Thin and Elastic Substrates for Ultrathin Multilayer Boards

Nozomu Takano / Toshiyuki Iijima / Masashi Tanaka / Yoshitsugu Matsuura
Hitachi Chemical Co., Ltd.
Ibaraki, Japan

Abstract

New substrates for ultrathin multilayer boards consist of ultrathin glass fabric and a novel low elastic modulus thermosetting resin system. They are composed of various lineups with the same resin system for the first time in the world; laminate (TC-C-100), prepreg (TC-P-100) , resin-coated copper (TC-F-100), adhesive resin film (TC-A-100). By using these lineups, it is possible to fabricate a variety of thin multilayer PWB. In particular, with TC-C-100 and TC-F-100, you can easily fabricate a bendable part and a multilayer part in a unity. Since the cover-layer and the bonding sheet are unnecessary, you can make thinner PWB of higher density. In addition, they will make the circuit manufacturing process simpler to provide thinner and bendable multilayer PWB with higher reliability.

Introduction

Mobile devices are becoming thinner and smaller every year. The printed wiring board (PWB) and the flexible printed circuit (FPC) installed in these devices are also becoming thinner and higher in wiring density[1]. This tendency will become more remarkable year after. In addition, the number of the parts mounted on PWB is increasing, where as the mounting area on PWB becomes smaller. In such situation, PWB suited for three-dimensional mounting will become indispensable in the future[2]. We have developed new substrates for ultrathin multilayer boards. By using these materials, you can materialize thin and bendable multilayer boards for three-dimensional mounting PWB. We named this material system "Composite of Ultimate Thin and Elastic materials (Cute)".

Development Concept

The concept of the new substrates is shown in Figure 1. We have developed a novel flexible thermosetting resin system. By using this resin system and ultrathin (about 19 um thick) glass fabric, we have realized the new thin and bendable substrates for multilayer PWB. These materials use copper foil with a very low profile (Rz=2-3 um).

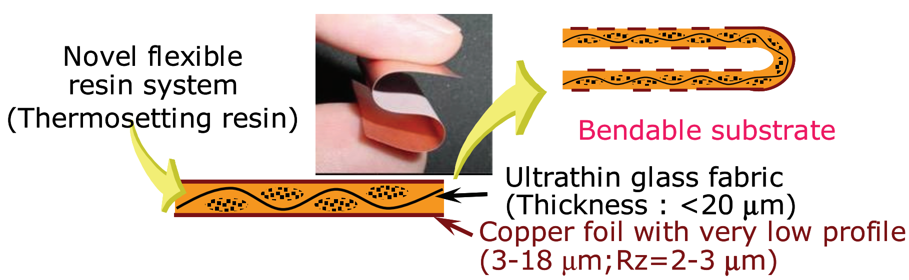


Figure 1 – Concept of a new substrates for thin and bendable multilayer PWB

One of the main points of the new materials is their product lineup. The new substrates consist of 4 products with the same resin system as show in Figure 2. We have developed a new double side laminate (referred to as C below), prepreg (referred to as P below), resin-coated copper (referred to as F below), and adhesive resin film (referred to as A below). The dielectric thickness of each material is about 50 um. By combining these products, you can easily materialize PWB of various compositions.

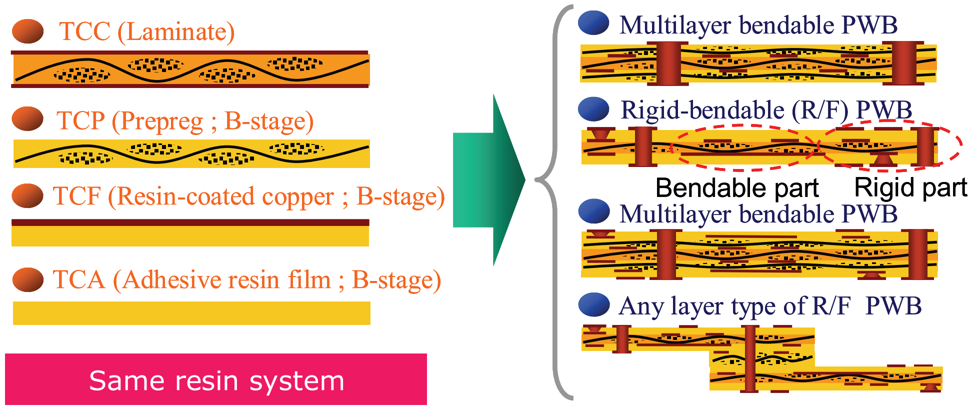


Figure 2 – Product lineup of new substrates

Target applications of new substrates

Figure 3 shows the main targets of the new materials. They are bendable multilayer PWB and high-density rigid-flex (R/F) PWB. Bendable interposers for PKGs and cables for connection will be other targets. The substrates containing glass fabric are more suitable for static bending parts than for dynamic bending parts.

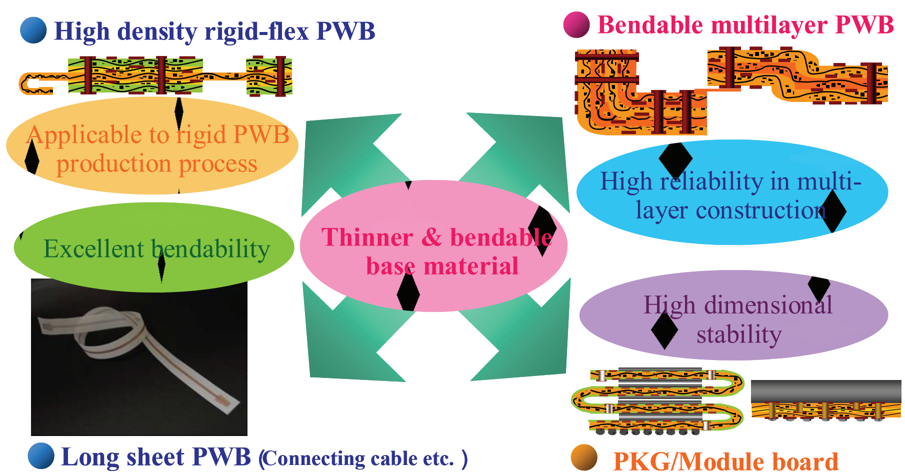


Figure 3 – Target applications of new substrates

Figure 4 shows the features of a multilayer board composition with these materials. By using only new substrates, you can fabricate R/F PWB easily. Putting the new resin coated copper on both sides of a new laminate makes this composition. After making via-holes (VIAs), a bendable part and a HDI part can be formed in a unity. In this case, the laminates in the bendable part play the role of cover-layer; these in the HDI part play the role of build-up material. Therefore, the cover-layer, non-flow prepreg, and outside layer of FR-4 become unnecessary, and the thickness of the multilayer wiring board can be reduced by about 50% compared with the conventional R/F PWB(Table 1). In addition, by using new substrates the complex processes (punching, pressing of the cover layer and FR-4, etc.) needed for the conventional R/F PWB can be simplified into a one-time pressing for a multilayer (Figure 5).

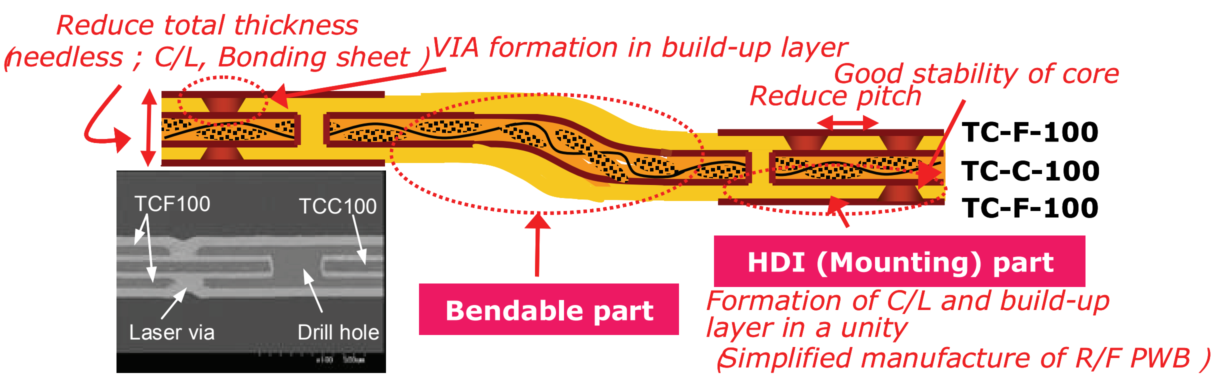


Figure 4 – Four layer build-up PWB with new substrates only

Table 1 - Thickness comparison of R/ F PWBs

Item	New substrates 4 layer PWB		Conventional 4 layer R/ F	
Construction	TCF:50µm TCC:50µm Cu:18µm Plating Cu:15µm		Single core :85µm P/P (NF):50µm CL:37µm Film:25µm Cu:18µm Plating Cu:15µm	
Material	Product	Thickness (µm)	Product	Thickness (µm)
Outer layer (L1)	MCF	50	Single side	85
Adhesive layer	Unnecessary		Non-flow P/ P	50
Cover layer	-	-	Cover layer	37
Inner layer (L2 L3)	Core	50	Adhesive film	25
Cover layer	Unnecessary		Cover layer	37
Adhesive layer			Non-flow P/ P	50
Outer layer (L4)	MCF	50	Single side	85
Total thickness *	-	216	-	462

* :Copper 18 µm, Plated copper 15 µm

Reduce thickness

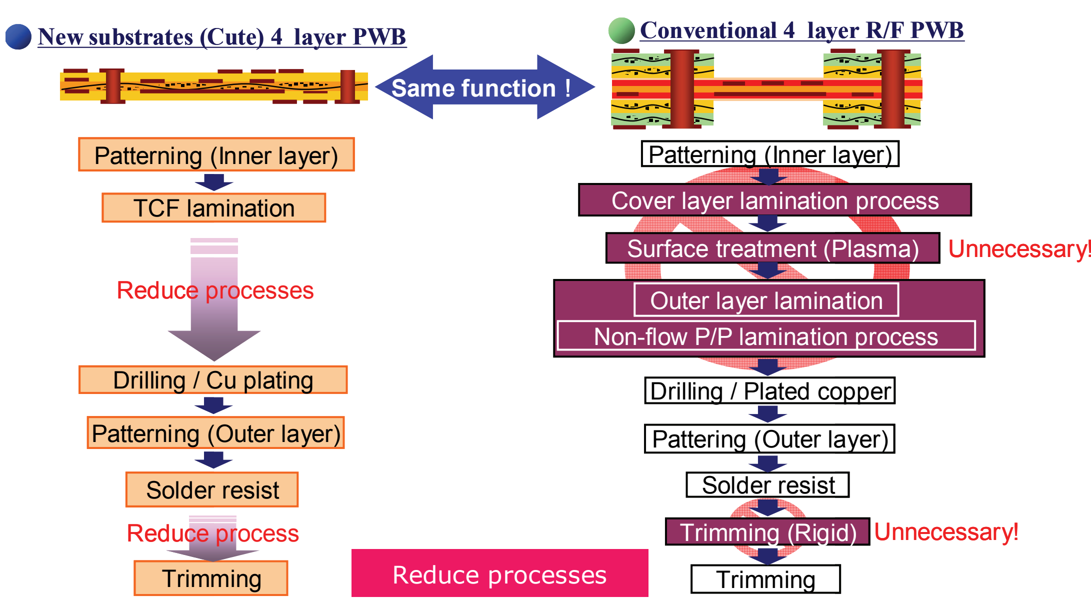


Figure 5 – Comparison of manufacturing process

General properties of new substrates

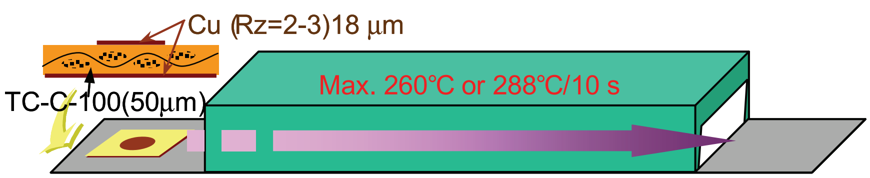
Table 2 shows the properties of C. It has good heat resistance to lead-free solder process, though having an elastic modulus lower than half that of FR-4. This elastic modulus is almost the same as that of polyimide (PI) film used for FPC. Moreover, the coefficient of thermal expansion in the x,y direction is very small. It is also a feature that the dielectric constant (Dk) is low (the same level as the PI film). Water absorption is about half that of PI film.

Table 2 - General properties of laminate (TC-C-100)

Items		Unit	TC-C-100 laminate (Standard type)	PI film
Glass fabric (Thickness)		μm	< 20	None
Thickcness		μm	50	25
Heat resistance	260°C/dip	PCT 2 h	Good	Good
	288°C float	s	> 180	-
TMA	CTE x,y	ppm/°C	5.0 - 7.0	13 - 16
	CTE z*	ppm/°C	300 - 400	-
	Tg	°C	40-50/140-160	240 - 280
DVE	E' (25°C)	GPa	6.0 - 9.0	5.0 - 7.0
Dk	1 GHz	-	3.5	3.4
Df	1 GHz	-	0.023	0.005 - 0.010
Water absorption	PCT 3 h	wt%	0.4 - 0.5	0.7 - 0.9
Cu peel strength	18(Rz=2-3) μm	kN/m	0.7 - 0.9	0.7 - 0.9
Flammability	UL-94	-	VTM-0 (Br)	VTM-0

*CTE z : 8 plies

One of the evaluation results of heat resistance is shown in Figure 6. The peel strength between substrate and copper foil didn't change after ten cycles of reflow process (maximum temperature 260 and 288 °C).



Test results

Items	Unit	Non	Max. 260°C	Max. 288°C
Heat resistance	cycle	-	>10	>10
Peel strength*	kN/m	0.84	0.86	0.84

* :After 10 cycles

Figure 6 – Heat resistance of TC-C-100 laminate

Trimming processability of new substrates

Another feature of new materials is their dust-free property. The cutting plane surfaces of new prepreg and laminate had no "crack of the resin" and "shagginess of the glass fiber" compared with those of FR-4 as shown in Figure 7. It was understood that there were only few dusts generated from P compared with FR-4 prepreg. This dust-free property is very effective in making the manufacturing process clean.

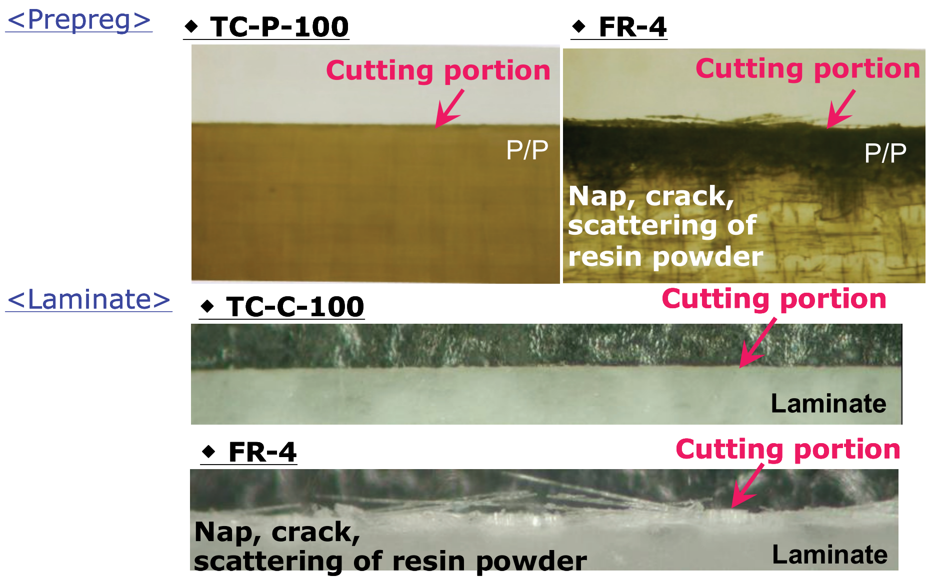


Figure 7 – Comparison of trimming processability

Bendability of a new substrate composition

The main feature of these substrates is their bendability. Figure 8 shows the bending test results. Four-layer composition for the test samples is the same as that of the bend part shown in Figure 4. For the 180-degree bend (folding), the electrical resistance didn't change up to 30 times of bending. Because this construction contains glass fabric, it should be best used for flex-to-install application. The bendability is enough for flex-to-install application.

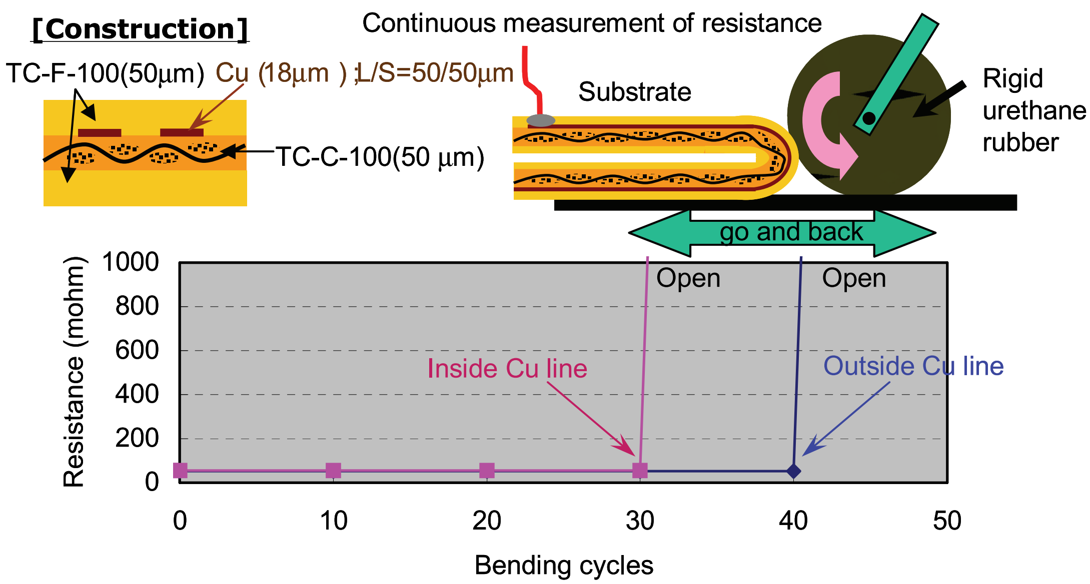


Figure 8 – Folding resistance of a new substrate composition (180º bend)

Reliability of new substrate compositions

Figure 9 shows the through hole reliability in the hot oil test. We tested several compositions in an accelerated condition. Each composition cleared over 50 cycles and proved to have almost the same level of reliability as FR-4.

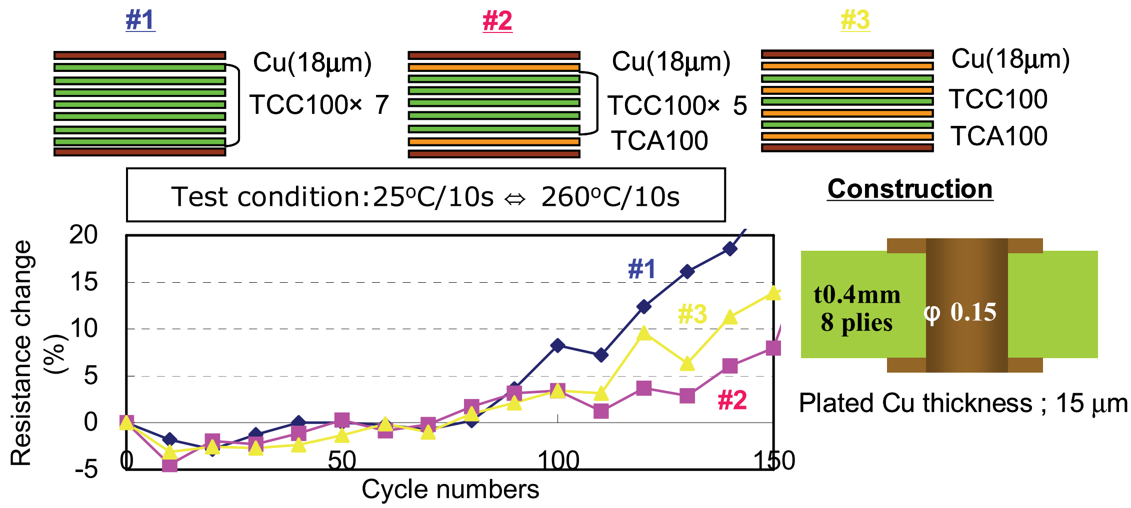


Figure 9 – Through hole reliability of new substrate compositions (Hot oil test)

General properties of new substrates under development

We have additionally been developing two halogen-free substrates as shown in Table 3. This is the halogen-free type of C. Its target application is consumer devices. We have also developed a high heat resistance halogen-free type. Its target is PKG interposer. Each substrate has almost the same bendability as C. The combination of these materials will satisfy customers' various needs.

Table 3 - General properties of TCC (Cute) series laminates

Items		Unit	TC-C-100 Standard type	TC-C-300 (Under development) Halogen-free	TC-C-500 (Under development) Halogen-free	FR-4	PI film 2 layer CCL
Heat resistance	288°C float	s	> 180	> 180	> 180	< 60	-
TMA	CTE x,y	ppm/°C	5.0 - 7.0	12 - 15	14 - 18	14 -16	13 - 16
	CTE z*	ppm/°C	300 - 400	150 - 250	150 - 250	50 - 70	-
	Tg	°C	40-50/ 140-160	20-40/ 140-160	180 - 200	120 - 130	240 - 280
Elastic modulus	E' (25°C,DVE)	GPa	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	23 - 27	5.0 - 7.0
Dk	1 GHz	-	3.3 - 3.5	under evaluation	under evaluation	4.0 - 4.2	3.4 - 3.5
Df	1 GHz	-	0.021-0.023	under evaluation	under evaluation	0.021-0.023	0.005-0.010
Water absorption	PCT 3 h	wt%	0.4 - 0.5	0.4 - 0.5	0.5 - 0.6	1.3 - 1.4	0.7 - 0.9
Cu peel strength	18μm(Rz=2-3mm	kN/m	0.7 - 0.9	0.9 - 1.0	0.7 - 0.8	1.4-1.6(Rz=4-5)	0.7 - 0.9
Dimensional	After Et.(MD)	%	-0.01± 0.03	under evaluation	under evaluation	-	-0.03± 0.05
stability	After Et.(TD)		0.01± 0.03	under evaluation	under evaluation	-	-0.05± 0.05
Flammability**	UL	-	VTM-0	(VTM-0)	(VTM-0)	V-0	VTM-0
Sample			Available	2006/1Q	2006/2Q	-	-

*CTE z : 8 plies (TC series), **(To be submitted to application)

Conclusion

New substrates are new multilayer materials with sufficient flexibility while maintaining the same excellent dimensional stability as the conventional rigid substrates. Moreover, they posses high heat resistance, low water absorption, and low coefficient of thermal expansions comparable to these of rigid substrates, and will be effective in making high-density multilayer wiring boards with higher reliability.

In addition, four available products (laminate, prepreg, resin-coated copper, and adhesive sheet) with the same resin system will meet the requirement of making thinner multilayer wiring boards as well as mounting three-dimensionally in a simple process. We are now developing a halogen-free type and high heat resistance type to meet the customers' diverse needs in the future.

References

[1] NIKKEI ELECTRONICS August 16, pp.55-62 (2004), in Japanese
[2] DENSHIZAIRYO, October (2004), in Japanese