

A novel halogen free and low Dk/Df laminate material for high frequency application

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Abstract

Halogen free laminate materials had been developed due to the market and RoHS or other environmental directive in past several years. However, high speed and low signal loss requirements are also needed for halogen free material because the application frequency of electronic products also becomes higher and higher. Therefore, the low Dk/Df value should be achieved by the special design for laminate resin. Based on the above background, a novel halogen free and low Dk/Df material, IT-178GD, was developed in ITEQ. The special flame retardants and resin are used in IT-178GD to achieve UL94V-0 and good dielectric property. Its Dk/Df value varies from 4.1/0.008 to 3.9/0.009 with the frequency increased from 1GHz to 10GHz. Except for the above stable dielectric property, IT-178GD has low CTE(50~260℃) about 3.2% and high thermal resistance (higher than 60min for T288), which assures high PCB reliability for IT-178GD. Therefore, IT-178GD is good environment-friendly choice for high speed and low signal loss application in high frequency communication in future.

Introduction

Halogen-free for flame retardant is the future tendency for electronic industry according to the present actions from environmental groups, for example, Greenpeace, and marketing campaign from OEMs/ODMs/EMSs etc. In fact, the marketing share has been higher and higher for halogen-free material in recent years. Besides the marketing motivation, halogen-free materials in the present market have low CTE and high thermal resistance, which is helpful to enlarge its application fields step by step. In addition, Df property can also be

improved comparing to tradition FR-4, owing to high inorganic filler ratio in halogen-free resin system. But the application frequency is mainly limited less than 3GHz~5GHz for present halogen-free materials. Their Dk/Df values measured by Cavity method are about 4.3~4.7/0.010~0.015 (1GHz), which almost can't meet the requirements of high speed and low signal loss in higher frequency than 5GHz~10GHz. This conclusion can be gotten according to the formula shown in Fig.1 and Fig.2^[1]. Moreover, the frequency will become much higher (10GHz~40GHz or above) for communication application in future in order to achieve large and fast data & photo transmission. Cisco, Alcatel IBM and other OEMs emphasized on this tendency for laminate material in past several years. So IT-178GD was developed to meet the above requirements.

$$Tpd = K \times \sqrt{\epsilon_{eff}}$$

Where:

Tpd = Propagation delay in nsec/foot based on the fixed PCB design.

E_{eff} = Effective relative dielectric constant of material

K = Constant

Fig.1

$$\alpha_d = K \times f \times \tan\delta \times \sqrt{\epsilon_{eff}}$$

Where:

A = Attenuation in dB/in

f = Frequency component in GHz

tanδ = Material dissipation factor

E_{eff} = Effective relative dielectric constant of material

K = Constant

Fig.2

Chemical Design in Theory

Low Dk/Df reinforcement and low Dk/Df resin are the general methods used to achieve low Dk/Df properties for laminate material. IT-178GD was designed by use of low Dk/Df resin that is of low polarity for the molecular structure of resin. Of course, some epoxy resin was also added into this resin system to get good impregnation, laminate and PCB processing ability. The resin of low polarity after fully cured has good heat resistance due to much phenyl and alkyl structure in resin molecule structure.

It is well-known that the balance between flame resistance of UL94V-0 and thermal resistance is very difficult to be gotten for halogen free materials. Normally, the flame retardants of phosphorus and nitride element are used to improve the flame resistance of resin system, such as reactive or additive phosphorus flame retardant, reactive or additive nitride flame retardant, or organic phosphorus plus nitride filler, etc. But there are different advantages and disadvantages for these flame retardants. So the selection of flame retardants is very important. The basic designing principle is that the negative effects on thermal resistance, dielectric and mechanical properties of laminate are very low. This principle was embodied in IT-178GD material. Especially, the dielectric properties of resin system were little affected with the flame retardants added including reactive phosphorus resin, nitride resin and inorganic filler. Meanwhile, the excellent thermal resistance and PCB processing ability were kept at the same level for the resin system of IT-178GD.

Characteristics

Experimental instruments

DSC Tg (TA, DSC Q10), TMA CTE/T288 (TA, TMA Q400), Anti-CAF tester (IMV, MIG 8600), Dk/Df tester (Cavity tester), IST tester (PWB Interconnect Solution Inc.), etc.

Laminate Properties

Comparing to the normal halogen-free material IT-150G, IT-178GD has higher Tg, lower Z-CTE and lower moisture absorption besides excellent Dk/Df

property. Therefore, IT-178GD is more suitable for lead-free solder process for multi-layer and high-layer PCB. This view will be validated in the PCB reliability section. The detailed data of laminate are show in Table 1.

Items	Unit	IT-178GD	IT-150G
Type	/	High Tg Halogen-free	Mid Tg Halogen-free
Tg(DSC)	°C	168	155
T288(TMA)	min	>60	>60
Td(5% wt loss)	°C	>350	>350
a1(before Tg)	ppm/°C	31	46
a2(after Tg)	ppm/°C	277	285
Z-CTE(50~260°C)	%	3.2	3.70
Peel Strength(1oz)	Lb/in	7.5	8.8
Moisture absorption (D-23/24)	%	0.13	0.15
288°C solder dipping (PCT 3hr)	min	>10	>10
Flammability	sec	94V-0	94V-0
Test sample: 1.0mm thickness (2116*8ply)			

Table 1

Dielectric Properties

As shown in Fig.3 and Fig.4 for 1.0mm thickness laminate stacked by 2116*8ply, IT-178GD has excellent dielectric properties. Moreover, its Dk/Df value is much lower than IT-150G's. Especially, the stability of Df when frequency increased is better than that of IT-150G. According to the formula in Fig.1 and Fig.2, we can conclude IT-178GD is more suitable for high frequency PCB application because of its low signal propagation delay and low signal transmitting loss at high frequency, especially above 10GHz. It can also meet the tendency of low dielectric property in communication field sponsored by end-user or OEMs, etc. The cavity method follows IPC 2.5.5.13. Its instrument is shown in Fig.5.

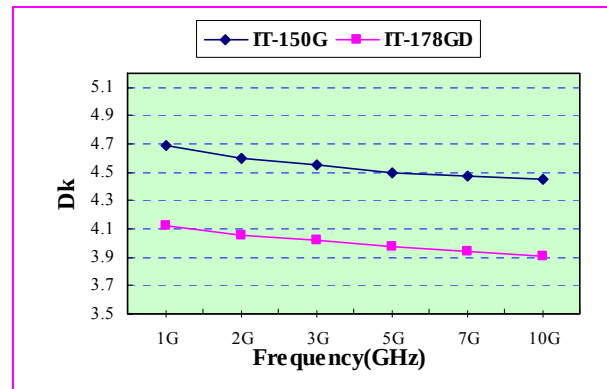


Fig.3

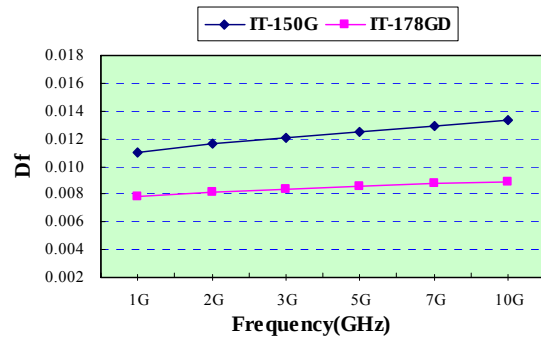


Fig.4



Fig.5

PCB reliability

18 layers PCB was built for IT-178GD's PCB reliability test. It is found that there weren't any defects for reflow (260°C peak temperature) 6cycles and 288°C solder floating test. The stack-up and their PTH micro-sections after reflow or solder floating test are shown in Fig.6, Fig.7 and Fig.8. IST test was done in IST tester (Fig.9) made by PWB Interconnect Solution Inc. It was also demonstrated that IT-178GD has excellent thermal resistance when no any defects were found after IST test shown in Fig.10 and Fig.11. Additionally, Fig.12 shows that IT-178GD is of good Anti-CAF performance contributed by its low moisture absorption and high thermal resistance. However, IT-178GD is a little brittle owing to its low polarity molecular structure. So the special drilling parameters are needed to get good hole-quality. 5~15μm/r for chipload and 5~10 for retract rate/infeed rate ratio were

used in small hole. Moreover, desmear plus plasma treatment was applied to eliminate ICD phenomena and decrease wicking size.

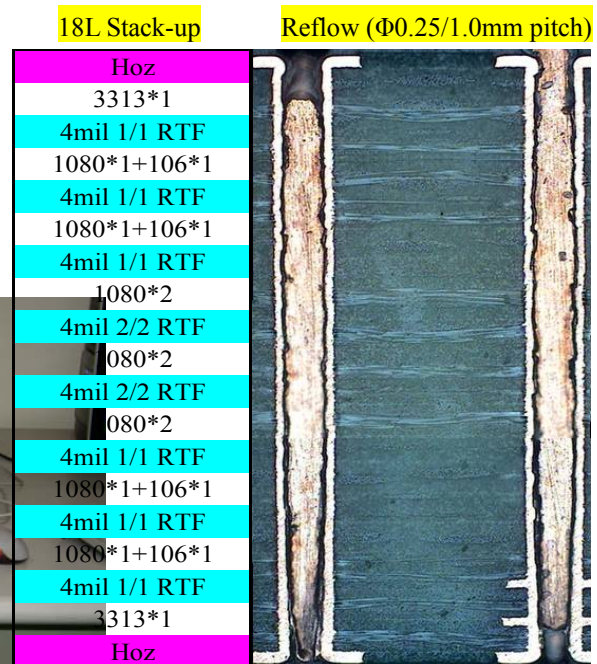


Fig.6

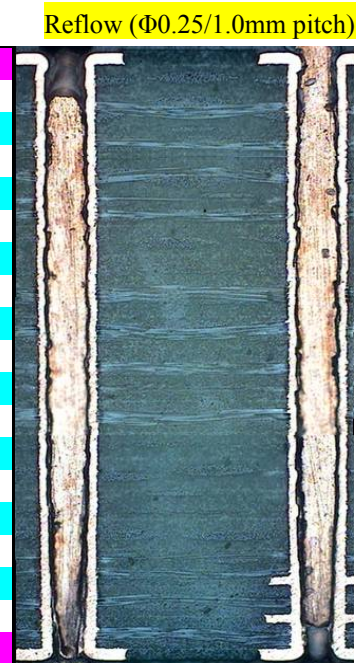


Fig.7 (X100)

Floating (Φ0.25/0.7mm pitch)

IST tester

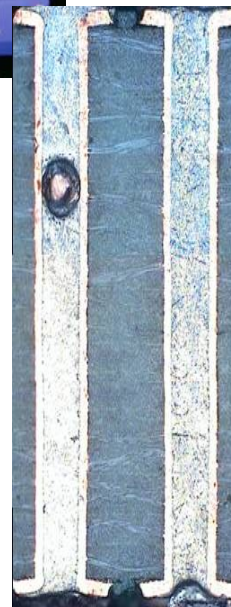


Fig.8 (X100)



Fig.9

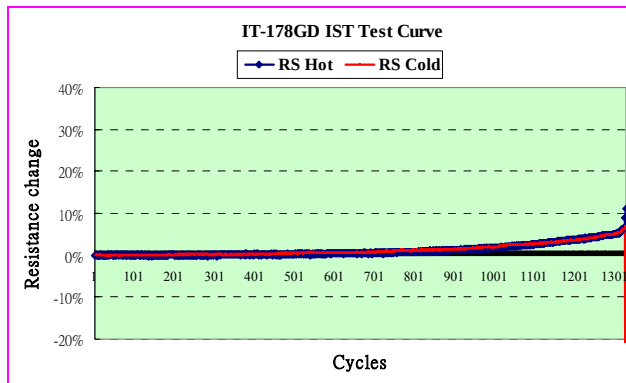
IST test curve (25 $\rightleftharpoons$ 150°C)

Fig.10

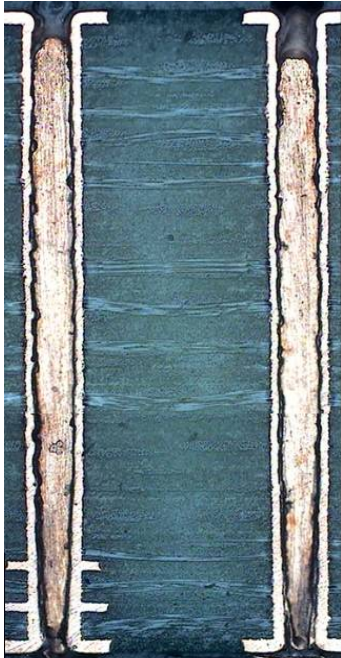
IST micro-section ($\Phi 0.25/1.0\text{mm}$ pitch)

Fig.11 (X100)

loss. Therefore, IT-178GD will be good environment-friendly material for high frequency communication application in soon future.

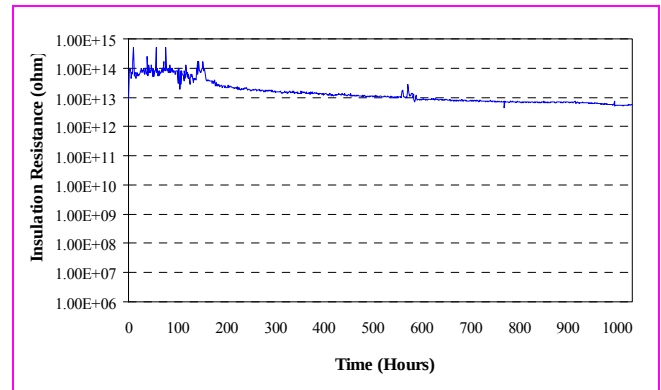
Anti-CAf test ($\Phi 0.25/1.0\text{mm}$ pitch)

Fig.11 (85°C/RH85%/50DV)

Reference

[1] Doug Leys, "Best Materials for 3~6GHz Design", Printed Circuit Design and Manufacture, November 2004.

Summary

In general, we can conclude IT-178GD has excellent performances, especially dielectric properties, according to the above experimental results. The application frequency is limited for present halogen free materials. However, IT-178GD can conquer this disadvantage. IT-178GD can pass many kinds of thermal resistance test, such as reflow 6cycles, 288°C solder floating, IST and Anti-CAF test, etc. These results show IT-178GD can meet the requirements of lead-free solder process. Moreover, it can achieve high signal propagating speed and low signal transmitting