

The Use of PTFE/Woven Glass Base Material in the PCB Industry

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It is amazing to hear comments in the pcb industry, such as „We do not use Teflon® base materials, because they are difficult to process“, „If Teflon® base material could be processed like FR4, then ...“, „The surface preparation of Teflon® base material is too complicated, too expensive, too awkward to handle, too ...“, „We have no special process line for Teflon® pcbs“, „We are not geared for speciality materials“, etc.

What is really hidden behind those statements? Are they justified or just based upon insecurities regarding PTFE/woven glass base materials?

If we look back not even ten years, PTFE (= polytetrafluoroethylene, Teflon®) base materials were really exotic materials with limited availability, and which could be processed with difficulties only. Mainly in the last few years tremendous efforts have been undertaken to wipe out those myths. In the past these types of base materials were mainly used in military applications, and therefore only required small volumes. However, since the first large volume commercial pcb application, LNBs for satellite television receivers, the PTFE world has changed dramatically.

Processing

PTFE is used as non-stick coating for commercial applications due to its inert molecular structure. Its surface can be „roughened“ only through drastic measures. For years a hole wall roughening of drilled PTFE/glass fabric base material for better adhesion of the through-hole plating was only possible through sodium naphthalene treatment. During this chemical reaction explosions of the released hydrogen can occur upon improper handling. Also the Effluent Treatment Manager of a pcb shop has „better“ chemicals on his wish list. Since plasma etch chambers are used in pcb manufacture, hole walls can be roughened without effluent and by taking care of the environment. With many pcb manufacturers also manufacturing flexible and/or rigid flex pcbs, plasma etch chambers are widespread throughout the industry, and do not require to be purchased specifically for PTFE/glass fabric. Plasma etch cycles using either nitrogen only, followed by an oxygen purge, or using Helium/Tetrachloromethane, make PTFE/woven glass base materials a material as problem-free as FR4 in this respect.

In order to roughen hole walls, holes have to be generated in the previous step. With PTFE being relatively soft in comparison to FR4, special drilling parameter are required for each PTFE/woven glass base material type. Not in the (currently inactive for new designs) MIL-S-13949S covered base materials with DK values between 2.95 and 3.50 can even be drilled using parameter almost identical to FR4: Cutting speeds of approximately 140 m/min, with higher feed rates for smaller hole diameters lift the insecurity of the unknown off a pcb manufacturer.

Both manufacturers of base materials and drill bits have jointly developed detailed drilling parameter which only require being programmed into the CNC drilling machines. The frequent demand that base materials for microwave applications should be drillable like FR4 for allegedly easier processing cannot be achieved in practise. It is a myth that base materials made of glass-reinforced thermoset plastics (these are resin system cured under heat) can be drilled like FR4. Each pcb manufacturer is also aware today of the fact that not even FR4s can be drilled the same: Due to the introduction of multifunctional FR4 systems with higher, but different glass transition temperatures depending on manufacturer, different drilling parameter might be required. Even slightly different parameters mean different settings at the drilling machine. But – what difference is there during programming to alter a number by 1 or 10?

The main differences to FR4 have now been addressed. Further process steps, such as photo resist processing, etching, through-hole plating, application of surface protection, etc. use pcb industry parameter.

Base Material Type	Dielectric Constant at 10 GHz	Tolerance	Dielectric Loss Factor at 10 GHz
RF-35	3.50	± 0.07	0.0018 **
TLC	2.75; 3.0; 3.20	± 0.05	0.0030
TLE	2.95; 3.0	± 0.05	0.0028
TLT	2.45; 2.50; 2.55; 2.60; 2.65 *	± 0.04	0.0006 *
TLX	2.45; 2.50; 2.55; 2.60; 2.65	± 0.04	0.0019
TLY	2.17; 2.20; 2.33	± 0.02	0.0009
CER-10	10		0.0035

* at 1 MHz

** at 1.9 GHz

Table 1: PTFE/Glass Fabric Base Materials (dielectric constant, dielectric loss factor)

Multilayer

Depending on the requirement there are several options to manufacture multilayers: All-PTFE multilayers are only possible through sweat bonding at very high temperatures. If RF properties are required for the dielectric to be generated, FEP or CTFE bonding films will be used. The most common option however is the hybrid multilayer, whereby the PTFE/woven glass is bonded to either double-sided FR4 or an FR4 multilayer using standard FR4 prepregs and press cycle (fig. 1). Since the oxidised copper-clad surface of PTFE/woven glass is bonded to the FR4 prepreg, guidelines for all-RF multilayer are not required.

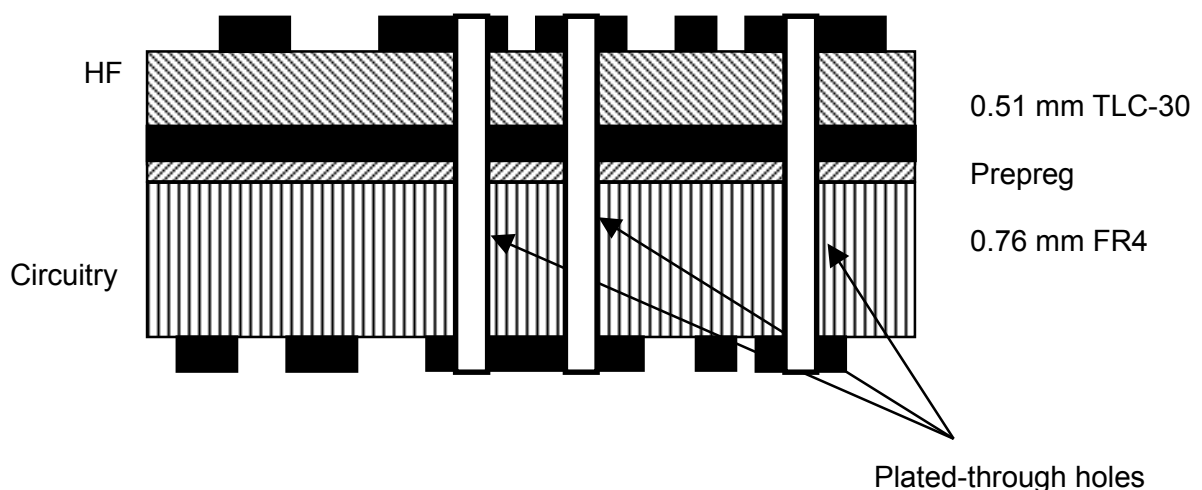


Fig. 1: 4 Layer Hybrid Multilayer

Considerable cost savings can be achieved this way when the total system is cost-analysed: Instead of several digital pcs and one RF pcb, all being connected by connectors, cables, etc., it

is possible to have them all as ONE multilayer. A further advantage is the so generated space saving in the housing. Some of the latest designs even incorporate PTFE/woven glass insertions in FR4-pcbs for RF areas.

Gained advantages are manifold apart from cost savings through elimination of cables and connectors, or space savings: Stiffness of the multilayer permits SMD assembly, etc. PTFE base material manufacturers can be contacted for detailed information.

Does this mean that every pcb manufacturer can process PTFE/woven glass base materials? The reply based upon manufacturing technology must be „Yes“, if a plasma etch chamber or equipment for a sodium naphthalene process is available. However, an understanding of the function and performance of a pcb at microwave frequencies is also of utmost importance.

The question regarding availability of PTFE/woven glass is easily answered: Due to an ISO 9002 certified base material production in Europe delivery times of 5 working days can be offered, which are only longer for special materials such as RA copper cladding, or heavy metal backing ≥ 0.80 mm (brass, aluminium, copper). No inventory costs for imports are required anymore. For critical secured sourcing of components a second source should be obtained if possible. The possibility of Dual Sourcing from one company exists today due to manufacturing plants in Europe and the US, thus rendering a cost-intensive qualification of a second source not necessary anymore.

PTFE/Woven Glass Base Materials vs. Thermoset Resin/Woven Glass Base Materials

Where are the advantages from the use of PTFE/woven glass base materials in comparison to those made of thermoset plastics (heat curing hydro carbon resins; most important example: FR4), for it is possible today to obtain dielectric constants between 3.3 and 4.0 with woven glass-reinforced thermoset resins other than FR4. If one knows the different behaviour of thermoplastics and thermoset plastics, advantages become obvious looking at impregnation and lamination processes: A thermoset resin requires a hardener/accelerator system to achieve the B-stage after impregnation. This state of partial polymerisation is obtained through a chemical reaction under heat in the treater. For this reason woven glass fabrics can only be impregnated once. Tremendous efforts have been undertaken in recent years to reduce variations of resin content and resin flow across the web in treaters. By applying minimum melt viscosity control for FR4 systems, flow behaviour of prepregs can be controlled much more uniformly in the laminate press. The exactness of the characterisation parameter has been ascertained through the high FR4 volume over a long period of time, and is therefore not available for other thermoset systems, in particular new developments. During lamination in the press the prepreg resin melts under heat until the cross-linking reaction overtakes and cures the resin under heat and pressure. The resin flow along the edges of a base material sheet, generated at the low viscosity stage, leads to a certain taper of the thickness profile across the sheet. This taper increases with increasing base material thickness, in particular when heavier woven glass fabrics are used.

In comparison to the just described behaviour of thermoset resins, the one of thermoplastics such as PTFE is completely different: Woven glass fabrics are impregnated in a treater similar than with FR4 resin, but now the advantages of PTFE become obvious: Due to the low viscosity of the aqueous PTFE dispersion, glass fabrics for base material must be impregnated on average 5 – 6 times in order to obtain adequate PTFE coating. Since PTFE does not undergo a cure mechanism, glass fabrics can theoretically be impregnated as often as required. An extremely even PTFE coating of the glass fabric is achieved through very slow treater speeds and multiple impregnation cycles. There is no resin flow variation across the web, because thermoplastics do not have a flow mechanism. This advantage also becomes obvious during lamination: At press temperatures > 360 °C only a softening and sintering occurs. This leads to PTFE/woven glass fabric base materials having a very exact thickness distribution without any taper towards the edges of a sheet. Listed thickness tolerances in the still used MIL-S-13949H confirm this fact (table 2). Thickness tolerance class IV for PTFE/glass base material demand significantly tighter values than even the close tolerance class III for glass fabric reinforced thermoset plastics.

Thickness and Tolerances for Laminates (MIL-S-13949H)			
Nominal Thickness of base mat. Without cladding	Class II reinforced +/-	Class III (2) reinforced +/-	Class IV GR, GX, GY +/-
Inch (mm)	Inch (mm)	Inch (mm)	Inch (mm)
.0010 - .0045 (0.025 - 0.11)	.0007 (0.018)	.0005 (0.013)	-
.0046 - .0065 (0.12 - 0.16)	.0010 (0.025)	.0007 (0.018)	- 3)
.0066 - .0120 (0.17 - 0.30)	.0015 (0.038)	.0010 (0.025)	.0075 (0.019)
.0121 - .0199 (0.31 - 0.51)	.0020 (0.051)	.0015 (0.038)	.0010 (0.025)
.0200 - .0309 (0.51 - 0.78)	.0025 (0.063)	.0020 (0.051)	.0015 (0.038)
.0310 - .0409 (0.79 - 1.03)	.0040 (0.102)	.0030 (0.076)	.0020 (0.051)
.0410 - .0659 (1.04 - 1.65)	.0050 (0.127)	.0030 (0.076)	.0020 (0.051)
.0660 - .1009 (1.66 - 2.54)	.0070 (0.178)	.0040 (0.102)	.0030 (0.076)
.1010 - .1409 (2.55 - 3.56)	.0090 (0.229)	.0050 (0.127)	.0035 (0.089)
.1410 - .2500 (3.57 - 6.35)	.0120 (0.305)	.0060 (0.152)	.0040 (0.102)

1) Tolerance value is determined by the nominal base thickness (less cladding). Tolerance is applied over the base plus cladding with no additional tolerance for cladding thickness allowed.

2) These tighter tolerances are available only through product selection on most material types

3) For some base material types, laminates below certain base thickness may not be producible, e.g. types GT, GX and GY under .010 inch (0.25 mm) core thickness may not be available (Amendment 2, Feb 29, 1996).

Table 2: Thickness Tolerances acc. to MIL-S-13949H

Why is an exact thickness distribution of base materials for use in RF and microwave technology of such importance? The thickness distribution in a composite material consisting of resin and glass fabric affects the uniformity of the dielectric constant and the dielectric loss factor. With microwave pcbs being mainly active components, variations of the dielectric characteristics inevitably lead to performance losses.

A further advantage of base materials from thermoplastics such as woven glass fabric reinforced PTFE over materials made from thermoset resins other than FR4 is the higher interlaminar bond strength and therefore also copper peel strength. Every pcb designer and pcb manufacturer knows the high peel strength of FR4, but also the fact that other resin systems exhibit significantly lower values, as recognised in MIL-S-13949H. Any additives to a resin system, e.g. fillers, automatically reduce the peel strength even further. Oblivious of this fact, PTFE/woven glass base materials exhibit minimal peel strength values of 1.8 N/mm (10 lbs./in) even with 0.5 oz/ft² (17.5 µm) copper foil. The peel strength issue is not as critical at the stage of pcb manufacture than during rework of the assemblies, when conductors are partially exposed to very high temperatures.

The molecular structure of PTFE is the reason for an extremely low moisture absorption of < 0.02 % of base materials. Microwave laminates made from thermoset resin systems exhibit significantly higher values. Moisture influence upon electrical behaviour (impedance) and also assembly (drying; delamination) is widely documented in the industry and does not require further explanation.

The flammability class UL-V0 plays an important role for commercial applications. PTFE/woven glass base materials meet the required values without any flame retardant. Microwave base materials based on thermoset resins mostly require flame retardants under lowering other properties, e.g. copper peel strength, or do not meet V-0 for thinnest material thicknesses.

Conclusion

PTFE/woven glass base materials are not surrounded by the myth of something exotic anymore. A secured manufacturing and defined processing to pcbs are the guarantors for it. Rapid growth of applications operating at high frequencies demands a material availability with proven performance over many years. These facts are both given with PTFE/woven glass base materials.

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