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Environmentally Friendly Low Transmission Loss Base/Multilayer Materials

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Abstract
The frequencies used to communicate and process information have been extended beyond the GHz band to the microwave band to handle the growing volume of data. Moreover, increasing global interest in environment protection is calling for base materials for printed wiring boards (PWBs) that can be based on restriction of the use of certain hazardous substances. We have developed new low- transmission-loss multilayer materials that have extremely low flammability without using any halogenated compounds.

The original resin modification, resin formulation, and flame retardant system techniques have enabled us to produce these new base materials having good dielectric characteristics (lower dielectric constants and dissipation factors), good flame retardancy, and high heat resistance. They will meet the requirement of high temperature soldering process using lead-free solder.

Introduction

Higher frequency of the signals used in information processing is accelerating in recent years with the development of the overall information communication technology. The base material for PWBs used in these fields is requires improvements its dielectric characteristics to achieve the reduction of delay time of signal propagation and transmission losses. Moreover, global environment problems such as global warming and acid rain have emerged as a latest trend; and the consciousness of environment protection is increasing on a global scale. As the EU directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) is enacted this will call for environmentally friendly base materials for PWBs.

This report describes new resin systems that have good dielectric characteristics (lower dielectric constants (Dk) and dissipation factors (Df)) without using halogenated compounds and are suitable for PWBs meeting high-speed communication and the high temperature soldering process using lead-free solder.

Development Concept

A base resin having polar groups causes its dipoles to polarize. The dipoles will repeat alternate polarization at extremely high speeds depending on the frequency. In this case, the friction by molecular motion generates heat and increases dissipation factor. Since base materials for high frequency will generate greater heat, they are required to have higher glass transition temperature (Tg) and better heat resistance. In order to make base materials nonflammable with halogen-free compounds, metal hydroxides are added as the filler, or the phosphorus compounds of phosphate esters are used as the flame retardant in general. However, problems are that metal hydroxides will structurally worsen the dielectric property and that phosphate esters are plasticizers and will deteriorate the heat resistance remarkably.

We have attempted to control both the flammability and the deterioration of heat resistance by adopting originally designed new resins having good heat resistance (high Tg) and dielectric properties (low Dk and Df).

Experimental

Preparation of Cured Resin and Laminate

The cured resin was prepared by casting the resin solution onto a PET film, drying it, rubbing it off into B-stage resin powders, and then pressing the powders into 1.0-mm-thick specimens using a PTFE spacer. The copper clad laminate was made by impregnating the resin solution into glass fabrics, drying them to get prepregs, and pressing them against copper foils. The pressing and curing conditions are 180°C/90min and 230°C/2h, respectively.

Properties of the Cured Resin

The dielectric properties of the cured resins were measured at 1 GHz with an impedance material analyzer based on IPC-TM-650. The transmission loss of the laminates up to 10 GHz at 25°C was evaluated by the triplate line resonator method on the wiring board specimens (dielectric thickness: 0.8 mm, copper foil: 18 µm thick, signal line width: 1 mm, characteristic impedance Z_o: 50 Ω) using a vector-type network analyzer. The Dk and Df were calculated on the basis of the attenuation curves (S21) of the transmission lines [1].

Tg of the cured resins was measured with a thermomechnical analyzer (TMA). The storage elastic modulus (E') measured with a dynamic viscoelastic analyzer (DVE).

Molecular Design of the Low-Df Resin System

The dielectric property of a resin depends on its molecular structure. To attain low dielectric constants, we examined several methods, i.e., atoms of poorer molar polarizability per molecular volume were introduced, polarity was reduced, high structure was introduced, or water absorption was reduced. When there is a polar group like a hydroxyl group in the structure, the dielectric property was especially lowered. The dielectric properties of olefin materials are good due to their structures.

We then began to use a modified low-dielectric polymer having straight-chain olefins and two kinds of functional groups as the base resin. Figure 1 shows the outline of structure of the polymer. The polymer showed good dielectric characteristics of Dk: 2.6 and Df: 0.001 (1 GHz). The two kinds of functional groups, Y and Z, are both thermosetting ones. The features are that, when these functional groups react with other resins, the low dielectric disincentive, -OH, is not formed and that the heat resistance can be improved when reacted with other resins. A Nitrogen atom was also introduced in the functional group Z and the resin became more heat resistant and flame retardant than the unmodified resin. This modified low-dielectric polymer is soluble in most solvents and can be easily changed into varnish.

So far, it has been made clear that the modified cyanate ester (CE) resin will improve the dielectric property of the cured resin[2-7]. We then made the modified cyanate ester resin react with the modified low dielectric polymer (Figure 2). Table 1 shows the physical properties of the cured resins with different combination of the two modified polymer. For the cured resins with modified low dielectric polymers, the Dk was improved from 3.02 to 2.72-2.88. In addition, the Tg was found to change with the amount of the modified low-dielectric polymer and the functional groups Y and Z. Tg was in the temperature range of 170^{o}C to 214^{o}C. It was found that both low dielectric constant and high Tg can be achieved by increasing the functional group Z. Moreover, it is possible to add necessary adhesion properties for base materials by using both the functional groups X and Z.

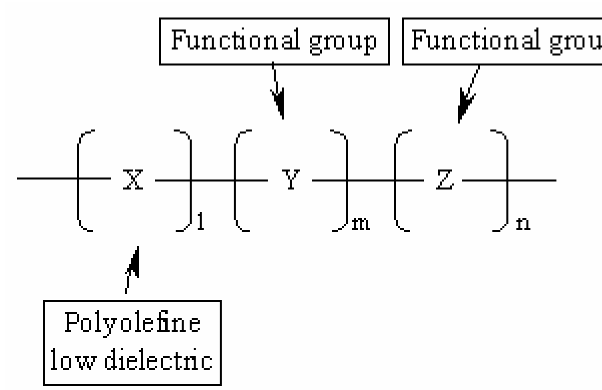

Figure 1 - Structure of Modified Low Dielectric Polymer

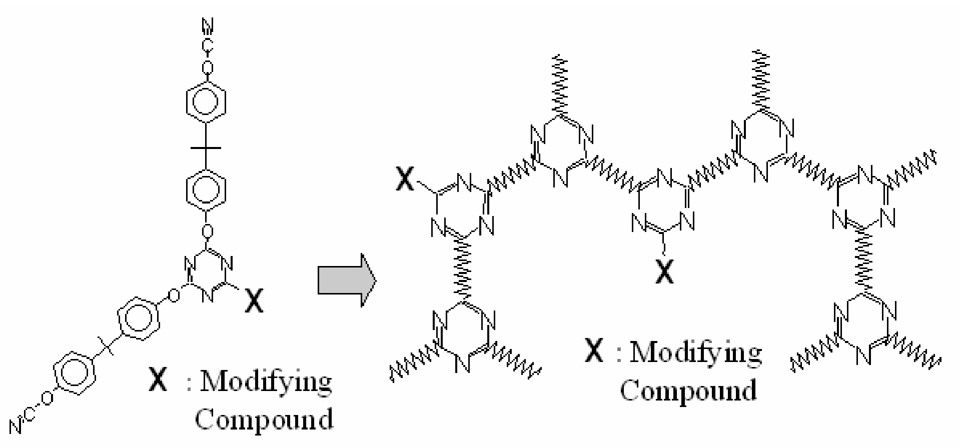

Figure 2 –Structure of Modified Trimmer and Cross-Links

Table 1 - Physical Properties of Cured Resins

	(I) (mol%)			(I)/(II)	Dk	Tg
	X	Y	Z	conc. (wt%)	(1 GHz)	(TMA,^{o}C)
01	75	25	0	33.3	2.75	180
02	75	25	0	50.0	2.72	170
03	75	18	7	50.0	2.77	180
04	75	8	17	50.0	2.82	185
05	75	0	25	20.0	2.88	194
06	75	0	25	33.3	2.85	205
07	75	0	25	50.0	2.82	214
08	87	0	13	50.0	2.79	179
09	92	0	8	50.0	2.75	166
ref.	-	-	-	none	3.02	201

(I): The modified low-dielectric polymer
(II): The modified CE resin

So, we selected (I) the modified low dielectric polymer, (II) modified CE resin, and (III) the thermosetting resin C which reacts with functional groups X and Z (Figure 3). Figure 4 shows the viscoelasticity spectra of the cured resins. The combination (I) + (II) + (III) had the same level of heat resistance as the combination (II)+(III). Figure 5 shows the dielectric characteristic of the cured resins of (I)+(II)+(III) combination. Dk and Df improved with the amount of (I).

We consider that it would be possible to maintain the performance needed for base materials and improve dielectric characteristic by controlling the amount of (I) in the (I)+(II)+(III) combination.

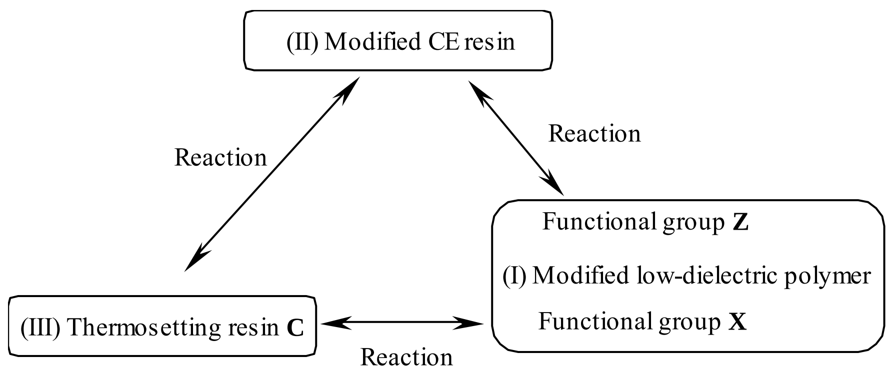

Figure 3 - Formulation Design of Cured Resin

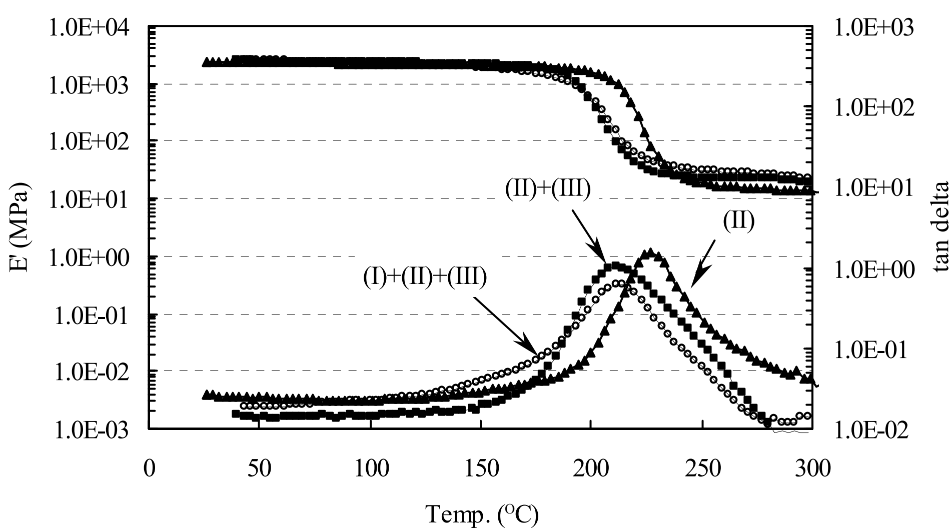

Figure 4 - Dynamic Viscoelastic Spectra of Cured Resins

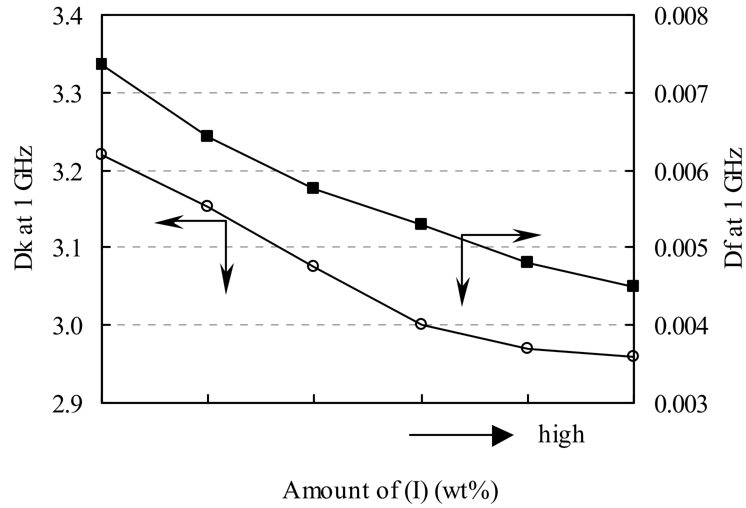

Figure 5 - Dielectric Characteristic of Cured Resin

Flame Retardant System for Lower Df

In order to make base materials nonflammable without using halogenated compounds, there are two techniques of adding metal hydroxides or phosphorus compounds of phosphate esters. Figure 6 shows the dielectric characteristics of the laminate produced by compounding aluminum hydroxide in the resin system. The Dk and Df increased with metal hydroxide amount. The flammability level (UL94) was V-1 at 125 phr, requiring a larger amount of metal hydroxide to attain V-0. Addition of metal hydroxides cannot be adopted for high-frequence-use materials.

We then selected a new halogen-free flame retardant compound with good heat resistance, which will not degrade dielectric characteristics. This flame retardant compound features a high thermal decomposition temperature and is added as a filler. Figure 7 shows the dielectric characteristics of the laminate produced by adding this flame retardant compound to the resin system. Increasing the amount did not affect the Dk and Df remarkably. The flammability achieved V-0 at 20 phr. Figure 8 shows the relationship between the amount of the new flame retardant compound and Tg. As the conventional condensed phosphate ester retardant increased, the Tg lowered remarkably, but the flammability was still insufficient. For the new flame retardant, flammability level V-0 was achieved with only a slight lowering of Tg.

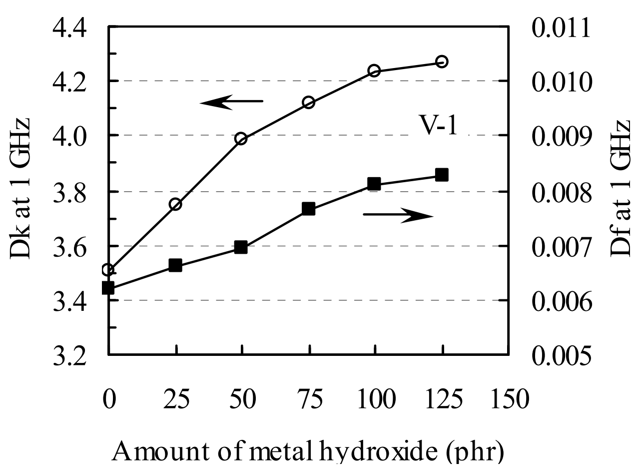

Figure 6 - Dielectric Characteristic of the Laminate with Aluminum Hydroxide

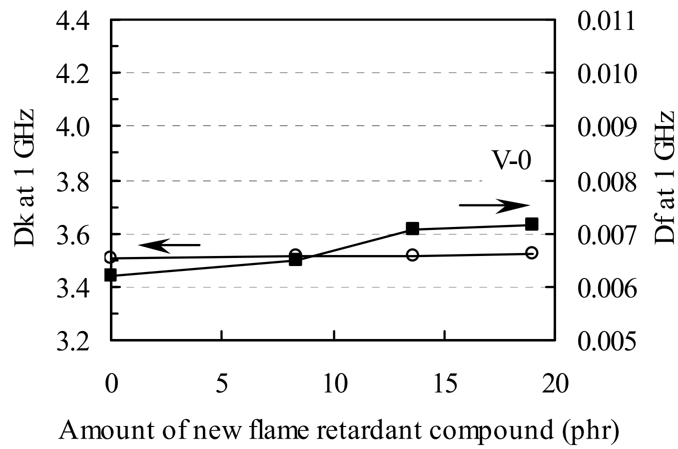

Figure 7 - Dielectric Characteristic of the Laminate With a New Flame Retardant Compound

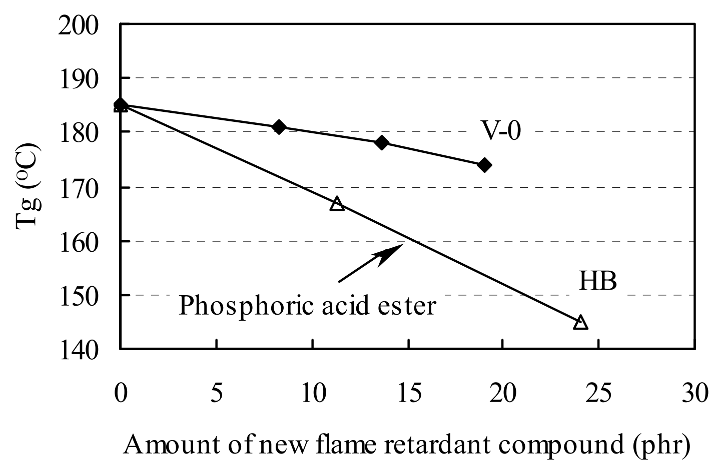

Figure 8 – Tg of the Cured Resin With New Flame Retardant Compound

Characteristics of New Materials

Two types of halogen-free low-transmission-loss multilayer materials were developed by combining the resin modification techniques, resin formulation techniques and flame retardant techniques described in this study. One is the standard type based on the low dielectric epoxy resin and the other is the low-Df type based on the new low-Df resin, both containing the new flame retardant system. Table 2 shows the general properties of the new laminates using E-glass fabrics.

The Dk and Df of these laminates were calculated from the transmission loss. The standard-type realized Dk of 3.87 and Df of 0.0120 at 1 GHz; Df is about half that of the conventional FR-4. The low-Df type achieved Dk of 3.60 and Df of 0.0060 at 1 GHz; Df is about one-fourth that of the conventional FR-4.

The new laminates are characterized by a Tg as high as 170°C. The copper peel strength was satisfactory for practical use. Moreover, they had a better solder resistance and a lower water absorption than the FR-4. They showed satisfactory flammability (UL94V-0) without using halogenated compounds.

Table 2 - General Properties of the New Laminates

Items	Cond.	Unit	New Materials		FR-4
			Standard type	Low-Df type	
Glass fabric type	-	-	E	E	E
Dielectric constant (Dk)*1	1 GHz	-	3.87	3.65	4.20
	3 GHz	-	3.84	3.64	4.10
Dissipation factor (Df)*1	1 GHz	-	0.0120	0.0060	0.0215
	3 GHz	-	0.0130	0.0073	0.0230
Copper peel strength (18 µm)	Standard (Rz:7-9 µm)	kN/m	1.3	1.0	1.5
	VLP (Rz:2-3 µm)		1.1	0.8	1.3
Tg	TMA	^oC	171	173	130
CTE	X1 (<Tg)	ppm/^oC	16	17	16
	Z1 (<Tg)		43	45	60
	Z2 (>Tg)		300	280	282
Heat resistance	260^oC/20 s Dipping*2	-	PCT-6h	PCT-6h	PCT-3h
	288^oC/10 s float	-	10 cycle OK	10 cycle OK	-
	T-288*3	min	< 5 min	> 30 min	< 5 min
Water absorption	C-168/40/90	wt%	0.30	0.25	0.43
CAF restraining property*4	-	h	>1000	>1000	>1000
TH wall roughness after drilling*5	-	µm	10-20	10-20	15-25
Flame retardancy	UL-94	-	V-0 Halogen-free	V-0 Halogen-free	V-0 Halogen

*1: Measured by the triplate-line resonator method using a network analyzer (25^oC)
*2: Moisture treatment condition, PCT(121^oC/0.22 MPa)
*3: Time to delamination at 288^oC (IPC-TM650 2.4.24.1)
*4: TH/TH wall thickness, 0.3 mm; Condition, 85^oC/85%RH/100 V dc
*5: 80,000 rpm, 2.40 mm/min, 10,000 hits

Dielectric Properties of New Materials

Properties at High Frequency

Figure 9 shows the transmission loss of the laminates. The new laminates showed lower transmission losses. For example, the loss at 3 GHz was 8.9 dB/m for the standard-type and was 5.4 dB/m for the low-Df type. The standard-type was able to reduce the transmission loss by about 3 dB/m compared with the conventional FR-4; the low-Df type by 7.23 dB/m.

Figures 10 and 11 are the calculated results of Dk and Df. The new laminates proved a slightly less frequency dependent. Water absorption was also less for the new laminates.

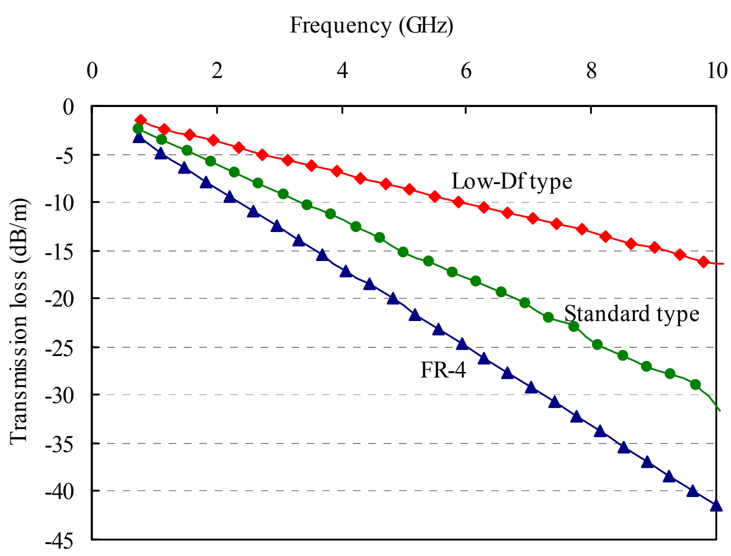

Figure 9 - Transmission Loss of the Laminates at High Frequencies Up to 10GHz

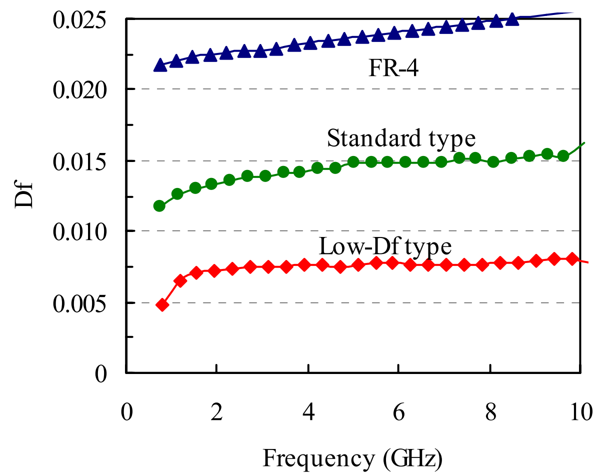

Figure 10 - Dielectric Constant of the Laminate at High Frequencies Up to 10GHz

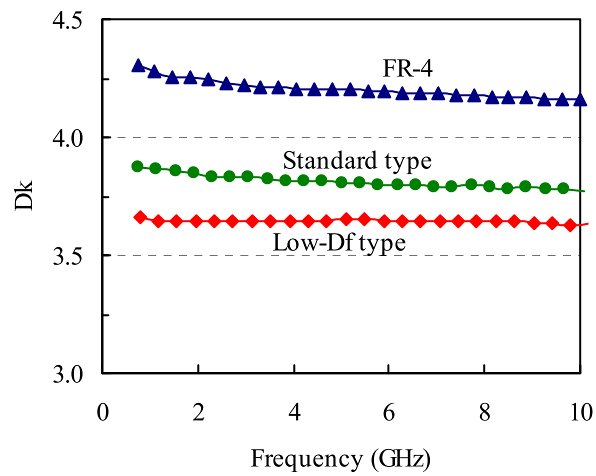

Figure 11- Dissipation Factor of the Laminate at High Frequencies Up to 10GHz

Simulation of Eye Pattern

Simulation of the eye pattern was carried out by S-parameter measurement with the network analyzer. The strip line parameters used were as follows: copper foil thickness, 18 µm; Z_o, 50 Ω; signal line width, 64-77 µm; dielectric thickness, 0.1 mm; and line length, 500 mm. Figure 12 shows the simulation results of the eye pattern of 5 Gbps (2.5 GHz) incoming-signal speed. The opening Tx and Vy of both the new laminates were better than those of the FR-4, demonstrating that these new laminates are reliable materials for good transmission.

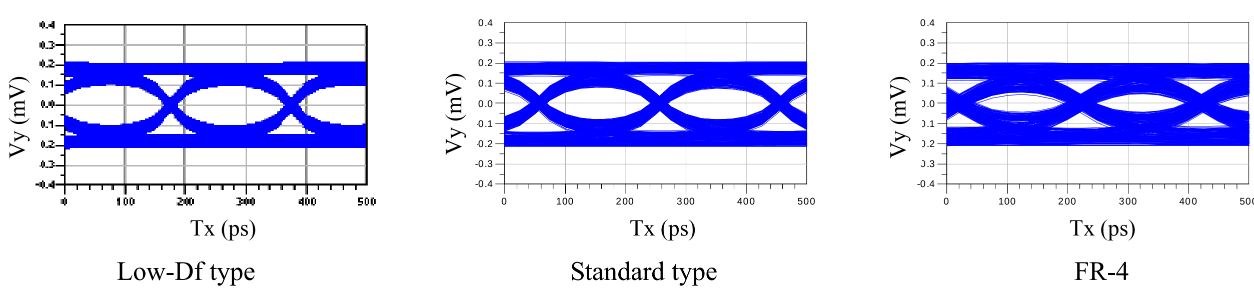

Figure 12 – Simulation Results of the Eye Pattern (5 Gbps)

Heat Resistance
No abnormality was detected in the new laminates after being subjected 10 times to a 10 s float on 288 ^oC solder. Moreover, low-Df type withstood the T-288 test (IPC-TM650 2.4.24.1) for more than 30 min. We concluded that these materials will meet the requirement of the high temperature soldering process using lead-free solder.

Processability of Multilayer Lamination
The process ability for multilayer lamination of both the new prepregs was almost the same as that of the FR-4 prepreg. In the theological viscosity-temperature profile, the low-Df prepreg showed a little higher melting viscosity than the FR-4 prepreg, but the viscosity rose relatively slowly toward curing. Therefore, the former showed the same ability as the latter in filling into inner layer patterns, demonstrating even a better accuracy in dielectric thickness.

Insulation Reliability
The ability to withstand ionic migration, or the resistance against conductive anodic filaments (CAF), was evaluated by monitoring the insulation resistance between through-holes with 0.3-mm-thick wall under 100 V dc application in a85^oC/85%RH atmosphere. The new laminates did not breakdown till after 1000 h, exhibiting good endurance against ionic migration (Table 2).

Drilling Processability
The drilling process ability of these new laminates was satisfactory. The roughness of the through-hole wall was measured from the cross-sectional photos. The wall roughness of both the new laminates was 70-80% that of the FR-4 (Table 2).

Conclusion
We have developed new base resins having Tg as high as 170 ^oC to meet the high temperature soldering process using lead-free solder, and lower Dk and Df to meet the higher frequency communication. The resin consists of (I) a modified low-dielectric polymer, (II) modified cyanate ester resin and (III) a reactant thermosetting resin. In the (I) + (II) + (III) combination, (I) can improve dielectric characteristics without lowering the overall heat resistance.

A new flame retardant compound other than metal hydroxides or phosphoric acid esters has been adopted which features high thermal decomposition temperature and will help the base resin to achieve V-0 at little addition without degrading dielectric characteristics and heat resistance.

The E-glass fabric laminate produced with the new resin systems proved to have satisfactory performance including process abilities, and better heat resistance as well as lower Dk and Df than the conventional FR-4, resulting in lower transmission losses in the microwave band.

Note: *The contents of this report are based on the results of experiments and do not represent a guarantee of the values for each property.*

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Hitachi Chemical

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Outline

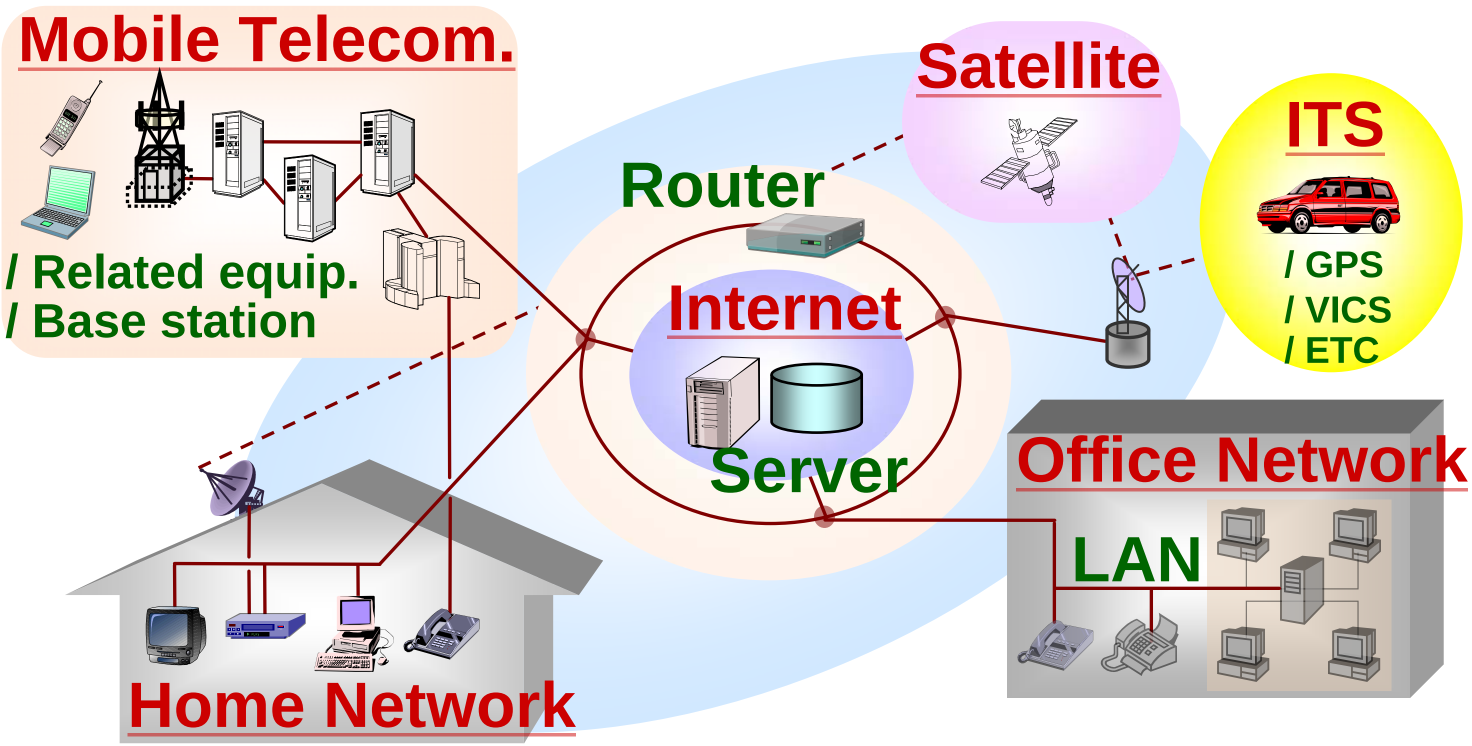
- Introduction
- Molecular Design of the Low-Df Resin System
- Flame Retardant System for Lower Df
- Characteristics of New Materials
  - / Dielectric Properties at High Frequency
  - / Laminate Characteristics
- Summary

Background ; Advanced Telecommunications

- To reduce transmission loss, **low dielectric constant (Dk)** and **dissipation factor (Df)** materials have been required.

Transmission loss ($\mathbf{a}$) = Conductor ($\mathbf{a}c$) + Dielectric ($\mathbf{a}d$)

$$ac \propto \sqrt{f} \quad , \quad ad \propto f \times (\sqrt{Dk} \times Df)$$



Background ; Global Environment Problems

- Increasing global interest in environment protection
- Strengthening of global regulation of hazardous substances

  - Waste electrical and electronic equipment (WWWE)
  - Restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)

    (to be in July 2006)

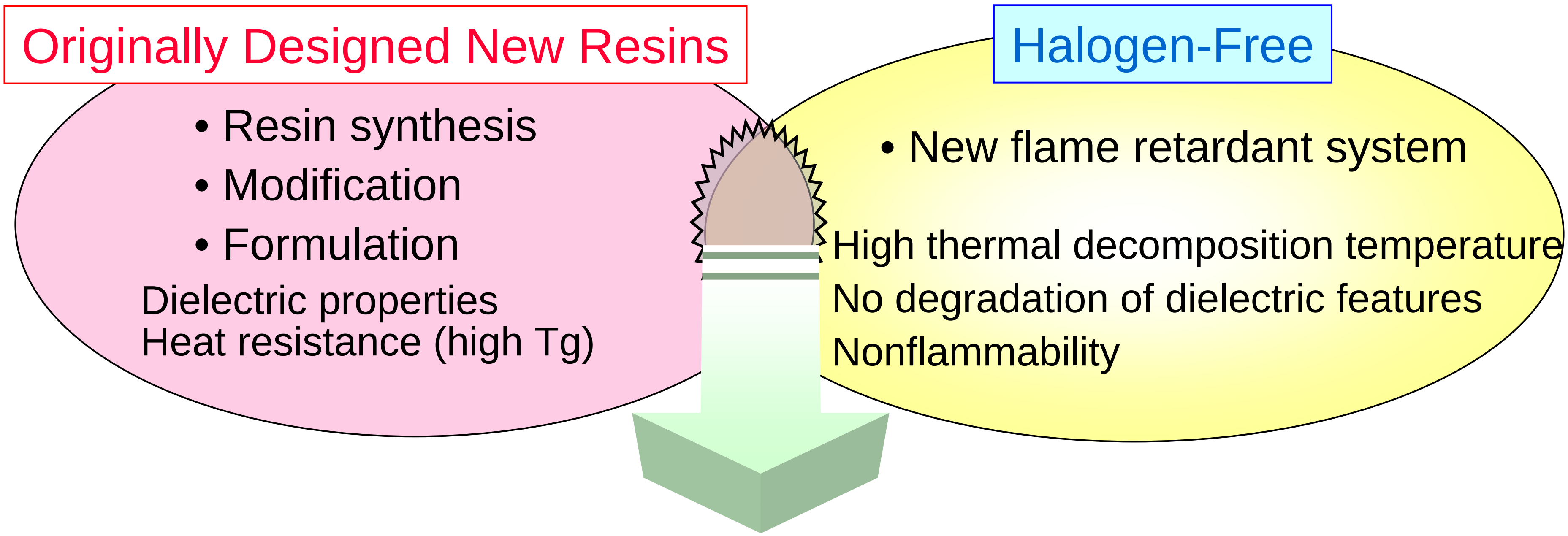
- Proper treatment of the components containing halogenated compounds
- Prohibition of use of lead, chromium (VI) compounds, mercury, and halogenated compounds (PBDE, PBB)

Halogen-free (halogen-free flame retardant system)

Soldering process using lead-free solder (at high temperature)

Development Concept of New Base Materials

Low Dk and Df, Halogen-free, high heat resistance materials have been required.

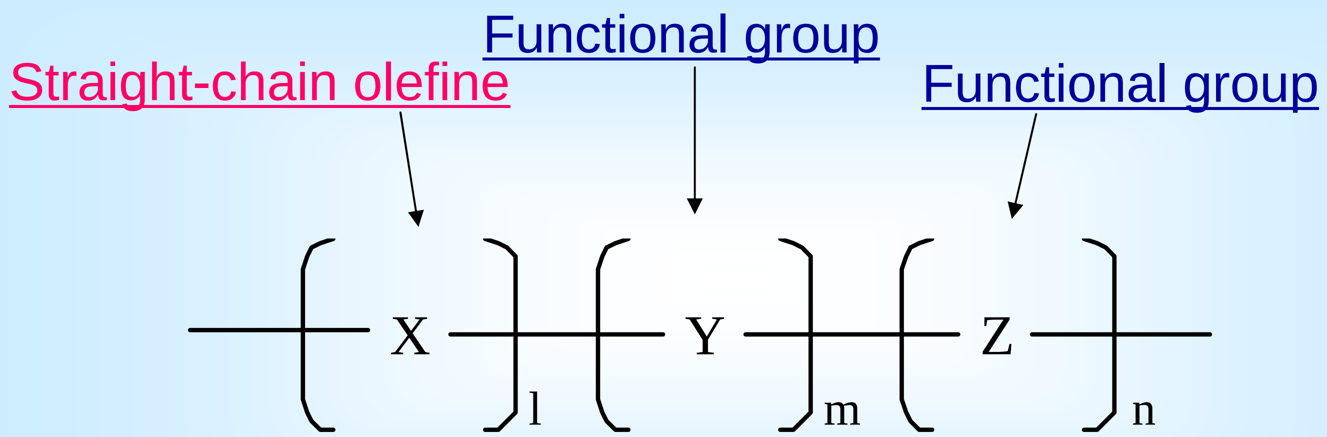


Two types of halogen-free low-transmission-loss materials

- Moderate dielectric properties and high heat resistance
- Superior dielectric properties and high heat resistance

Base Resin (I) Modified Low-Dk, Df Polymer

- Selection of a modified low-Dk, Df polymer



Outline of the structure of the modified low-Dk, Df polymer

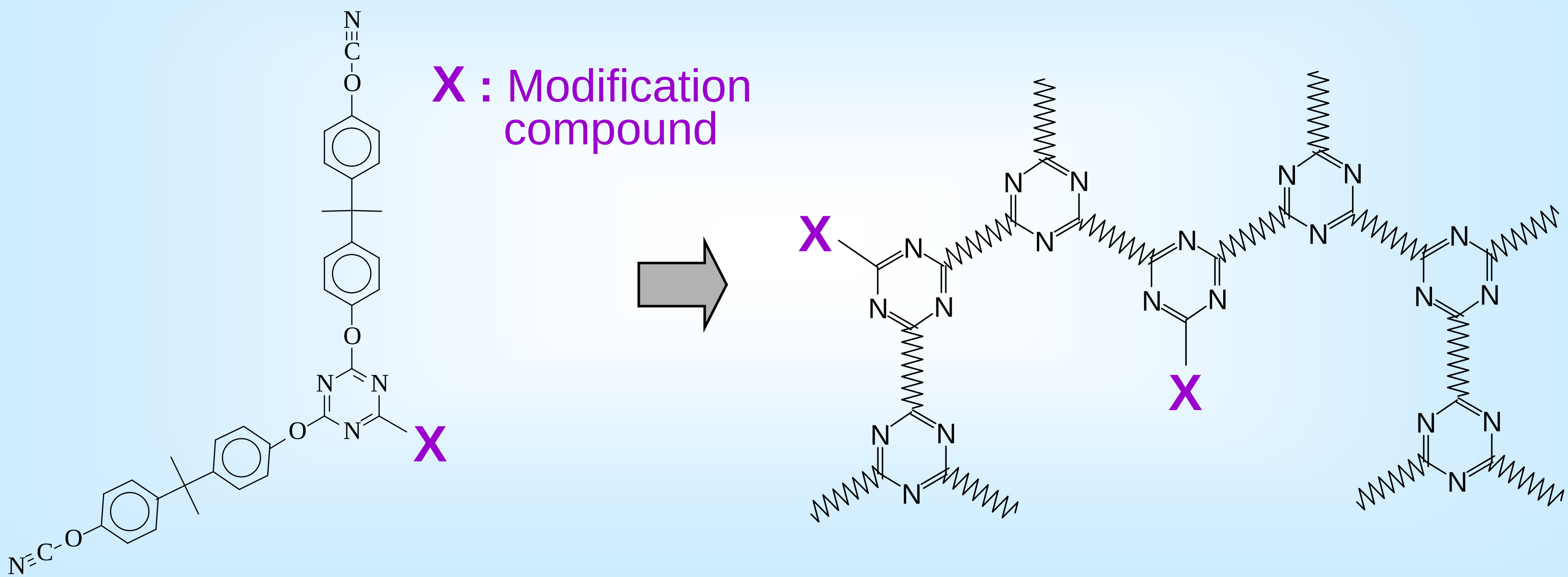
Feature

Dk: 2.6, Df: 0.001 (1GHz) ; Effect of straight-chain olefines
Both the functional groups,Y and Z, are thermosetting.
Hydroxyls (-OH) are not formed.
Nitorogen atom is introduced in group Z.
(for heat resistance and flame retardancy)

Base Resin (II) Modified Cyanate Ester Resin

- A modifying compound is incorporated in a triazine ring, building a loose cross-link structure.

Modified trimer | **Modified cured resin**



Reaction rate of -OCN increases. (Cyclotrimerization rate increases.)

Larger molecular chain between cross-linking points
⇒ Flexible and less brittle

Dielectric Properties of Modified CE Resin

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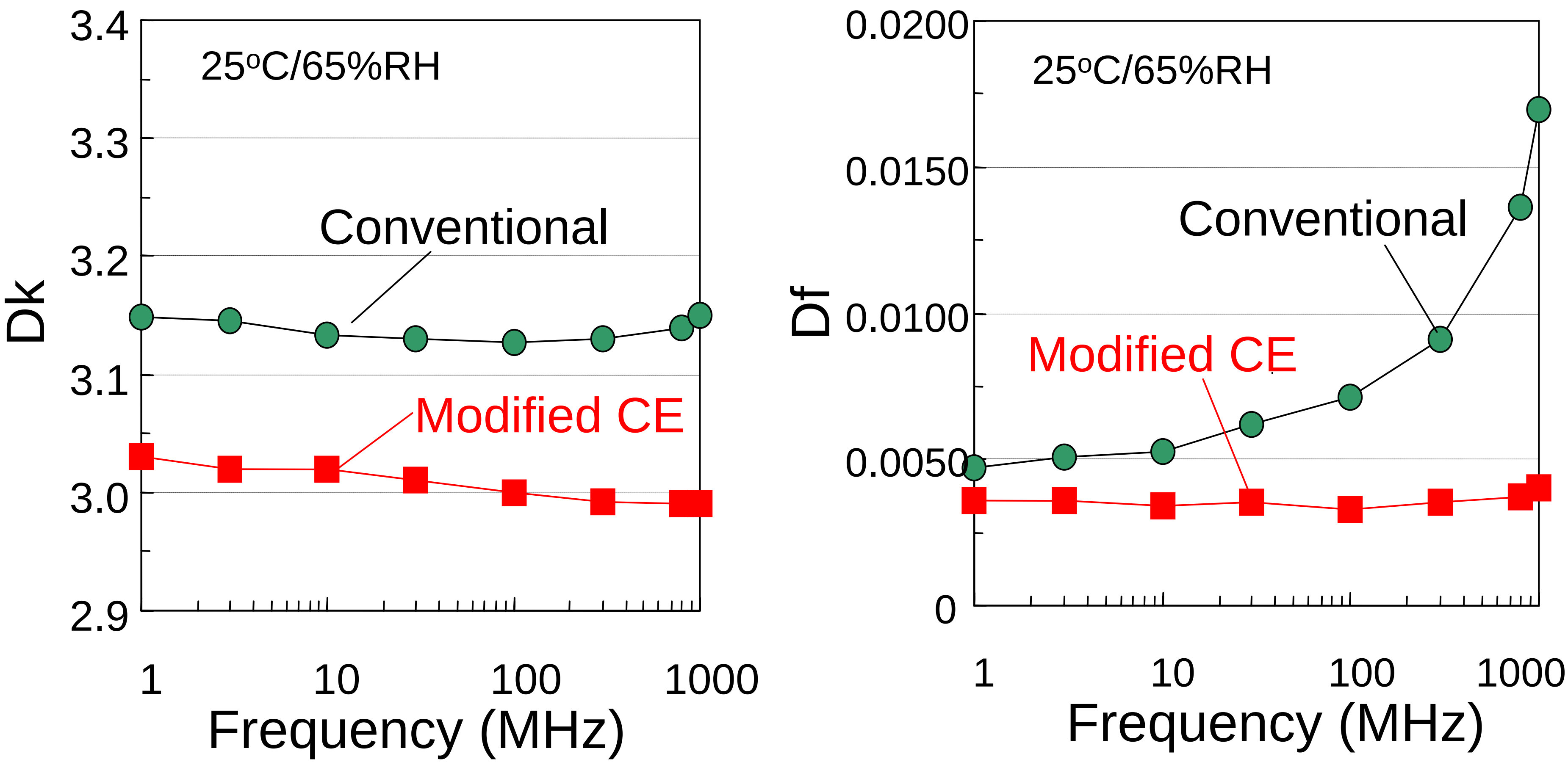


This modifying technique is effective in lowering Dk and Df.

Combination of Two Modified Polymers

Physical properties of cured resins

	(I) (mol%)			(I)/(II)	Dk	Tg	Adhesive
	X	Y	Z	conc. (wt%)	(1 GHz)	(TMA, ^{o}C)	strength
01	75	25	0	33.3	2.75	180	poor
02	75	25	0	50.0	2.72	170	poor
03	75	18	7	50.0	2.77	180	poor
04	75	8	17	50.0	2.82	185	poor
05	75	0	25	20.0	2.88	194	poor
06	75	0	25	33.3	2.85	205	poor
07	75	0	25	50.0	2.82	214	poor
08	87	0	13	50.0	2.79	179	poor
09	92	0	8	50.0	2.75	166	poor
ref.	-	-	-	none	3.02	201	good

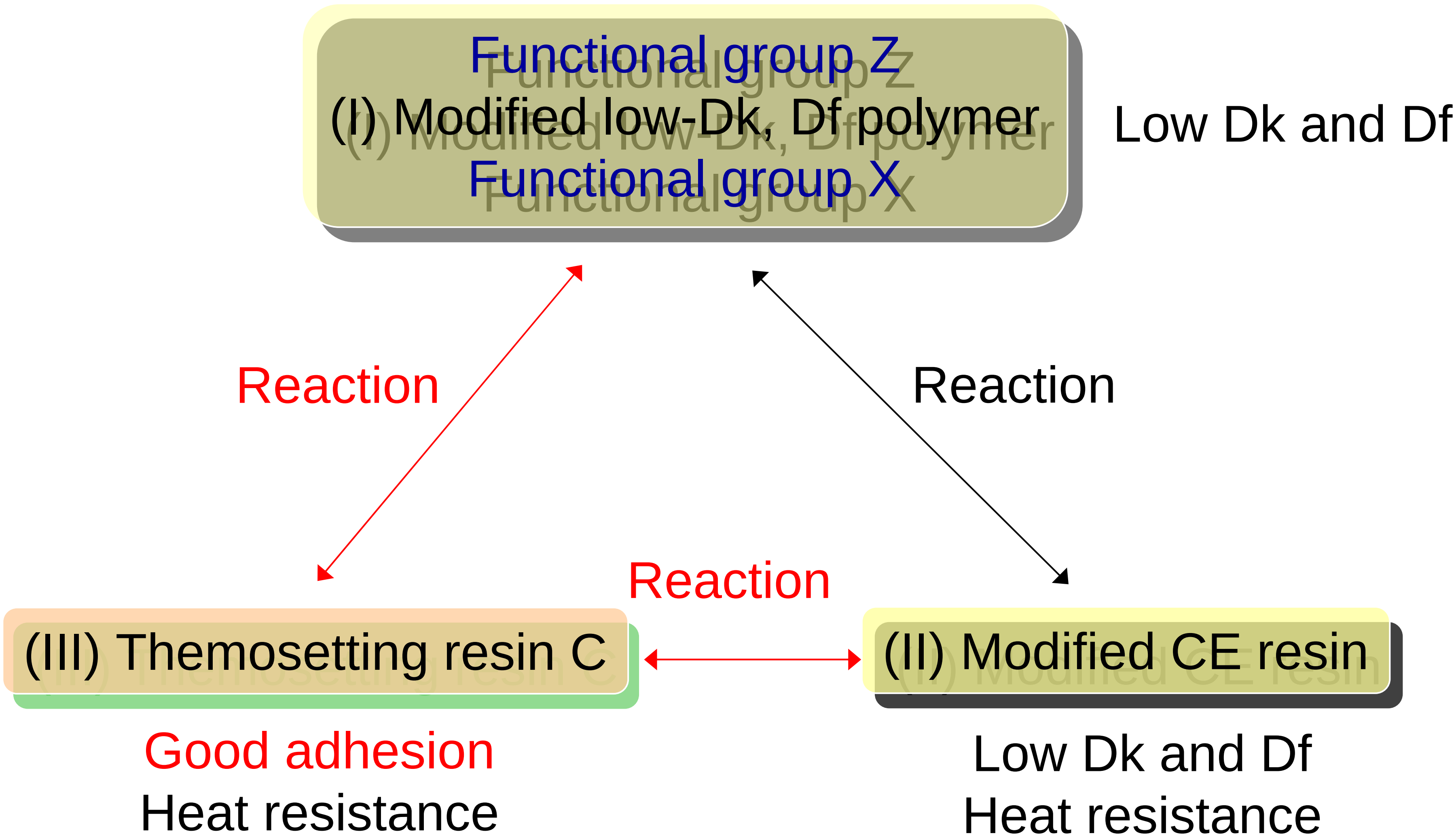
(I): Modified low-Dk, Df polymer
(II): Modified CE resin

Dk and Tg will vary with the amounts of the modified low-Dk, Df polymer and the functional groups Y and Z.

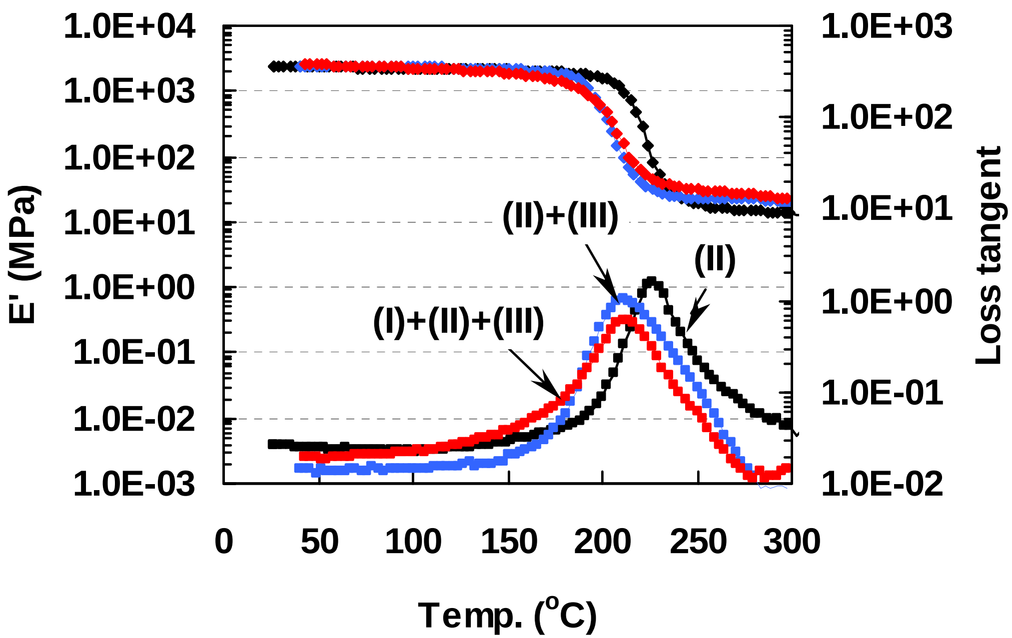
Dk: 3.02 → 2.72-2.88 Tg: 170-214^{o}C

Next problem to be solved is the degradation of adhesive strength.

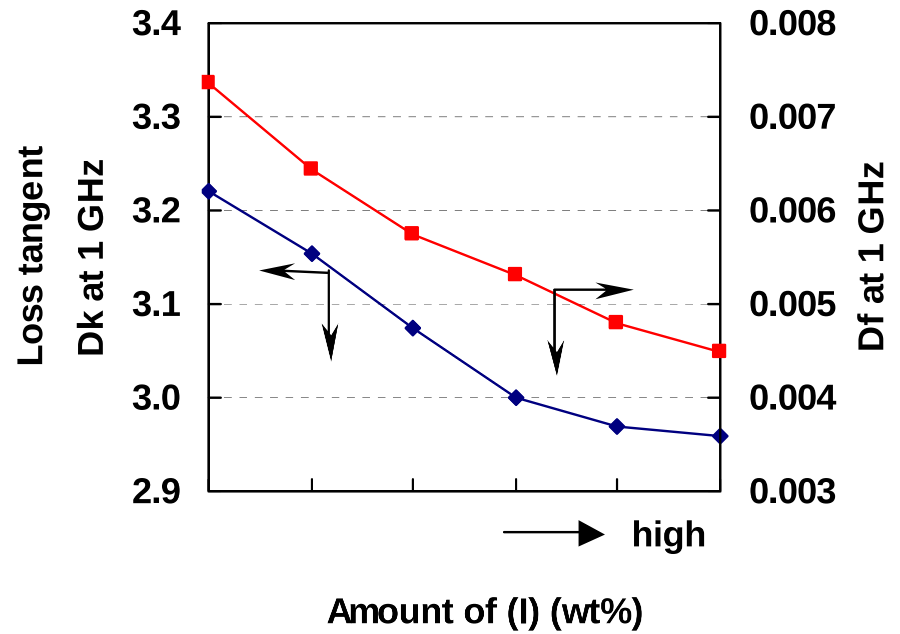
Formulation Design of Cured Resin



Characteristics of Cured Resin



Dynamic viscoelastic spectra of cured resins



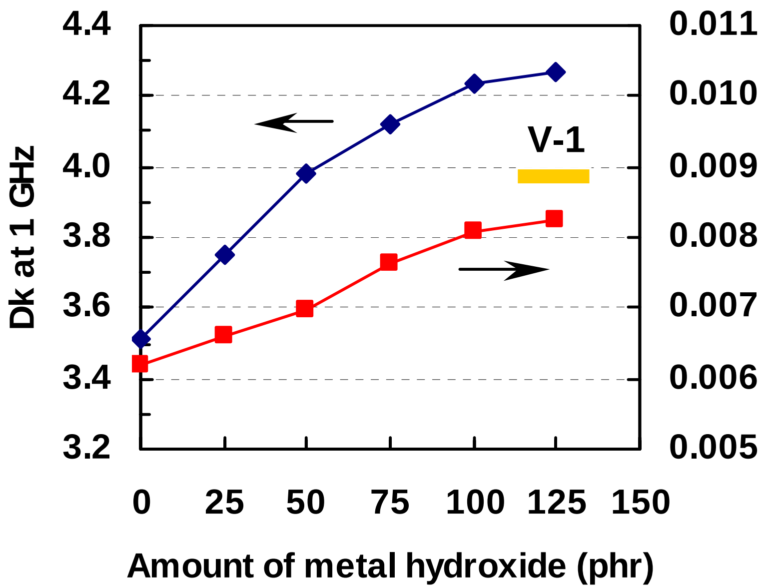
Dielectric characteristics of cured resins

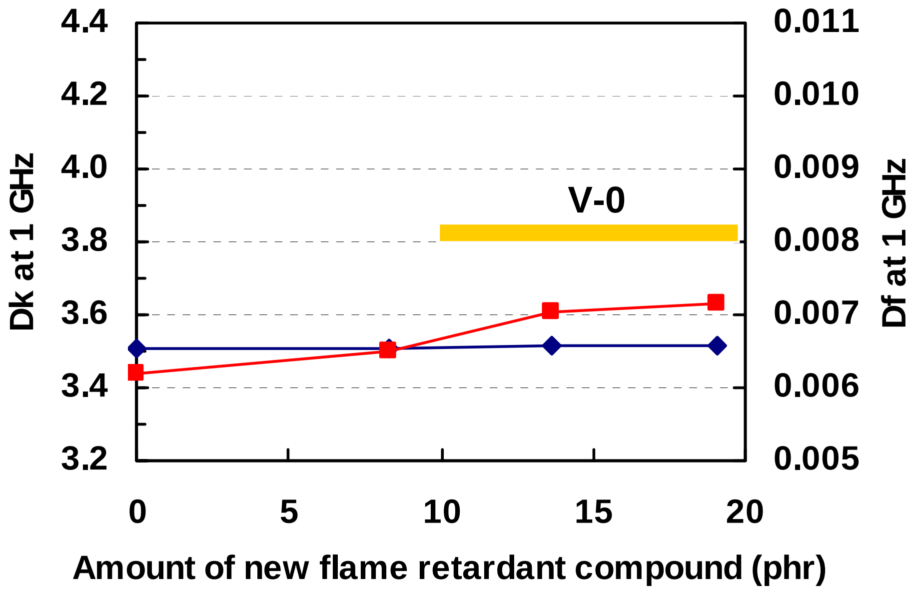
- Heat resistance (Tg) is practically constant.
- Dielectric properties will improve with the amount of the modified low-Dk, Df polymer.

Flame Retardant System for Lower Df

Selection of a new halogen-free flame retardant system

Features; • High thermal decomposition temperature (>320°C)
• Applicable in filler form
• Slighter degradation of dielectric features and nonflammability than metal hydroxides
• Slighter lowering of Tg than phosphate esters





Dielectric characteristics of the laminate with flame retardants

Characteristic of Laminates with Flame Retardant

Item	Cond.	Unit	cf.	#1	#2	#3
Base resin	-	-	Originally designed new resins			
Flame retardant	-	-	-	Aluminum hydroxide	Phosphoric acid esters	New
Tg	TMA	^{o}C	185	150	145	174
Dielectric constant (Dk)	1GHz	-	3.5	4.3	3.5	3.5
Dissipation factor (Df)	1GHz	-	0.006	0.008	0.007	0.007
Copper peel strength	18 μm	kN/m	1.2	1.0	1.0	1.0
Flame retardancy	UL-94		HB	V-1	HB	V-0

Low Dk and Df is compatible with high heat resistance and halogen-free by use of originally designed new resins and a new flame retardant system.

General Properties of the New Laminates

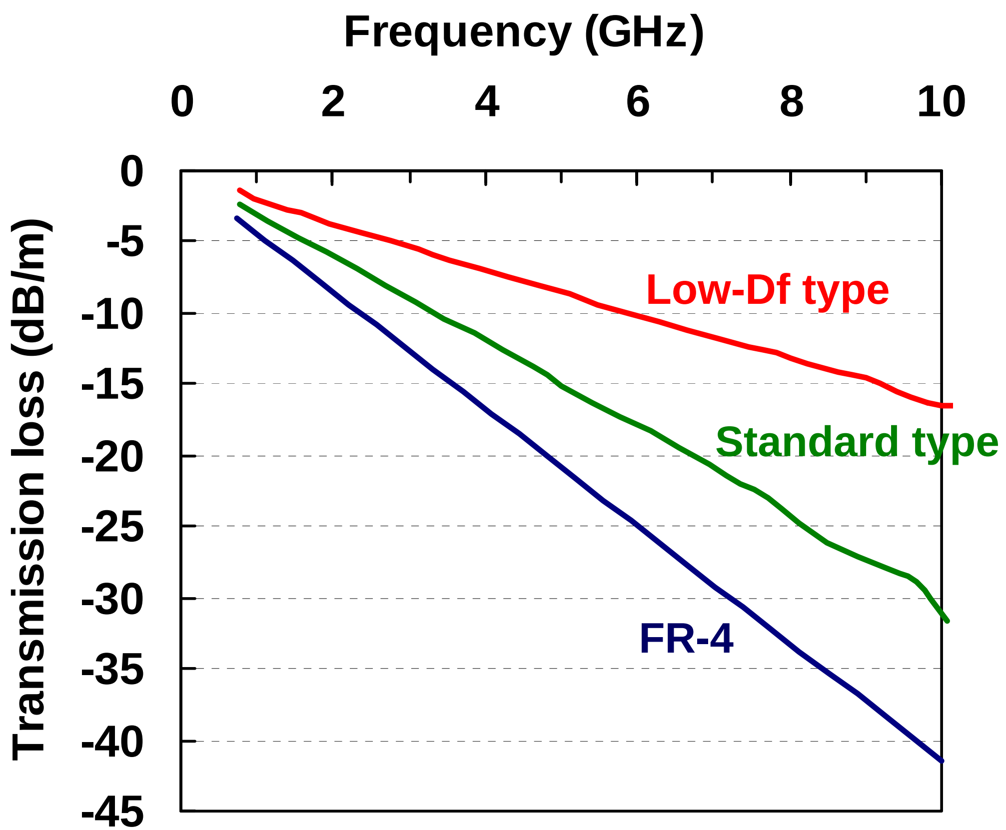
Items	Cond.	Unit	New Materials		FR-4
			Standard type	Low-Df type	
Glass fabric type	-	-	E	E	E
Dielectric constant (Dk)*1	1 GHz	-	3.87	3.65	4.20
	3 GHz	-	3.84	3.64	4.10
Dissipation factor (Df)*1	1 GHz	-	0.0120	0.0060	0.0215
	3 GHz	-	0.0130	0.0073	0.0230
Copper peel strength (18 µm)	Standard (Rz:7-9 µm)	kN/m	1.3	1.0	1.5
	VLP (Rz:2-3 µm)		1.1	0.8	1.3
Tg	TMA	°C	171	173	130
CTE	X1 (<Tg)	ppm/°C	16	17	16
	Z1 (<Tg)		43	45	60
	Z2 (>Tg)		300	280	282
Heat resistance	260°C/20 s dipping*2	-	PCT-6 h	PCT-6 h	PCT-3 h
	288°C/10 s float	-	10 cycle OK	10 cycle OK	-
	T-288*3	min	5-10	> 30	< 5
Water absorption	C-168/40/90	wt%	0.30	0.25	0.43
CAF restraining property*4	-	h	>1000	>1000	>1000
TH wall roughness after drilling*5	-	µm	10-20	10-20	15-25
Flame retardancy	UL-94	-	V-0 Halogen-free	V-0 Halogen-free	V-0 Halogen

*1: Measured by the triplate-line resonator method using a network analyzer (25°C)
*2: Moisture treatment condition, PCT(121°C/0.22 MPa)
*3: Time to delamination at 288°C (IPC-TM650 2.4.24.1)
*4: TH/TH wall thickness, 0.3 mm; Condition, 85°C/85%RH/100 V dc
*5: 80,000 rpm, 2.40 mm/min, 10,000 hits

High-Frequency Characteristics of Laminates

< Measuring conditions >

/ Triplate-line resonator method using a network analyzer
/ Temperature and humidity: 25°C / 60%RH
/ Laminate thickness: 0.8 mm(signal/ground-distance: 800 mm), Copper foil: 18 μm
/ Signal conductor line width: 0.8 mm(Zo: ca. 50 ohm)



Attenuation constant at 3 GHz

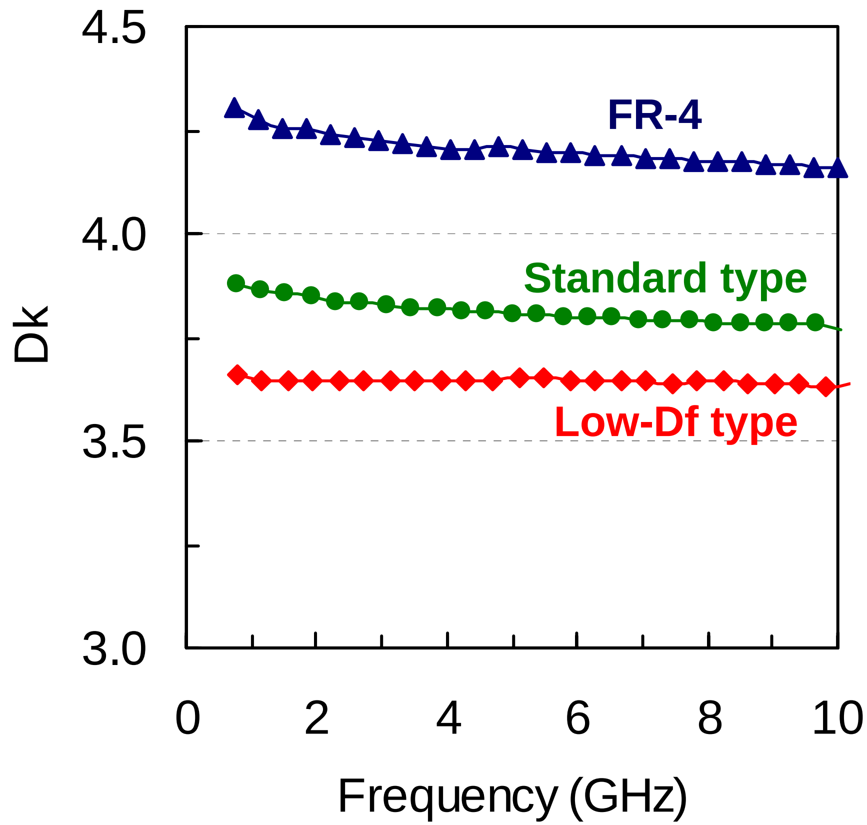
- Standard type: 8.9 dB/m
- Low-Df type: 5.4 dB/m
- FR-4: 12.6 dB/m

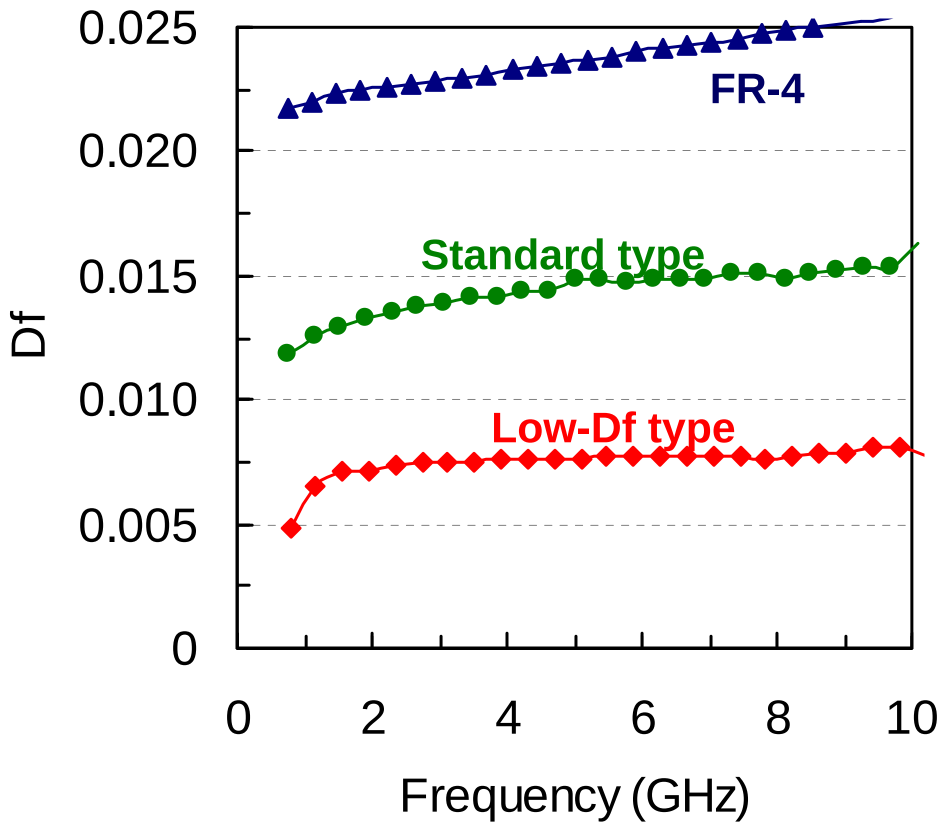
Dielectric Properties (vs. Frequency)

< Measuring conditions >

/ Triplate-line resonator method using a network analyzer

/ Temperature and humidity : 25°C / 60%RH





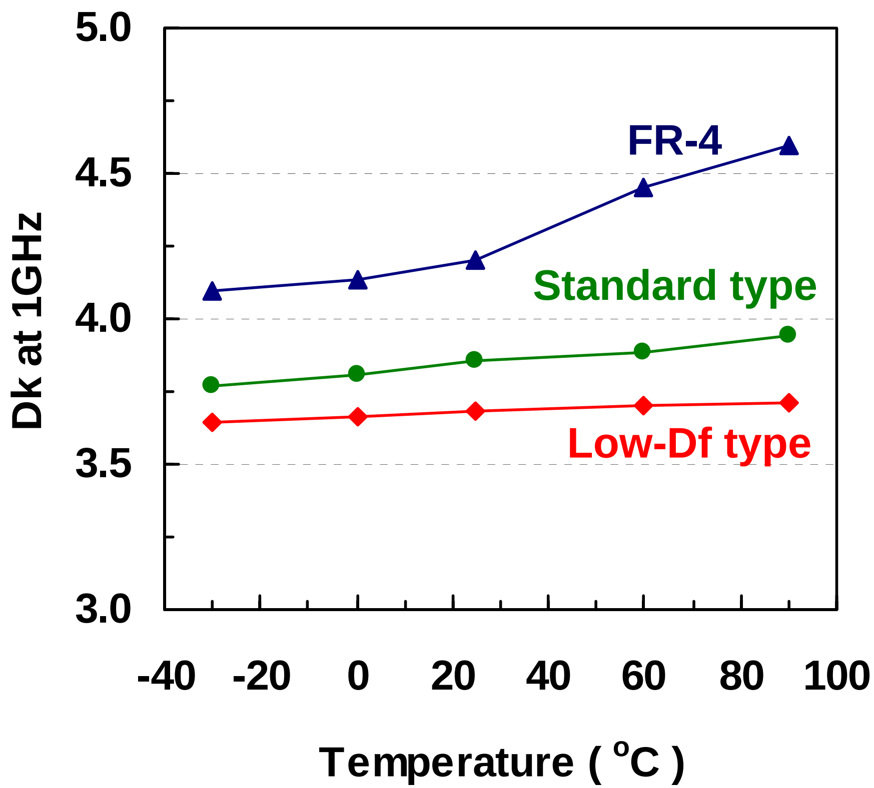
Good stability of dielectric properties in wide frequency bands

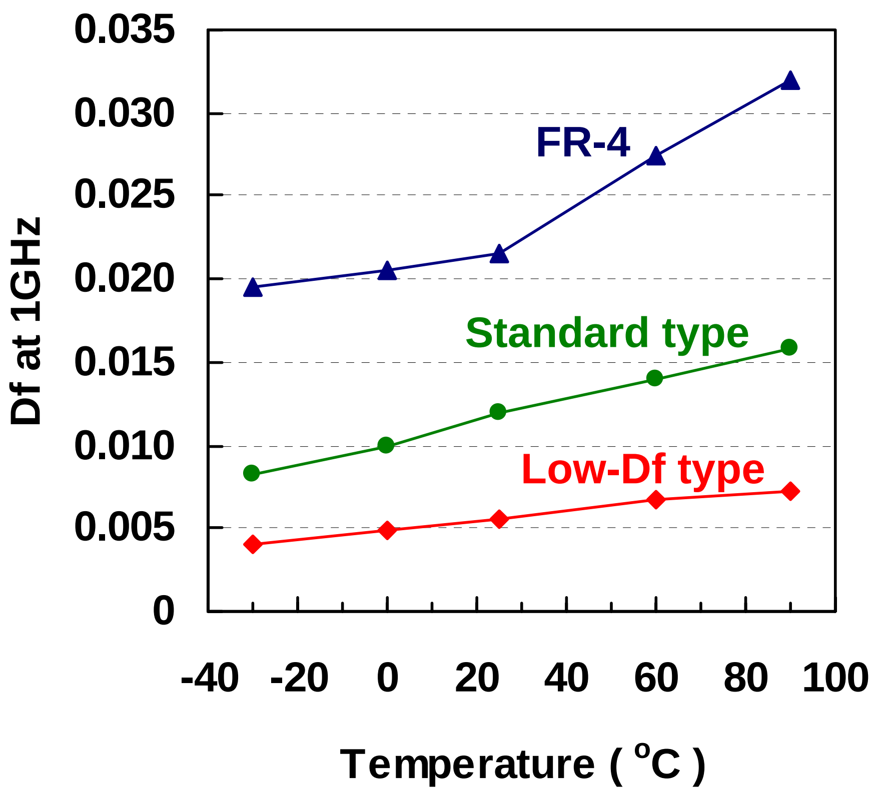
Dielectric Properties (vs. Temperature)

< Measuring conditions >

/ Triplate-line resonator method using a network analyzer

/ Temperature : -30 to 90^{o}C





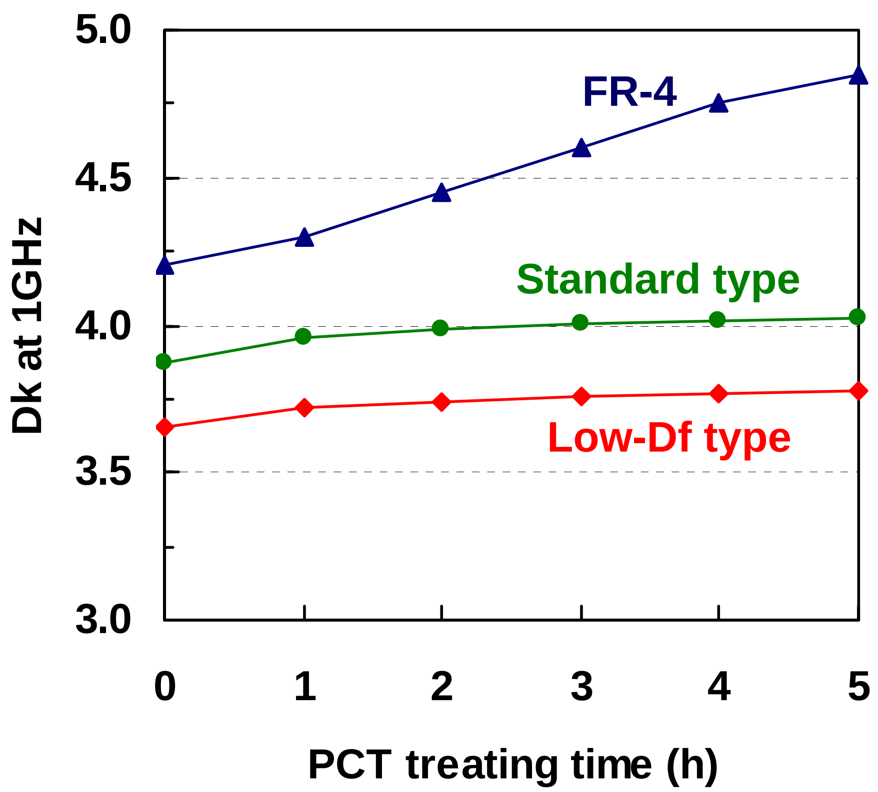
Good stability of dielectric properties against temperature

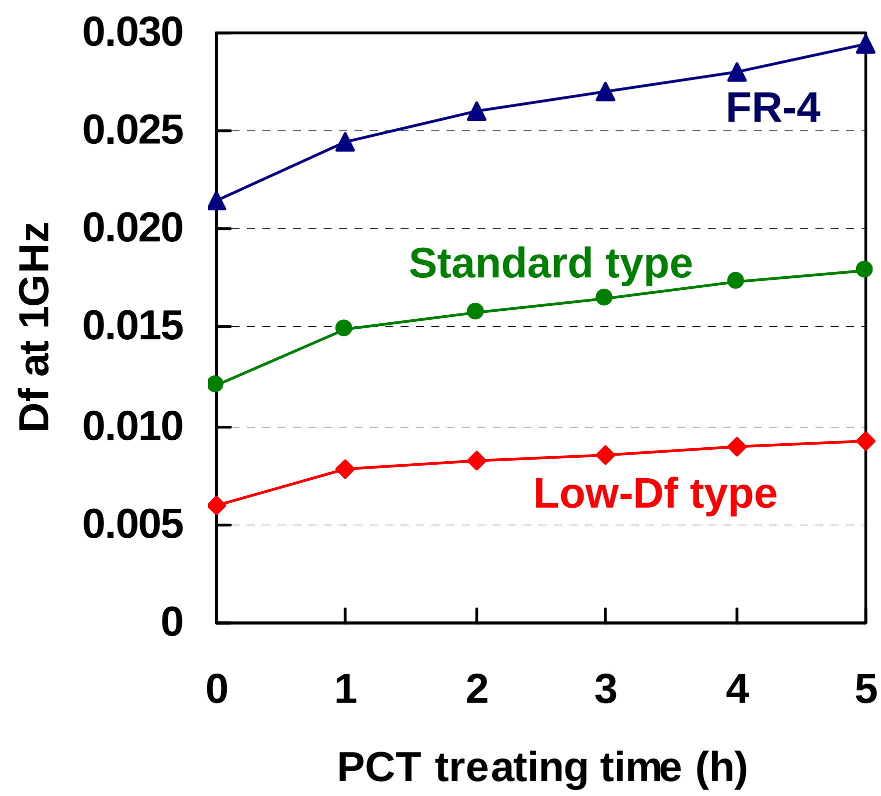
Dielectric Properties (vs. PCT Treatment)

< Measuring conditions >

/ Triplate-line resonator method using a network analyzer

/ Moisture absorption treatment : PCT(121^{o}C/0.22 MPa) 1 - 5 h





New types have stable Dk & Df against PCT treatment compared FR-4

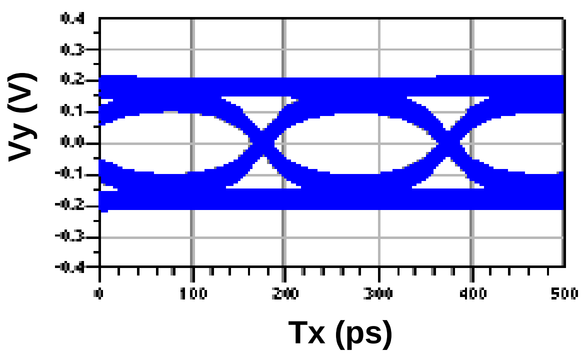
Simulation of the Eye Pattern (2.5 GHz)

Simulation of the eye pattern by S-parameter measurement with the network analyzer.

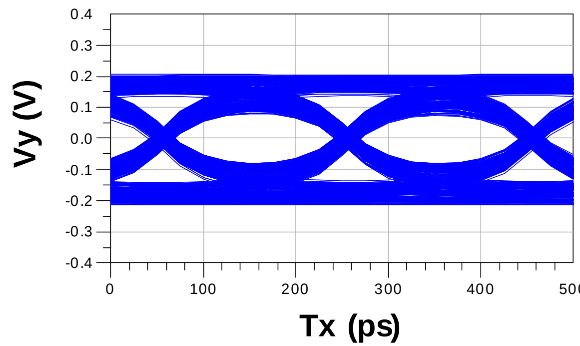
< Strip line parameters >

/ copper foil thickness : 18 μm / Zo : 50 ohm / signal line width : 64-77 μm

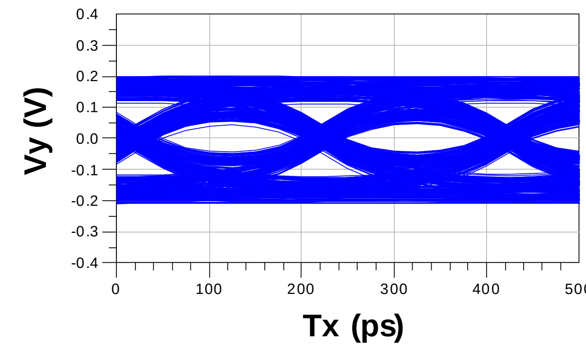
/ dielectric thickness : 0.1 mm / line length : 500 mm



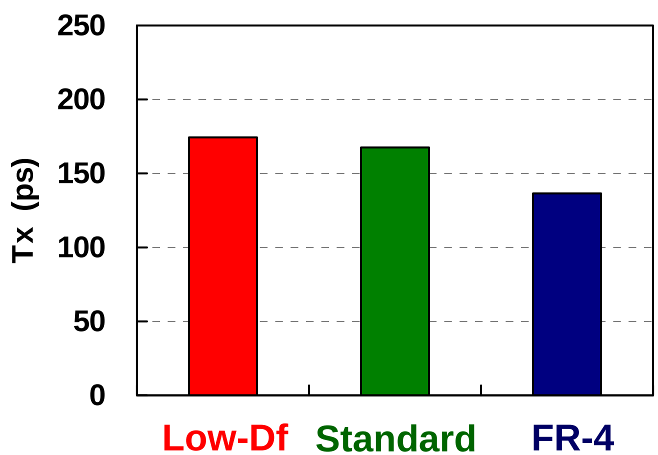
Low-Df type

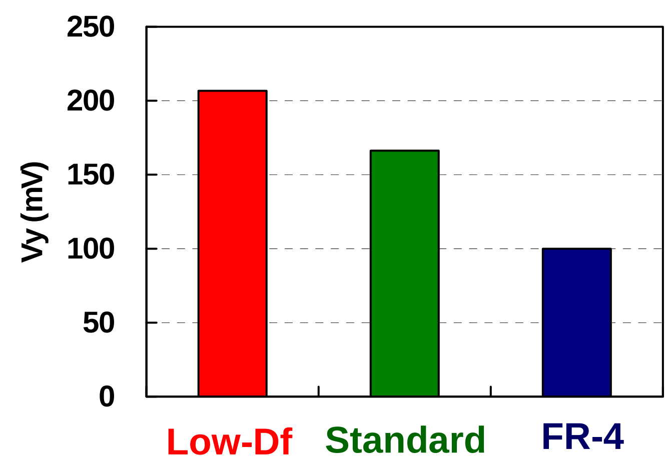


Standard type



FR-4





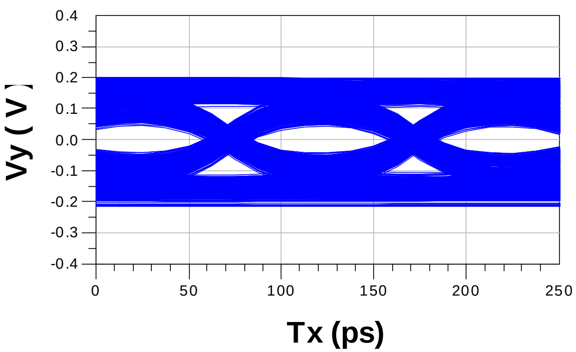
Simulation of the Eye Pattern (5 GHz)

Simulation of the eye pattern by S-parameter measurement with the network analyzer.

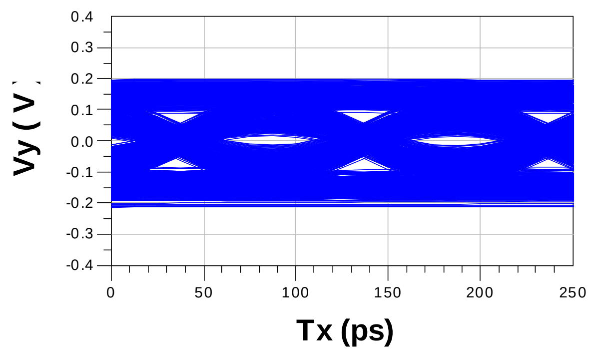
< Strip line parameters >

/ copper foil thickness : 18 μm / Zo : 50 ohm / signal line width : 65-77 μm

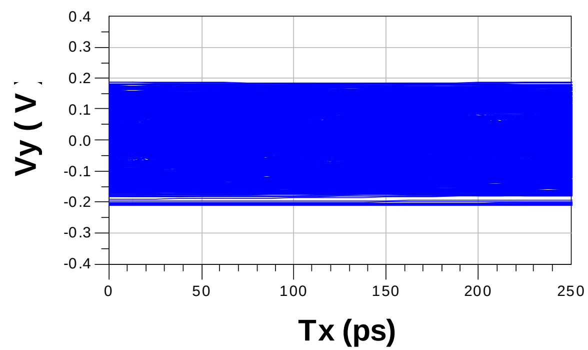
/ dielectric thickness : 0.1 mm / line length : 500 mm



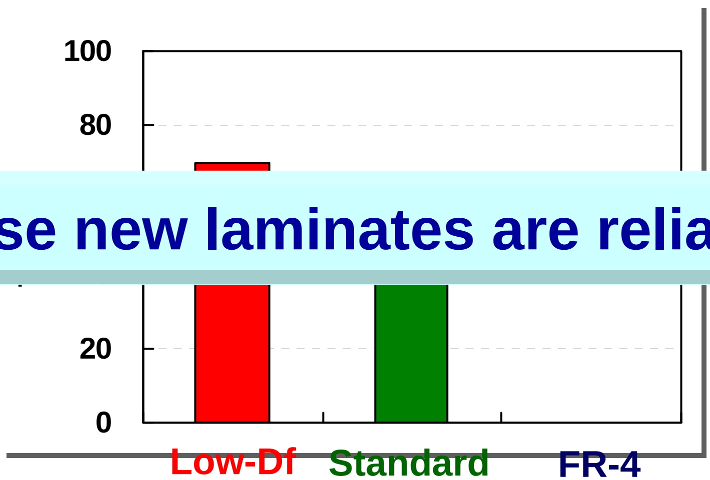
Low-Df type

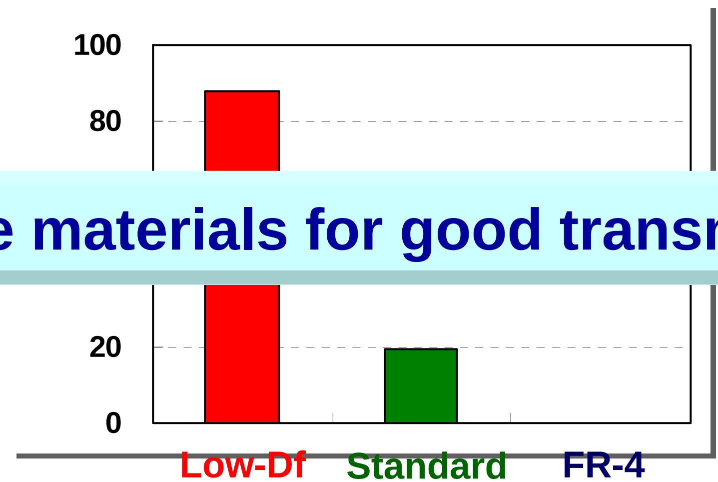


Standard type



FR-4



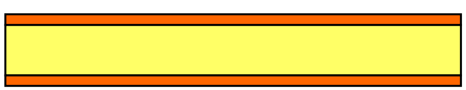


These new laminates are reliable materials for good transmission.

Heat Resistance (2 Layer Board)

Layer count	Condition		Standard type	Low-Df type	Conventional FR-4
2	Thermal decomposition	TGA	330	350	310
	Time to delamination	288°C (IPC-TM650 2.4.24.1)	5-10 min	> 30 min	< 2 min
	Thermal stress test	288°C solder 10 s floating	10 cycle OK	10 cycle OK	3 cycle OK
	Solder floating test	288°C solder floating	> 300 s	> 300 s	< 60 s
	Solder dipping test	PCT+260°C solder 20 s dipping	6 h OK	6 h OK	3 h OK

Laminate structure



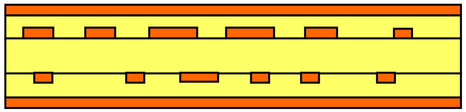
t0.8 mm, Copper foil: 18 µm
(Solder dipping test on etched-off copper foil)

High thermal decomposition temperature and high heat resistance

Heat Resistance (4 Layer Board)

Layer count	Condition		Standard type	Low-Df type	Conventional FR-4
4	Thermal stress test	288^{o}C solder 10 s floating	10 cycle OK	10 cycle OK	2 cycle OK
	Solder floating test	288^{o}C solder Floating	> 300 s	> 300 s	< 60 s
	Solder dipping test	PCT+260^{o}C solder 20 s dipping	2 h OK	3 h OK	0.5 h OK

Laminate structure



t0.8 mm 4 layer board , Inner copper foil: 35 µm
Outer copper foil: 18 µm

(Solder dipping test on etched-off outer copper foil)

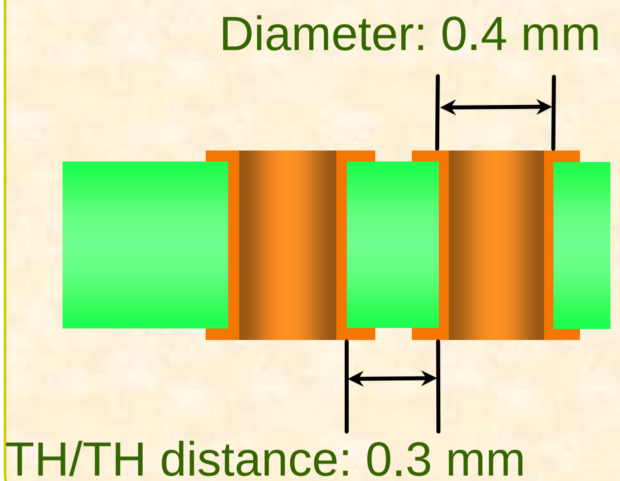
Two types of new materials will meet the requirement of the high temperature soldering process using lead-free solder.

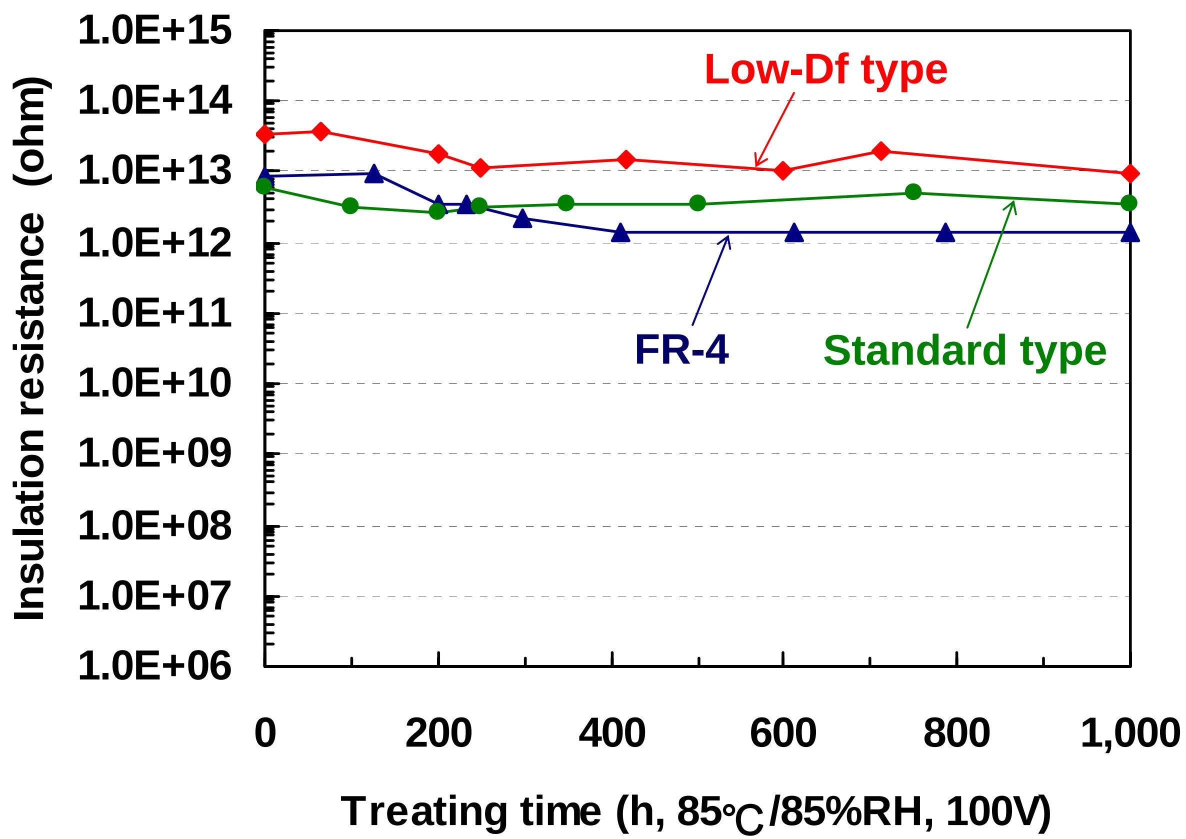
Insulation Reliability (CAF Preventing Property)

CAF : Conductive Anodic Filaments

< conditions >

- 85°C / 85%RH, 100 V
- t0.8 mm (Cu : 18 µm)



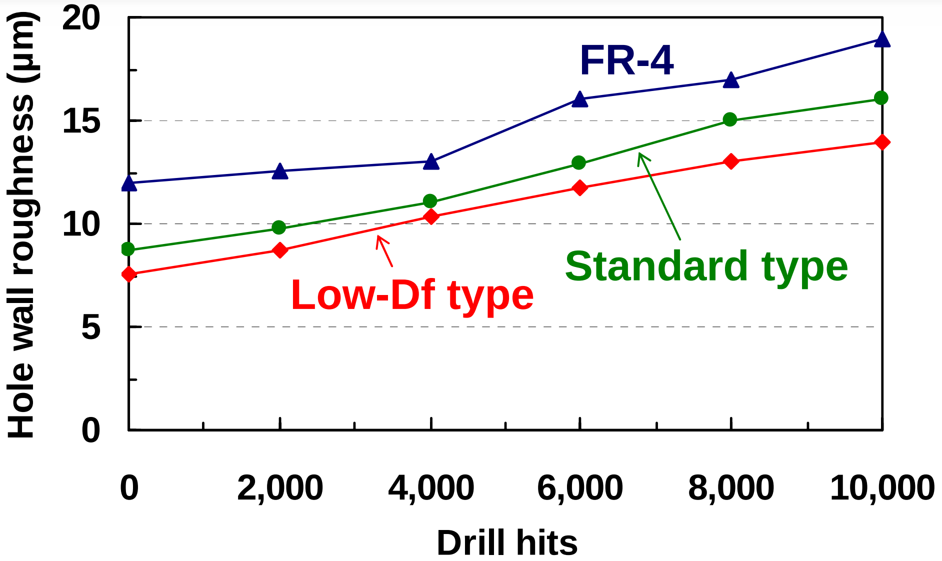


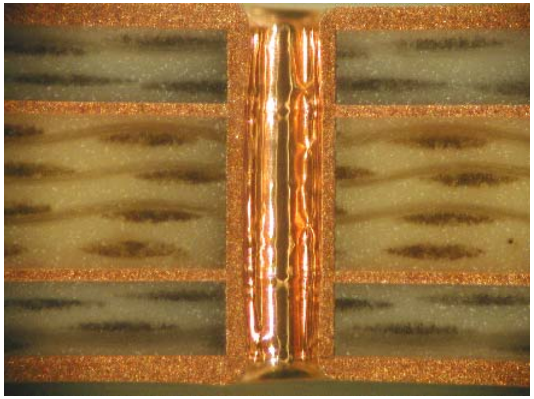
Good CAF preventing property

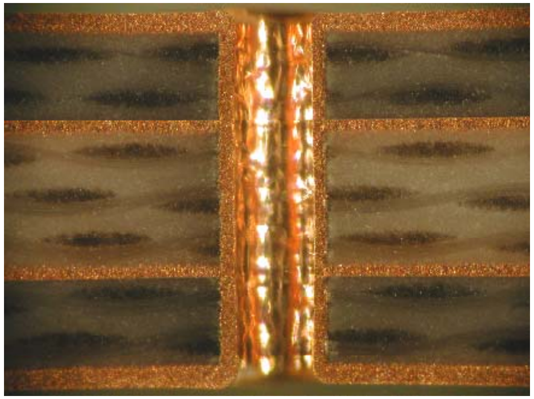
Drilling Processability

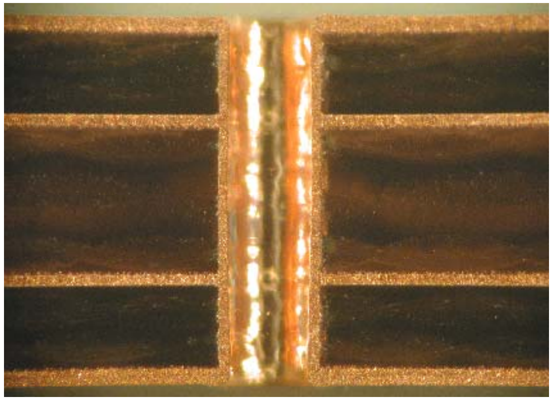
< conditions >

/ Diameter : 0.3 mm
/ Revolution : 80,000 rpm
/ Feed speed : 2,400 mm/min
/ Number of drill hit : 10,000 hits
/ Construction : t0.8 mm(Cu:18 μm)
4 layer board X 3 ply




Low-Df type


Standard-type


FR-4

The wall roughness of new laminates is 70-80% that of FR-4.

Conclusions

- Compatibility of low Dk and Df with high heat resistance and halogen-free nonflammability has been achieved in PCB materials by using originally designed new resins and a new flame retardant system.
- We have developed two types of low-transmission-loss multilayer materials with these new techniques. One has moderate Dk and Df, and the other has superior Dk and Df effective in decreasing the signal attenuation, through PCBs in high-frequency bands.
- These new laminates have high heat resistance(Tg as high as 170^{o}C) to meet the requirement of the high temperature soldering process using lead-free solder, as well as better Insulation reliability and drilling processability than FR-4.

Note: *The contents of this report are based on the results of experiments and do not represent a guarantee of the values for each property.*