speeds and increased packaging densities at current impedance levels. It is the low dielectric loss however, which turns high-speed digital into a success story: Signal traces can become longer, and power input can be reduced – both at improved signal integrity. Fig 1 demonstrates that the dielectric loss of such base materials is more consistant at higher frequences than that of FR4.

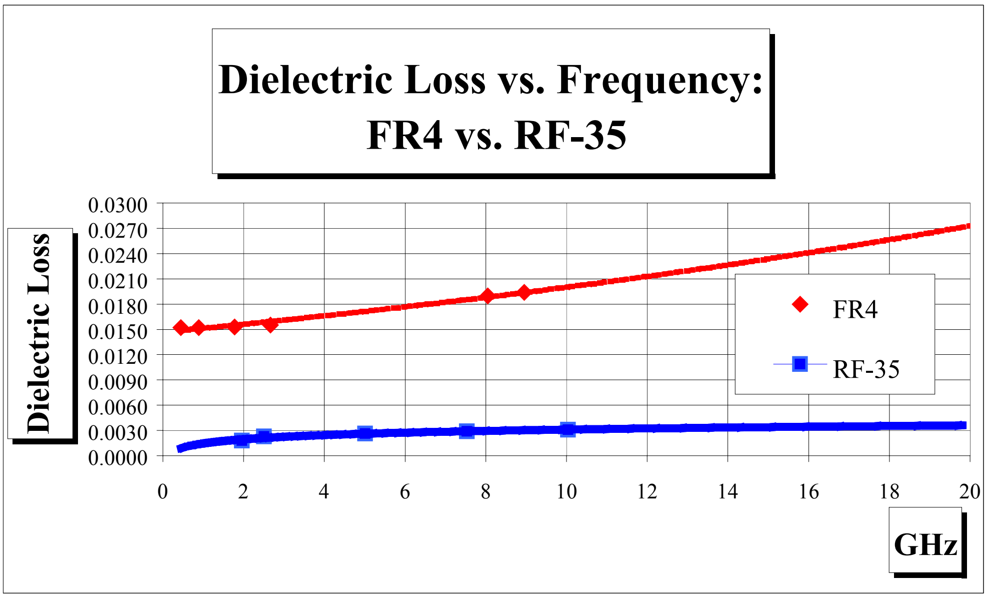

Fig. 1: Dielectric loss vs. frequency: FR4 vs. RF-35 (source: Taconic)

Fast transmission rates for high-speed digital are at 2.5 Gb/s today. However there are applications at prototype stage of 7.5 and 10 Gb/s. So-called „eye patterns" are used to define signal integrity. Fig. 2 demonstrates that a so-called low loss base material is already superior to FR4 at 2.5 Gb/s!

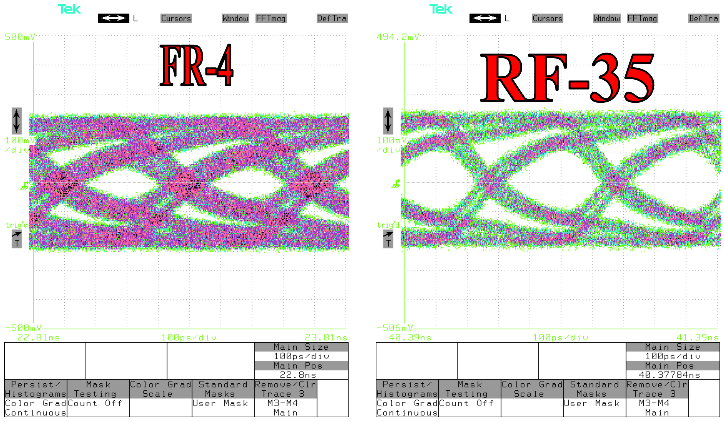

Fig. 2: Eye patterns of a 200 micron (8 mil) signal trace (1 m signal length, edge-coupled, 2,5 Gb/s).
FR4: time: 52% open, amplitude: 18,1 % open;
RF-35: time: 72,9 % open, amplitude: 36,7 % open.
(source: Teradyne)

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High Performance Base Materials

Table 1 contains an overview of commercially available high performance base materials. The array of used resin systems is evidence that base material manufacturers choose different paths for their solutions. It remains the choice of a design engineer, which solution will be used for individual requirements.

Manufacturer	Type	Availability	ε_R	tan δ	Tg (DSC)
Taconic	RF-35	Laminate: multiples of 0.25 mm	3.5 (2 – 10 GHz)	0.0018 (2 GHz); 0.0030 (10 GHz)	> 315 °C
Taconic	RF-35P	Laminate: multiples of 0.05 mm	3.5 (2 – 10 GHz)	0.0018 (2 GHz); 0.0030 (10 GHz)	> 315 °C
Taconic	TacPreg™ TP-32	Prepreg: multiples of 0.075 mm (development product; co-manufacturing agreement with Isola)	3.2 (2 – 10 GHz)	0.005 (10 GHz)	
Taconic	TacSpeed 3200	Laminate: multiples of 0.050 mm (development product; co-manufacturing agreement with Isola)	3.2 (2 – 10 GHz)	0.005 (10 GHz)	
Isola	IS630	Laminate: multiples of 0.050 mm Prepreg: multiples of 0.075 mm (both are development products; co-manufacturing agreement with Taconic)	3.2 (2 – 10 GHz)	0.005 (10 GHz)	
Isola	FR408	Laminate: 0.050 mm and thicker; Prepreg: various glass fabric types	3.7 (1 GHz)	0.010 (1 GHz)	180 °C (DSC)
Isola	Gigaver 210	Laminate: 0.05 mm. increments of 0.025 mm; Prepreg: various glass fabric types	3.9 (1 MHz) 3.5 – 3.9 (1 GHz) = f(resin content)	0.005 (1 MHz)	175 °C (DMA)
Nelco	N4000-13	Laminate & Prepreg	3.7 (2.5 GHz) 3.6 (10 GHz)	0.014 (2.5 GHz) 0.014 (10 GHz)	210 °C (DSC)
Nelco	N6000	Laminate & Prepreg	3.5 (1 Ghz) 3.5 (10 GHz)	0.007 (1 GHz) 0.009 (10 GHz)	210 °C (DMA)
Arlon	25FR	Laminate: 0.15 mm. 0.20 mm. 0.25 mm. usw. Prepreg: various glass fabric types	3.58 (10 GHz)	0.0035 (10 GHz)	260 °C
Gore	Speedboard C	Prepreg only	2.59 (1 GHz) 2.56 (10 GHz)	0.0035 (1 GHz) 0.0038 (10 GHz)	190 °C
Rogers	4003	0.20 mm. 0.51 mm. etc.	3.38 (10 GHz)	0.0027 (10 GHz)	> 280 °C
Rogers	4350B	0.17 mm. 0.25 mm. 0.51 mm. etc.	3.48 (10 GHz)	0.0040 (10 GHz)	> 280 °C
Rogers	4403	Prepreg: multiples of 0.10 mm	3.20 (10 GHz)	0.005 (10 Ghz)	> 280 °C
Polyclad	PCL-LD-621	Laminate: 0.050 mm and thicker; Prepreg: various glass fabric types	3.2 (1 GHz) 3.2 (10 GHz)	0.005 (1 GHz) 0.008 (10 GHz)	190 °C (TMA)

Table 1: High performance base materials; (source: [2] with additions for Taconic and Isola. as well as up-to-date data sheet information of the individual manufacturers)

Why is RF-35 being used more and more in the industry? Due to its nature of being a ceramic-filled PTFE (Teflon™)/glass fabric base material it is supposed to be an even more exotic material than base material manufactured of glass fabric-reinforced thermoset resin with or without ceramic fillers. Contrary to popular belief RF-35 can be processed like FR4 – as any other low loss base material! The same process steps are required. only desmearing using permanganate has to be replaced with plasma (or sodium naphthalate) in an off-line process. Leading OEMs prefer RF-35 (and now also RF-35P) due to its significantly higher copper peel strength. in particular for 18 micron (0.5 oz) copper claddings (table 2).

LaminateType	Copper Peel Strength (18 µm)	Copper Peel Strength (35 µm)
FR4		2.0 N/mm
PPE/PPO resin	0.8 -1.2 N/mm (depending on manufacturer)	0.8 -1.2 N/mm (depending on manufacturer)
BT/Epoxy resin		1.23 N/mm
Hydrogen carbon resin		0.88 N/mm
RF-35	1.5 N/mm	1.8 N/mm
TLY-5	2.0 N/mm	2.1 N/mm

Table 2: Copper peel strength values of various high performance base materials of 0.51 mm (20 mil) thickness; (source: data sheets of individual manufactureres)

An additional advantage is seen in the absence of bromine in Teflon™ base materials. This bromine-free resin system provides the flammability class of UL94 V-0. without any required addition of flame retardants.

Multilayer/Backpanels

Teflon™/glass fabric base materials can be laminated together with FR4 prepregs and FR4 inner layers for mixed dielectric multilayers. This technology has been in use for several years already. e.g. in power amplifiers for mobile phone infrastructure. collision avoidance radar sensors. etc.

High-speed digital printed circuit boards are typically large-sized high-layer count multilayers. known as backpanels. Their sizes vary from 410 x 657 mm up to 900 x 150mm. Up to now the the unavailability of ultra-thin laminates and prepregs prevented single-component constructions.

RF-35P is a proven technological advancement which enables the manufacture of thinnest inner layers down to 50 micron (0.05 mm) thickness in production quantities. Based on this technology TacPreg™ TP-32 prepregs are currently undergoing field trials. First results in standard multilayer constructions (that is prepregs and copper foil used to form outer layers) look very promising (fig. 2). Commercialisation is planned for the second half of 2002.

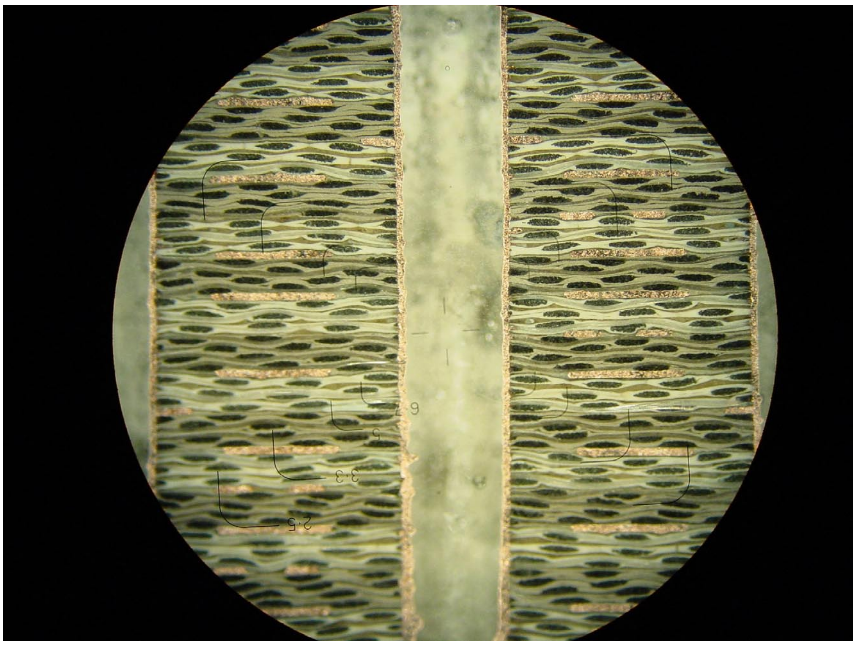

Fig. 2: Microsection of a 20-layer multilayer. using RF-35P and TacPreg™ TP32 (source: Teradyne)

These initial results have been given an additional boost by the recent signing of co-manufacturing agreements between Taconic and Teradyne for laminates and prepregs to be used for very large sizes backpanels in the USA. and between Taconic and Isola for any other sized applications worldwide. This provides high-speed digital design engineers with dual-sourcing of one and the same laminates and prepregs!

Summary

Recent new developments as well as advancements of low loss base materials and prepregs have demonstrated that challenges of availbility and product breadth can be met. Very high reliability multilayers can now be manufactured.

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