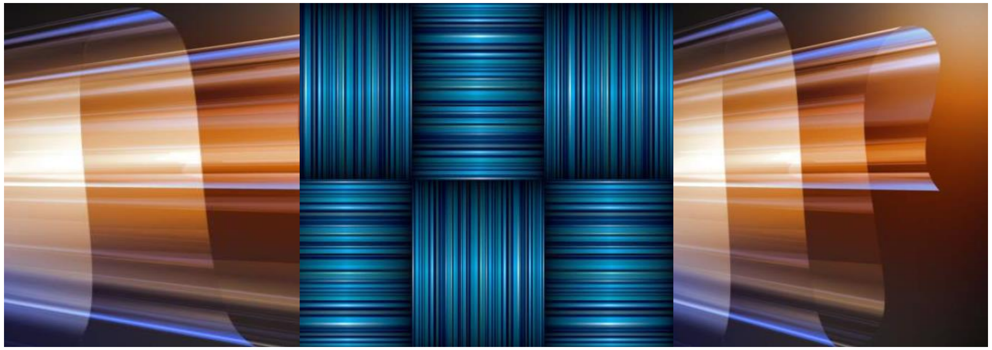
orbotech
The Language of Electronics

Substrate Materials



Aliza Mizrachi

Substrate Materials

Agenda:

Two presentations are planned:

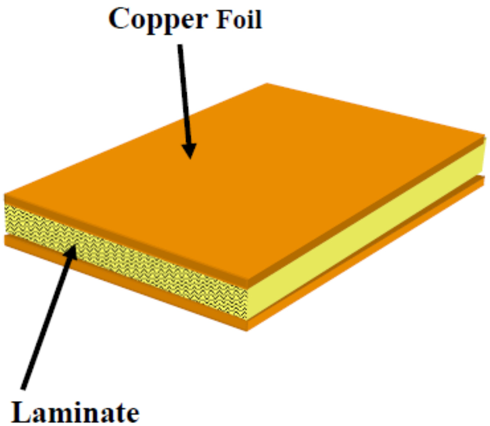
One presentation on substrates Materials

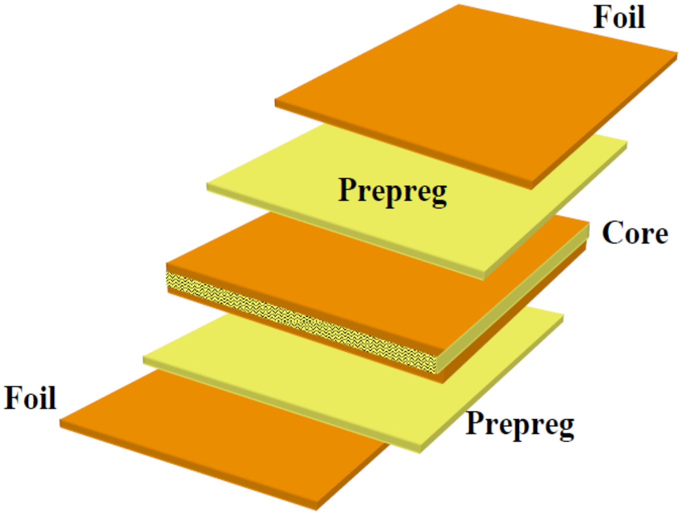
** General overview of basic material (prepreg and core)

** Materials for advance package

Substrate Materials - Overview

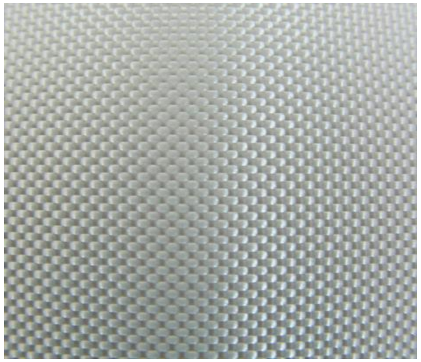
PCB Material





Copper Foil

Prepreg Type

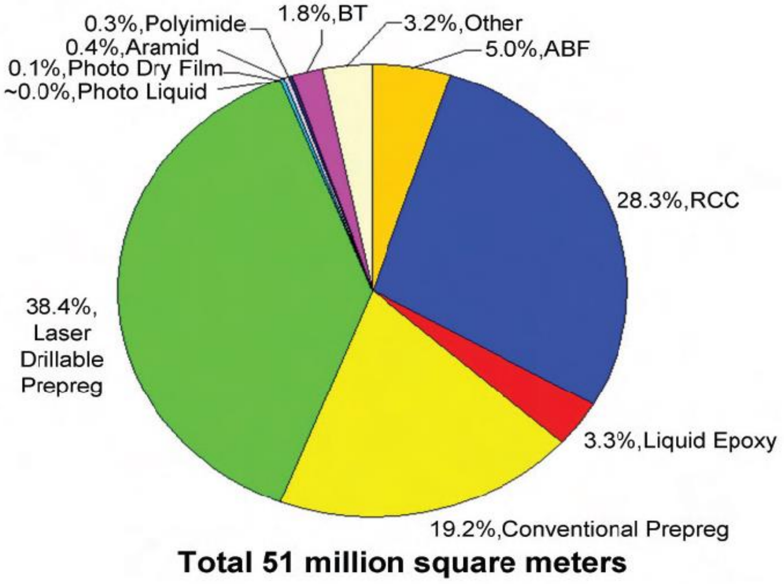


Substrate Materials - Overview

- Substrate materials market worldwide estimated to be 51 million square:

Materials type used:

- Laser Drillable Prepregs
- RCC
- Conventional Prepregs
- ABFilm
- Epoxy
- Other
- BT- (Bismaleimide-Triazine)
- Aramid (Synthetic fibers)
- Polyimide Nylon as a group of synthetic polymer.
- Photo Dry film
- Photo Liquid



Substrate Materials - Overview

- Majority of the materials are mixed with **Epoxy**
- Some are with **BT** mixture of bismaleimide
- **PPE** (polyphenylene oxides polymer)
- **Cyanate Ester (cyanide group)** chemical substances generally based on a bisphenol
- **Acrylates** (polymers as plastic).
- **Polyimide: (**Kapton) blend of polyimide resin with epoxy or 100% polyimide, best reliability of high-density, used in rough environmental conditions such as extreme differences in hot and cold temperature
- The newest materials are the growing number of laser drillable prepregs.

*** Their popularity is a result of their, excellent electrical performance due to having lower dielectric constants and loss tangents than many of the thermosets materials.

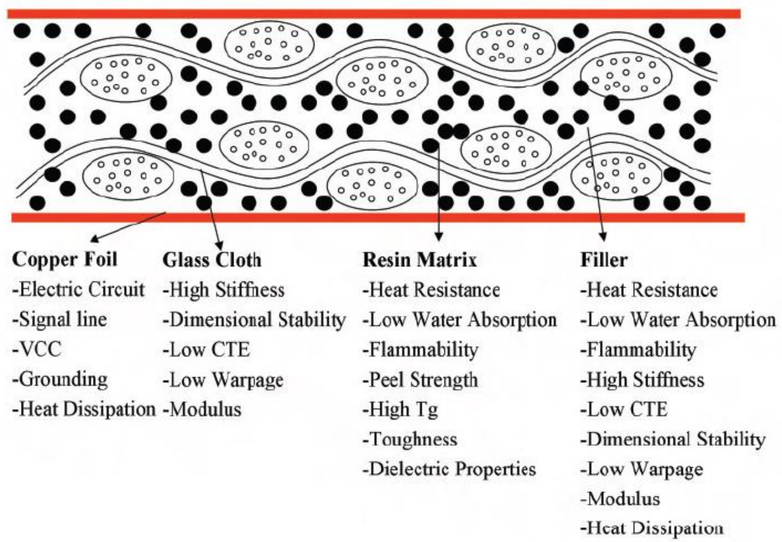
*** Their high melting points and chemical resistance make desmearing a critical process.

Substrate Materials Including Thermally Cured and Photo-Cured

Type of Materials	Thermally Cured Resins (Tg)					Photo Cured Resins	
Suppliers	Halogen-free	LD Prepregs	RCC	Film Type	Ink Type	Film Type	Ink Type
Isola	X		150 160				
Polyclad			165 200				
Nelco			180				
NanYa	X	X X	172 180				
Asahi Chemical			X	X			
Ajinomoto Fine Technology	X		177	9X	X		
Tamura Kaken					X		X
Shipley Far East							X
Taiyo Ink			UD	UD	X		X
Chuba Specialty Chemical							X
Oy Pent						X	
Tokyo Ohba Kogyo					X		
Hitachi Chemical			135 190	X		X	
Asahi Denka Kogyo					X		X
Toshiba Chemical			X				
Matsushita Electric works	X		170 155				
Mitsubishi Gas Chemical			220				
Nippon Industries			X				
Mitsui Metal & Mining	X X		150 190 130 165				
Sumitomo Bakelite			X	X			
Nippon Paint						X	X
Doosan	X		145 185				
Grace Electron		X					
Sheng Yi	X X		155 165				

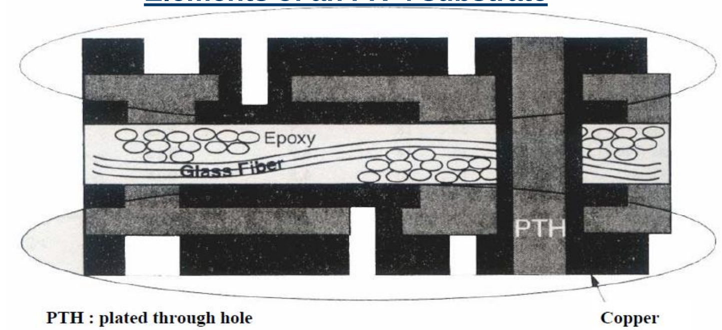
Substrate Materials - Overview

- The major material components of PCBs are the polymer resin (dielectric), with or without fillers, reinforcement, and metal foil.
- To form a PCB, alternate layers of dielectric, with or without reinforcement, are stacked in between the metal foil layers.
- There have been many advances in the resins used to make PCBs over the years. Epoxy has been a staple due to its relatively low cost, excellent adhesion (both to the metal foils and to itself), good thermal, mechanical, and electrical properties.
- The demands for better electrical performance,
  ability to withstand lead-free solder temperatures,
  changed the basic epoxy chemistry dramatically over the years.
- Dk of the glass cloth more closely matches the Dk of the resin
  This provides a distinct advantage of low loss clothes in applications.



Composition of laminate and its functions

Elements of an FR-4 substrate



Substrate Materials - Overview

Resin/Filler

- Epoxies are thermosetting resins and use hardeners and catalysts to facilitate the cross-linking reactions that lead to the final cured product.
- Over the last several years, resins have been modified to change the curing chemistry to make the resins more robust during the higher temperatures of lead-free soldering.
- Other resins are in common use and are typically chosen to address specific weaknesses of epoxy systems.
- BT-Epoxy for organic chip packages due to its thermal stability.
- Polyimide and cyanate ester resins are used for better electrical properties (lower Dk and Df) .
  Sometimes they will be blended with epoxy to keep costs down and improve mechanical properties.
- Thermoplastic resins are
  polyimide and polytetrafluoroethylene (**PTFE** - **Teflon**)
  Unlike the thermosetting version of polyimide which is brittle.
- **Thermoplastic version is flexible and supplied in film form.**

Resin/Filler	T_g[℃]	Lateral CTE[ppm/℃]	ε (at 1 MHz)	Water absorption	Peel strength of foil [N/mm]
Phenolic/Paper	125	14 ... 18	4.5	0.75	>2.0
Epoxy/Glass(FR-4)	130	14 ... 18	4.9	0.15	>2.0
Polyimide/Glass	250	12 ... 16	4.5	0.35	>1.4
Polyimide/Quartz	280	6 ... 8	4.0	0.35	>1.2
Epoxy/Aramid	180	7 ... 9	3.9	0.44	>1.7
BT-Epoxy	185	13 ... 14	4.3	0.19	>2.0
Cyanate ester	240	-	3.7	0.40	>6.0
Polyimide/Aramid	230	7 ... 9	3.6	0.81	>1.6

Substrate Materials - Overview

- **Resin materials**

Resin systems are moving toward higher Tg and better electrical properties than conventional epoxy.

The Tg of 180℃ is proving to be very cost-effective.

Typical Resin Properties

Resin System	ε[1MHz]	T_g [℃]	Relative cost
FR-4-epoxy	3.5-3.60	125-135	1
Polyfunctional FR-4	3.5-3.60	140-150	1-2
High Temperature one component epoxy system	3.90-4.00	170-180	3-6
Bismaleimide Triazine epoxy(BT)	3.2-3.30	180-190	3-6
Polyimide epoxy	3.5-3.6	250-260	10-20
Cyanate ester(CE)	2.80-3.50	240-250	20-30
Polyimide	3.30-3.40	>260	10-20
PTFE(melting point)	2.03-2.09	327	10-15

Substrate Materials - Overview

Each material has Loss Tangent (DK, Er)

The property of a material determines the relative speed that an electrical signal will move in that material.

Signal speed is inversely proportional to the square root of the dielectric constant.

Low dielectric constant will result in a high signal propagation speed, and a high dielectric constant will result in a much slower signal propagation speed.

Typical dielectric constants (Dk) of materials as measured at 1 Mhz

Material	Dk
Hard Vacuum (~air)	1.0
Pure Teflon®	2.1
Type GY Teflon®-Glass	2.2 - 2.3
Type GX Teflon® Glass	2.55
Filled PTFE (CLTE-XT)	3.0
Polyimide-Quartz	3.5 - 3.8
Polyimide-Glass	4.0 - 4.6
Epoxy-Glass (FR-4)	4.4 - 5.2
BT-Epoxy	3.8 - 4.0
Non-woven Aramid Epoxy	3.8 - 4.1
Woven Aramid Epoxy	3.8 - 4.1
Ceramic-Filled Teflon®	6.0 - 10.2
Water	70.0

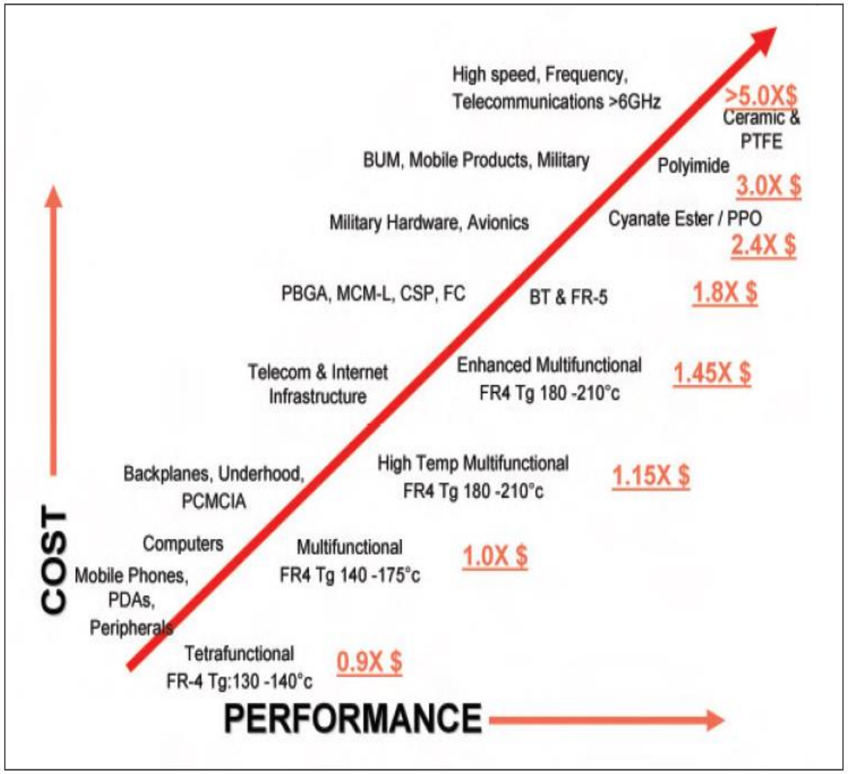
Substrate Materials - Overview

CTE (Coefficient Thermal Expansion) of materials in x-y direction : ppm/℃

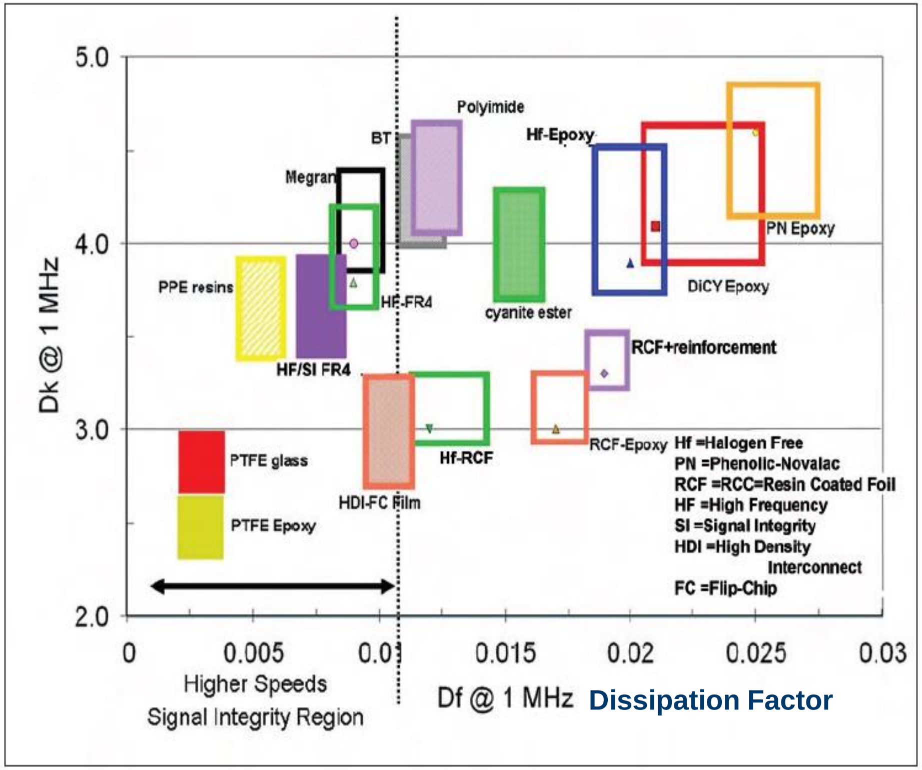
Materials	Substrate Type (x-y direction : ppm/℃)	PWB Type (z-direction: ppm/ ℃)
Epoxy/E-glass	13-17	75-95
BT Epoxy/E-glass	12-16	72-83
Polyimide/E-glass	12-15	67-76
CE/E-glass	11-14	52-62
Epoxy-Quartz	8-13	70-81
BT-Epoxy/Quartz	8-11	63-75
Polyimide/Quartz	8-11	61-71
CE/Quartz	8-9	50-60
Epoxy/Aramid	7-11	90-100
BT Epoxy/Aramid	6-10	82-92
Polyimide Thermount/Aramid	6-10	84-95
CE/S-glass	8.5-10	45-55
CE/S-glass(4HS)	7-9	45-55

BT : Bismaleimide Triazine
CE : Cyanate Ester

Substrate Materials - Overview



Relative costs of dialectrics compared to their performance



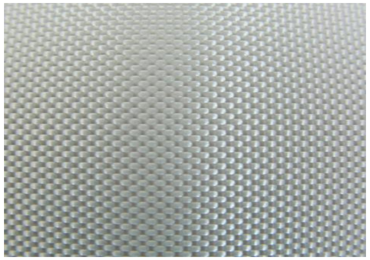
Typical epoxies and other resins and their electrical properties

orbotech. The Language of Electronics

Substrate Materials

Three basic material types: non-woven glass, woven glass, and filled:

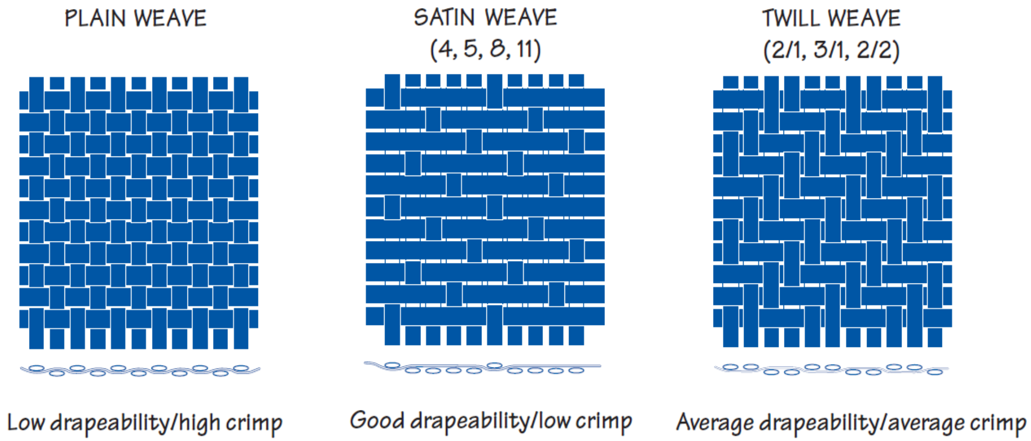
- GR, GP (non-woven, random fiber reinforced) , GT, GX, GY (woven reinforced) and filled material has no designation. All based on (PTFE or Teflon®) resin chemistry.
- Non-woven (GR) materials contain a dispersion of glass microfibers in the substrate. These are typically materials with low DK (2.20 - 2.35). They work very well at the higher frequencies, **but the dissipation factor is not good**.
- Woven glass (GT, GX, GY) materials are made using fine weave glass cloth. These materials have dielectric constants in the range of 2.40 to 2.60, but **poor mechanical and thermal stability in multilayer** designs.
- GX series are epoxy-based with phenolic hardener (Melamine).
- GY series use a phenolic ester hardener (based on Silica).
- GZ series use a cyanate ester hardener, Plastic type (ABF GC), Electronic chip adhesives and encapsulation.



- Filled materials have dielectric constants ranging from 2.94 to 10.8. Ceramic or other suitable material that can be used to raise the dielectric constant. may also contain non-woven or woven glass. The type of filler and construction determines the dielectric constant as well as the dissipation factor.

Woven Reinforcements Fiberglass

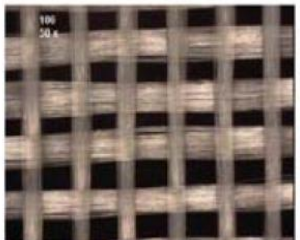
- Most of the dielectric materials incorporate reinforcement into the resin system. Reinforcement usually takes the form of woven fiberglass.
- Woven fiberglass is just like any other cloth, made up of individual filaments that are woven together on a loom.
- By using different diameter filaments and different weave patterns, different styles of glass cloth are created.
- Fiber-reinforced materials provides more flexibility of resin systems and thickness in any given HDI design.
- As the designs become more complex, and the layer counts increase, fiber-reinforced materials offer lower Z-axis expansion, lower X-Y expansion rates, more thickness latitude, resistance to cracking, and a wide variety of resin options which not possible with other approaches.



Woven Glass Cloth Styles

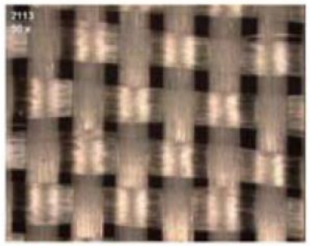
Combinations of glass styles used in a stack-up, innovation of different weaving helps to achieve data transmission rates of 100 Gbps and beyond.

106

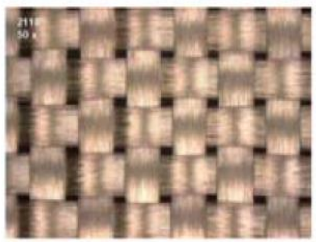


1080

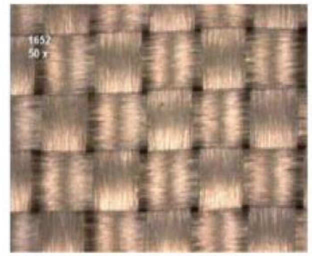
2113



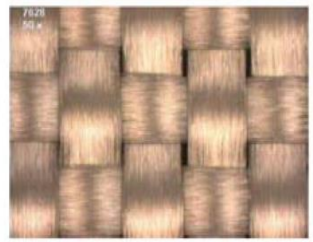
2116



1652



7268



North America	Asia-Pacific	Europe
106	106	106
1080	1035	1080
1067	1078	2113
1086	1080	3070
2113	1067	2116
3313	1086	1634
3070	2313	1647
2116	3313	1651
1652	2116	1501
7628	1501	2165
	1506	2157
	1652	7628
	7628	

Prepreg Availability 半固化片型号

Ventec Company

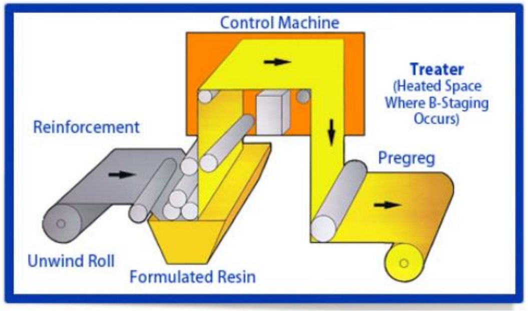
- **Laser Drilling Glass: 1086, 1078, 1067, 1037, 1027, 1017, 101**
- Normal Glass: 1080, 106, 104
- Standard available resin systems are as below:

Resin Content	101	1017	1027	1037	106	1067	1078	1080	1086	
VT-42/42S	-	-	-	-	75%	-	-	63%	63%	-
VT-441/447	72%	75%	70%	71%	76%	71%	65%	65%	65%	-
VT-481/47	-	-	-	-	76%	74%	65%	66%	-	68%
VT-464/464(M)	-	73	-	-	75%	-	65%	63%	-	-
Pressed (mil)	1.4	1.2	1.6	1.9	2.5	2.5~2.8	3.2	3.0	3.6	3.9
Pressed (mm)	0.035	0.030	0.040	0.048	0.063	0.063~0.071	0.081	0.076	0.091	0.099

Reinforcements Fiberglass

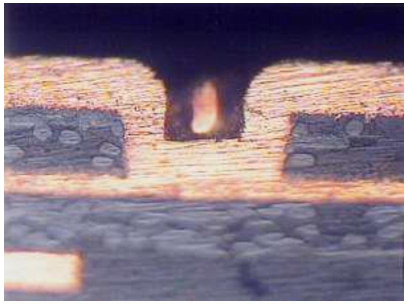
- Resin is coated to produce the prepreg, Mostly use **E-Glass** (Electrical Grade Glass) standard.
- Reinforcement contributes significantly to physical and electrical properties, generally used in **epoxy and polyimide** laminates.
- Other substrates - used in specialty materials: **Nonwoven aramid**, **woven Kevlar® aramid**, **woven quartz cloth**. In addition of several chemical composition variations on the standard glass (such as **S-Glass**) can also be used in specialty applications.
- Started with thousands of individual yarns rolled into a master beam, or roll, weaving, and "scoured“ to remove different size of yarns and then heat cleaning.
- Organosilane finishing applied (a fraction of a percent of the raw weight) to provide a cloth surface which can be wet and bonded with other various resin. High temperature finishes such as amino-silanes (**E-Glass**) intended for polyimide. Finish affects how the resin will wet the surface during prepregging.
- Lightweight clothes with high resin are smooth, better fill for internal copper etched patterns, Heavier clothes are less expensive.

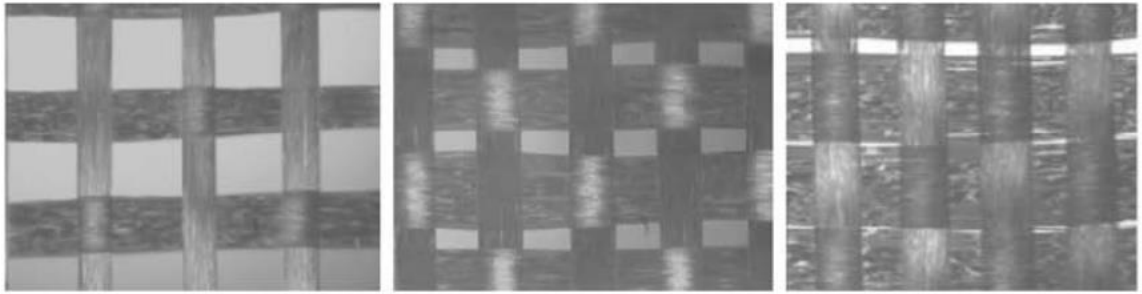
Prepreg



Woven Glass Fiber

- Presents significantly different properties, the difference being attributable to the reduction of the effect of surface defects and control an important performance. **started in1960s** where they were used as a high performance replacement paper reinforcements.
- Woven glass fiber provided reinforcement to complement the properties of epoxy resin, adding high tensile strength and dimensional stability.
- The process of glass fiber production did not changed over 50 years, however there is number of important developments that have enabled substrates made with woven glass clothes.
- The developments are in order to accommodate **microvia technology requirements by laser**. The difference in ablation rates between fiberglass and the surrounding resin can cause poor hole quality. fiberglass cloth is not uniform due to having areas with no glass. Usually the drilling is set up for the hardest
- In recent years the demand for package substrate with thinner and higher density required build up with new materials for interconnect between the chip and substrate board.

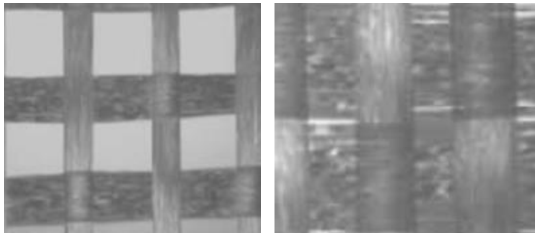




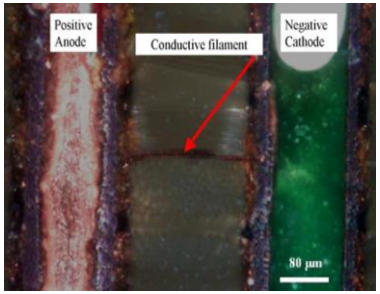
Advanced Glass Reinforcement Technology

The benefits of spread glass

- The use of lasers to form microvias in PCBs is commonplace, However the laser ablation rate of glass is significantly lower than that of the resin matrix.
- First the use of spread glass was to minimize the effect of differential ablation rate. Second reducing the number of laser pulses required and improving the quality of the hole.
- Additional significant improvement is better wet the fibers during the finish which is used to create good chemical bond between the glass reinforcement and the resin matrix.
- This benefit extends also to the impregnation process when the resin is coated onto the glass cloth to produce a prepreg.
- Traditional tightly bound bundles of glass fibers can lead to defects in the resin/glass, In some cases can present conductive anodic filamentation (CAF), failure mode for woven glass-reinforced laminate which is copper short between two sides of hole.
- Spread fibers improves the accessibility of the individual fibers and enabling improved wetting.
- **Robust thermal bond strength**, which is needed for a number of high I/O PBGA rework and removal procedures, and very good peel strengths even after thermal conditioning.



Conductive Anodic Filamentation (CAF)

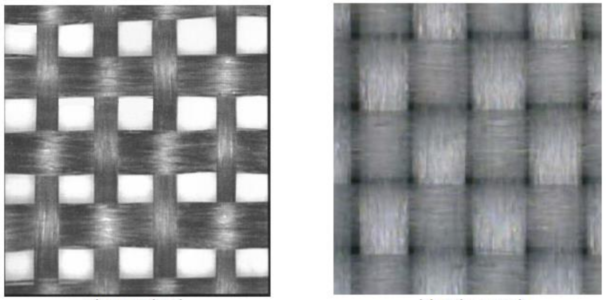


Advanced Glass Reinforcement Technology

The benefits of spread glass

- Glass fibrs should be: with high tensile strength, dimensional stability, good chemical resistance, sensitivity to moisture and good electrical insulator.
- Performance characteristics are greatly enhanced due to homogeneous insulating layers between copper traces.
  “fiber weave effect” (FWE), signal skew is completely eliminated.
- In traditional fiber glass, the yarns are coated with silane (silicon compounds), but the heat cleaning step reduces the glass cloth strength by approximately one third.
- In the new process, resin is applied on surface of individual glass fibers immediately as they are formed and remains on the yarn and glass cloth throughout the manufacturing process.
- Direct application of a final resin-compatible finish during the fiber-forming process provides a better interface between the glass fiber reinforcement and the resin matrix.

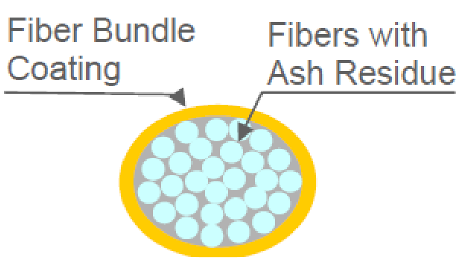
Each has exactly the same quantity of glass with the same number of warp and weft yarn



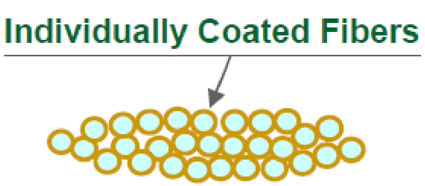
a) Standard b) Advanced

Thicker and unevenly distributed leading to inconsistent substrate properties

**Glass fiber bundle is twisted to give strength and mechanical integrity to the yarn.
Making thicker cross-points in the glass cloth.
Also contributor to stresses within the laminate**



Traditional Yarn
Twisted fiber bundle



Direct Finish
advanced untwisted yarn

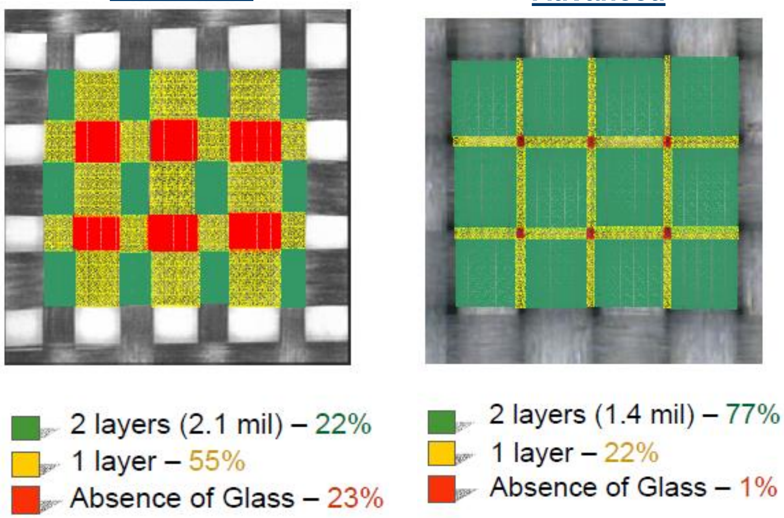
Advanced Glass Reinforcement Technology

Advanced glass cloth, prepreg with high Tg for chip package

* Flat and smooth glass cloth
* Improve laminate surface planarity
* Improvements in ”telegraphing”
* Convenient to laser-drill
* Improve laser-drilled hole geometry
* Hole plating quality and laser drilling speed
* Homogeneous Dk and Df reduced signal skew and less impedance variation.

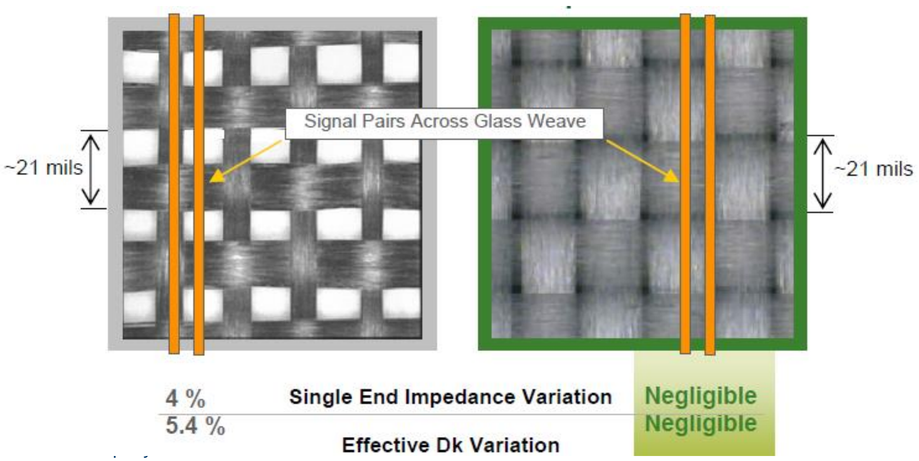
The same amount of glass

Traditional **Advanced**



Colors illustrate layer coverage

Different Dk between glass and resin



Dk of new weaving glass cloth is lower than E-glass in traditional cloth.

	Traditional 1080	NovaSpeed™ 1080
Fabric Thickness	2.1 mil (mm)	1.4 mil (mm)
% Coverage (2 / 1 / 0 layers)	22 / 55 / 23	77 / 22 / 1
Dielectric Constant (Dk)	6.6 – 6.9	4.5 – 5.0
Dissipation Factor (Df)	0.006 (avg.)	0.005 (avg.)

Laser Via and Hole Formation Evolution

Comparative Benefits of Laser Drillable Multilayer Materials

Property	Resin Coated Copper	E-Glass Advanced Materials	Laser Drillable LD™ Advanced Materials
Print Through	Moderate	Good	Excellent
Outer Dielectric Tolerance	± 15%	±10%	±10%
Maximum Laser Drillable Dielectric Thickness	80 micron	240 micron 2,3 ply constructions	240 micron 2,3 ply constructions
Laser-Drilled Hole Geometry and Plateability	Good	Fair	Excellent ⟸
Dimensional Stability	Moderate	Good	Excellent ⟸
Resin Cracking	Possible	No	No
Typical Laser Drilling Speed (500 Hz TEA CO_2 Laser 75-micron Dielectric)*	50 micron: 1 pulse 80 micron: 1 pulse* *Application dependent	50 micron: 4–5 pulses 80 micron: 6–8 pulses* *Application dependent	50 micron: 3–4 pulses 80 micron: 5–6 pulses* *Application dependent
Material Options (volume availability)	Epoxy High Tg Epoxy	Epoxy High Tg Epoxy Low Loss Epoxy Low CTE Epoxy APPE Polyimide Low Loss Polyimide Cyanate Ester	Epoxy High Tg Epoxy Low Loss Epoxy Low CTE Epoxy APPE Polyimide Low Loss Polyimide Cyanate Ester
Z-Axis Range	+5.0%	1.7% –4.5%	1.7% –4.5%
X-Y CTE Range PPM/°C	30–40	10–16	10–16 ⟸
Tg Range °C	130–170	130–250	130–250
Plasma Compatibility	Yes	No	No
Optimum Layer Counts	2–12	2–50	2–50 ⟸
Minimum Copper (microns)	5	5	5
BGA Rework	Fair	Excellent	Excellent ⟸
Low Dk Resins	Yes	Yes	Yes N4000–13, N6000
Chip Packaging	Yes	Yes	Yes

Laser Via and Hole Formation Evolution

- Laser-drillable prepregs and laminates allow many options for laser microvia formation in a conventional multilayer process. Back- plane technology with high overall thickness designs can easily benefit from this approach because of the need for the lower z-axis expansion afforded by fiber reinforced dielectrics.

- In the past, laser drilling through a glass-reinforced substrate was an intriguing idea, but not very practical, two separate laser systems, with different wavelengths.

- One laser to remove the copper foil, the alternate laser can have a different frequency and pulse configuration that allows fast and clean removal of the glass fibers and resin, thereby forming a reliable microvia hole (**Galvo Process**).

- **The benefits of laser-drillable E-Glass reinforced** materials include faster laser processing, cleaner hole formation, lower thermal-mechanical expansion rates, better hole-wall adhesion during the metallization process, uniformity of material in the multi-layer structure and better fill of buried via stacks.

Resin Type	Fiber Type	Application n	Tg ° C DSC TMA * DMA	X/ YCTE - 40 C +125 ° C PPM	Z CTE – 50 ° C to +260 ° C %
Resin Coated Copper	None HDI	135 – 140	155 – 170	30 – 40	5.0% +
Epoxy	N4000 – 2 LD	Broad Spectrum	140	12 – 16	4.5
Epoxy	N4000 – 6 LD	Low CTE	180	10 – 14	3.8
Epoxy Low CTE	N4000 - 7 LD	Low CTE	155	10 – 14	3.7
Epoxy Low Loss	N4000 – 13 LD	Low Dk 1 - 5 Ghz	210	10 – 14	3.5
BT	N5000 - 32 LD	Telecom	180	10 – 14	3.8
BT JEDEC	N5000 LD	PBGA, HDI	* 190	10 – 14	3.6
APPE	N6000 LD	1 – 10 Ghz	* 210	10 – 14	3.5

Table of Laser Drillable Fiberglass

Cloth Style	Warp x Fill	Glass cloth thickness (mm)		Air Permeability (M3/M2min)		Warp & Fill yarn width (mm)			
						Standard		LDP	
		Standard	LDP	Standard	LDP	Warp	Fill	Warp	Fill
1015	75 X 75	- -	0.020	- -	23-45	- -	- -	0.163	0.270
1027	75 X 75	- -	0.020	- -	22-42	- -	- -	0.163	0.270
1037	71 X 74	- -	0.025	- -	20-40	- -	- -	0.210	0.270
106	56 x 56	0.037	0.028	120-140	20-40	0.138	0.254	0.163	0.385
1067	70 x 70	- -	0.033	- -	9-14	- -	- -	0.215	0.351
1078	54 x 54	- -	0.044	- -	9-14	- -	- -	0.255	0.419
1080	60 x 48	0.055	0.045	85-105	20-40	0.213	0.296	0.283	0.413
1086	60 x 61	- -	0.047	- -	6-10	- -	- -	0.285	0.398
2112	40 x 40	0.071	0.069	60-75	5-20	0.318	0.439	0.356	0.537
2113	60 x 56	0.070	0.065	32-50	4-12	0.302	0.319	0.329	0.452
2313	60 x 64	0.072	0.067	17-30	3-8	0.308	0.311	0.313	0.403
2116	60 x 58	0.092	0.088	8-18	5-10	0.360	0.365	0.365	0.395

Glass fibers

Glass fiber - consist of numerous extremely fine fibers of glass. Has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber, much cheaper, and significantly less fragile when used in composites.

- Glass fibers used as a reinforcing agent for many polymers: FRP (Fiber Reinforced Polymer) .
- Composite material called Glass Reinforced Plastic (GRP), is especially good thermal insulator. Contains little air and more dense than glass wool.

Composition of glass: E-glass, D-glass, S-glass, R- glass, E-CR-glass, C-glass, T-glass, L-glass.…

- **E-glass** - the most fiberglass production in the world **("E" because of initial electrical application**). excellent electrical insulation and low moisture absorption.
- **D-glass** - has a low **dielectric constant** (Dk) , but other properties are not so good as E- or S-glass
- **S-glass** - used when high tensile strength (modulus) is important **(“S” for stiff)**.
- **R-glass - (“R” for reinforcement).**
- **C-glass** - **(“C” for chemical resistance)** having very high chemical resistance
- **T- glass** - **(“T” for thermal insulator)**
- **L- glass - (“L” for low - loss)**

L-Glass Fiber for High Frequency - AGY

L-Glass, S-2, S-3 HDI - Improved Signal Integrity.

AGY - leading global producer of glass fiber yarns and high strength glass fiber reinforcements.

To insure the integrity of the signal, Low Dk (dielectric Constance), low Df (Dissipation Factor), ideally for high signal speed, better than traditional E- glass /Epoxy substrate.

Traditional low loss laminate produced in two ways:

1. Higher performance epoxy resin conjunction with E- glass (limited Dk, Df).

2. Combines very low Dk/Df resin such as PTFE, with ceramic and lower E-glass. But the process reduces the dimensional stability, and costs expensive.

- New glass fibers (range of sizing for thermoplastic systems) are coated with a chemical sizing (higher level of silica) that facilitates customer processing and sizes for higher performance woven.

- L- glass, attractive for IC package and cost-effective alternative (4 micron).

10GHz	E-glass	L-glass
CTE / ppm	5.4	3.9
Dk	6.81	4.86
Df	0.0060	0.0050

Glass fiber Fillers

Advanced Filler System - Glass fiber: E-Glass, S-Glass, D-Glass %

	Composition	E-Glass	S-Glass	D-glass	Quartz	Kevlar	Technora HM-50
Silicon dioxide	SiO_2	52-56	64-66	73-75	99.97		
Aluminum oxide	Al_2O_3	12-16	22-24	0-1			
Calcium oxide	CaO	15-25	<0.01	0-2			
Magnesium oxide	MgO	0-6	10-12	0-2			
Boron trioxide	B_2O_3	8-13	<0.01	18-21			
Iron(III) oxide	Fe_2O_3	-	0.1	-			
Zirconium Oxide	Zr_2O_3	-	<0.1	-			
Coefficients Thermal Expansion	CTE [10^{-6}/K]	5.01	2.80	2.00	0.54	-5.20	-7.50
Dielectric Constant	ε(1MHz)	5.80	4.52	3.95	3.78	4.00	4.00
	Thickness [mm]	0.05-0.23	0.06-0.18	0.06-0.18	0.08-0.13	0.1	0.1

Kevlar : Quartz and aramid

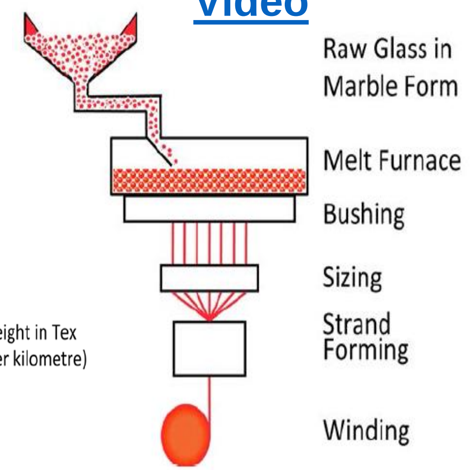
orbotech. The Language of Electronics

Glass Fiber Production Process

Glass fiber

- Glass formulation is melted in a furnace and the molten glass is then mechanically drawn into single filaments through small holes in a platinum/rhodium alloy bushing.
- The filaments are next gathered into bundles called strands and are then coiled onto bobbins to form a yarn
- During the strand forming process a size is applied in order to protect the glass surface to avoid the formation of defects that would weaken the fibres.
- The individual filaments for PCB substrate use are commonly between 5 - 9 microns diameter, gathered together into stands of between 204 - 408 filaments to form a yarn.
- One square foot of 0.062” glass fiber reinforced PCB laminate contains over 500 miles of individual glass filaments.

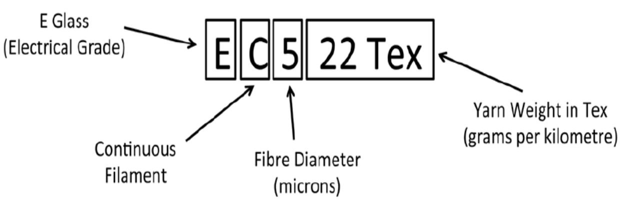
Video



Glass yarn common types

Yarn Designation	Filament Diameter	Filaments per Strand
EC9 68 Tex	9 Microns	408
EC7 22 Tex	7 Microns	225
EC6 34 Tex	6 Microns	408
EC5 22 Tex	5 Microns	408
EC5 11 Tex	5 Microns	204

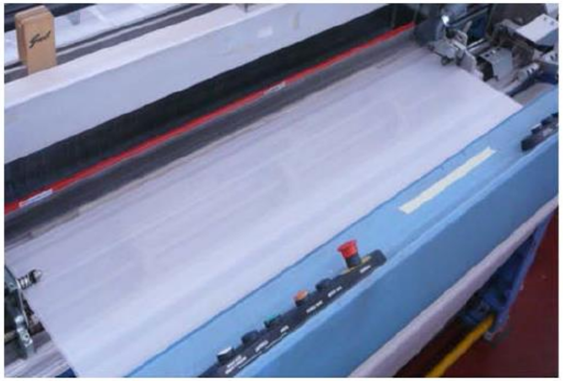
Glass yarn designation



Glass Cloth Weaving

- Yarn transferred on bobbins in order to form the warp threads which run in the machine direction up to 3 kilometers length. Depending on the total number of threads required for a given type of glass weave (style)
- Loom beam is installed on the weaving loom, cloth is formed by interlacing filling yarns.
- Additional finish is applied In order to provide maximum adhesion of the cloth to the various resins matrices.

Video



Traditional woven glass cloth styles

Style	Glass Thickness (mm)	Weight (gsm)	Threads per cm	Yarn
7628	0.17	203	17.3 x 12.2	EC9 68/EC9 68
2116	0.095	104	23.6 x 22.8	EC7 22/EC7 22
2125	0.09	87	15.7 x 15.4	EC7 22/EC9 34
2113	0.079	78	23.6 x 22.0	EC7 22/EC5 11
1080	0.05	47	23.6 x 18.5	EC5 11/EC5 11
106	0.033	24	22.0 x 22.0	EC5 5.5 /EC5 5.5

Prepreg Production

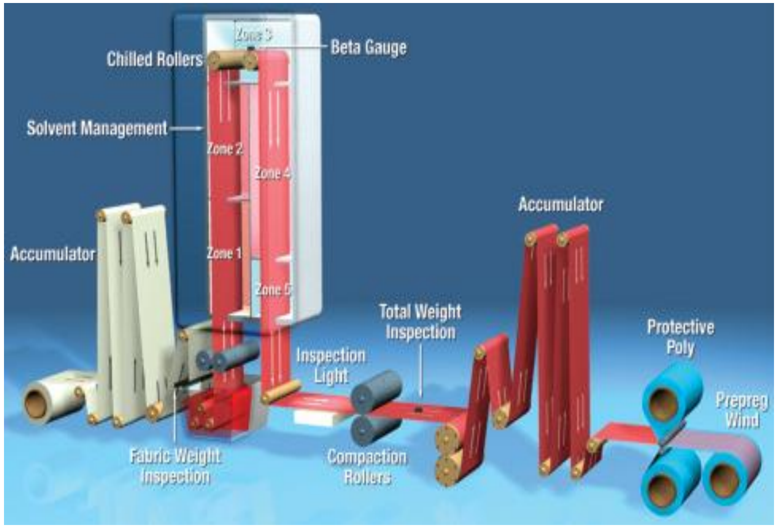
<u>How are prepreg made</u>?

Process under controlled heat and pressure release

A: Compounding. It is the activation of the epoxy-resin by mixing together precise amount of the resin components in a batch tank.

B: In order to impart mechanical rigidity to the final laminate, above resin blend is reinforced with glass cloth as filler material. As the filler material constitutes about 40-50% of the laminate bulkiness, it contributes significantly to mechanical, electrical and chemical properties of the laminate.

C: The C-staging operation is the final curing process after laminating the copper foil to the prepreg material.



One step process for woven and impregnation

Prepreg Production Advanced Technology

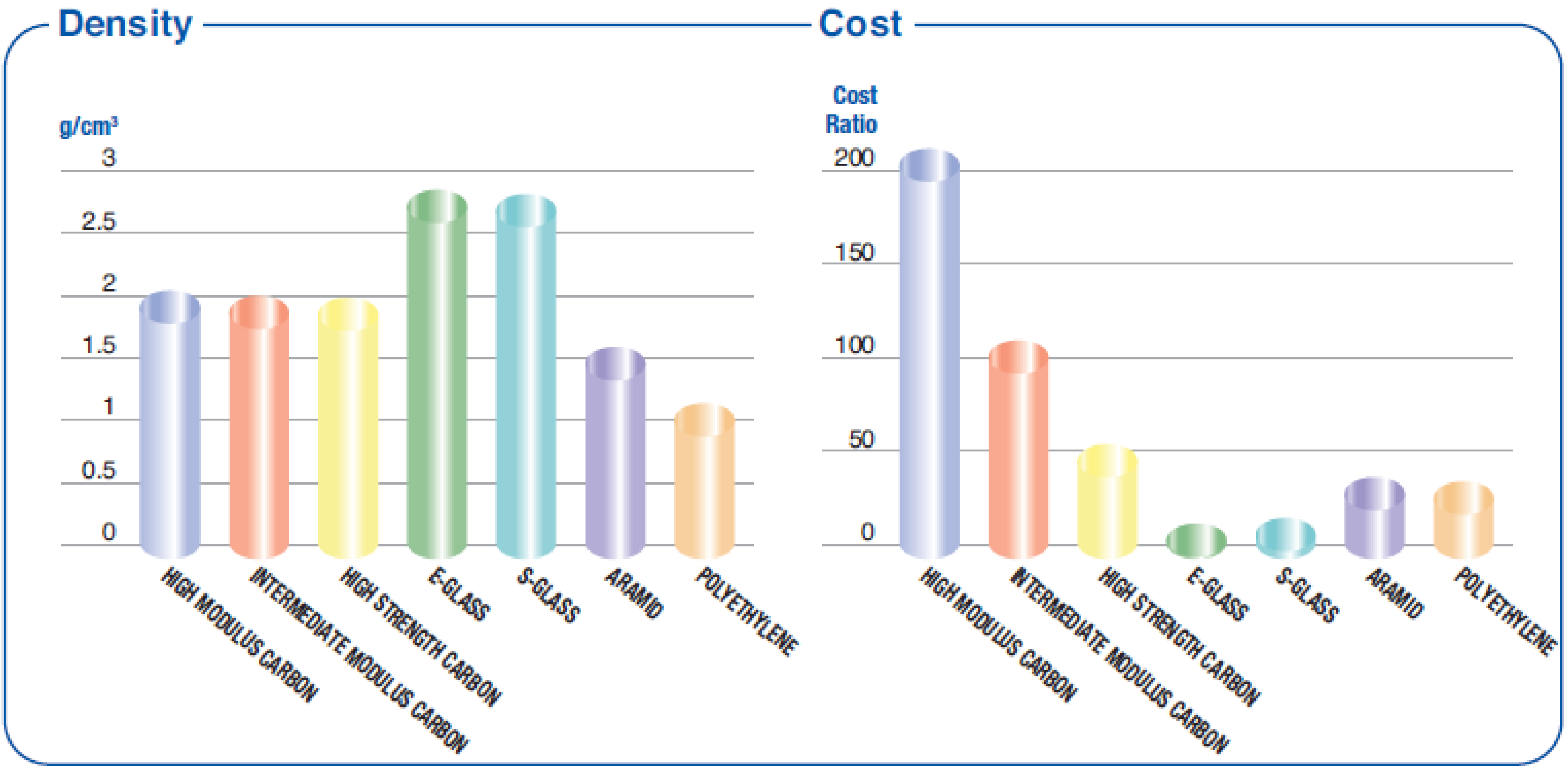
- New requirements of materials: thinner, smaller, faster interconnect, thermal resistance, ultra-thin dielectrics, small-hole formation and high temperature resins.
- Recent developments materials improve: Dimensional stability and surface smoothness: patterning of smaller feature, reducing their DK, dissipation factor to meet the requirements for very high frequency RF and replacing glass reinforcement with laser process able materials to make laser drilling easier.
- Linear lamination ⇒glass filaments - instead of woven,
  very thin filaments
- Aramid paper reinforced laminates,
  using paper-like nonwoven aramid cloth
  with epoxy-resin impregnation,
  exhibit very good dimensional stability with near-to silicon CTE,
  smooth surface and can be easily processed by laser.

Video **Video1**

Glass reinforcements used for fiberglass are supplied in different physical forms, microspheres, chopped or woven.

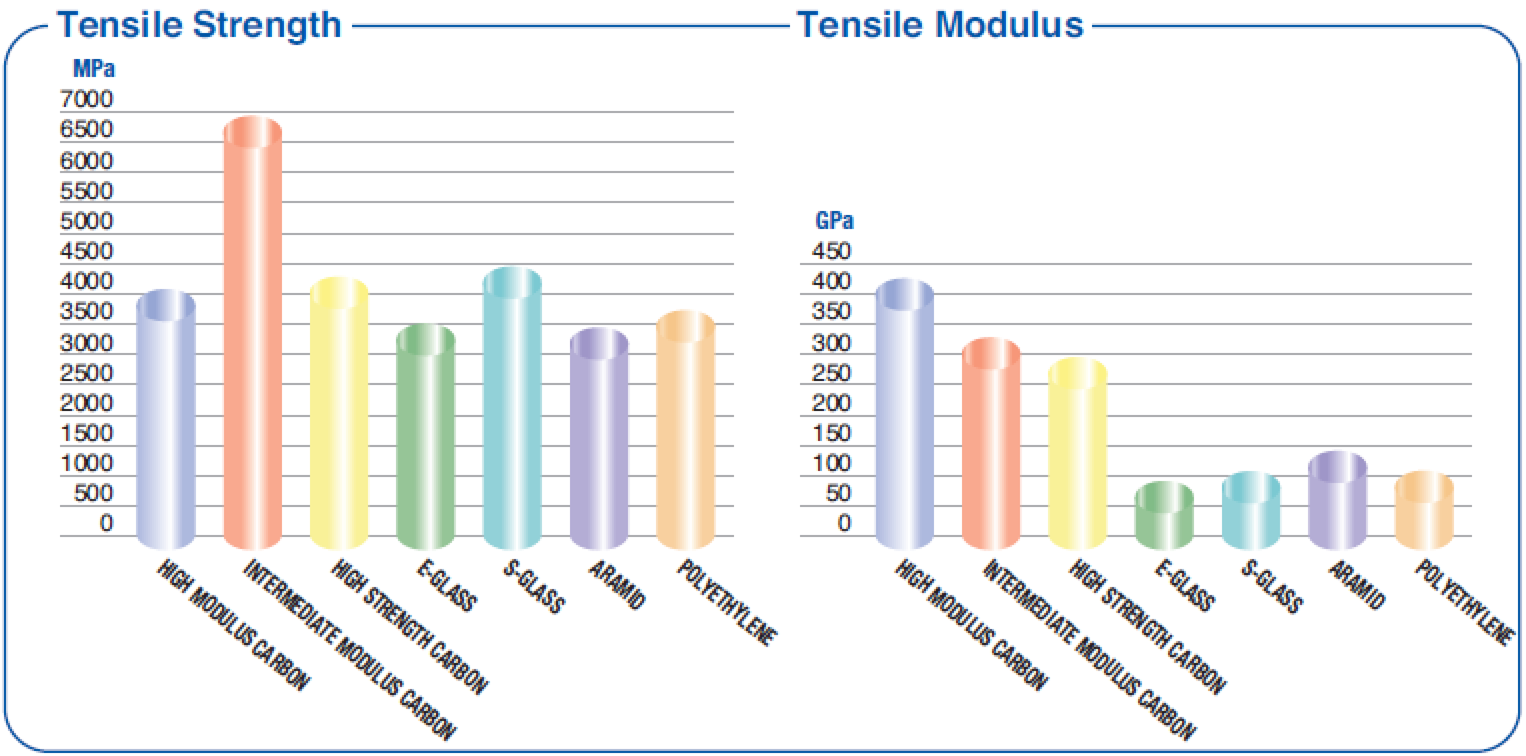
Criteria for Fiber Selection

Density and Cost

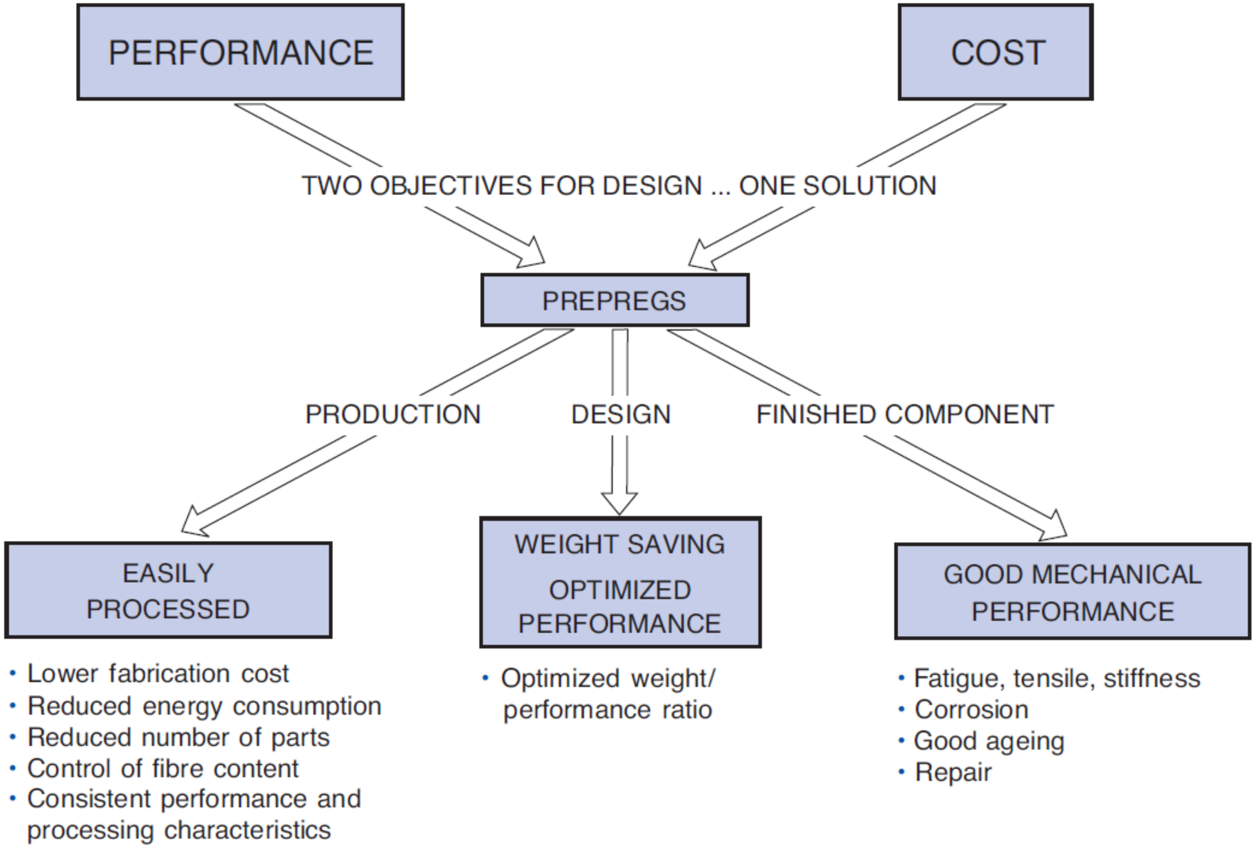


Criteria for Fiber Selection

Strength and Modules



Performance and Cost

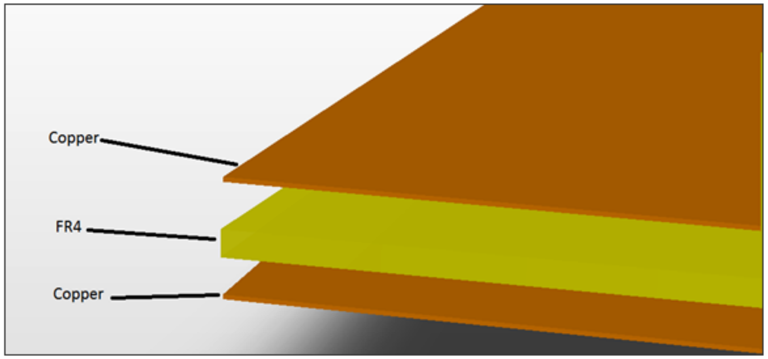


Core Material

- Base material, or the insulating board of a rigid PWB, is a sheet of laminate reinforced resin. Epoxy, phenolic, and polyimide resin
- Reinforcing materials, or fillers are typically glass cloth, paper, asbestos, aramid, nylon.
- <u>Main parameters</u>, Glass transition temperature (Tg), hardness, brittleness, elastic modules, coefficient of thermal expansion(CTE), specific heat.

<u>Core Laminate types:</u>

- Organic resin
- Inorganic filler
- Copper conductor

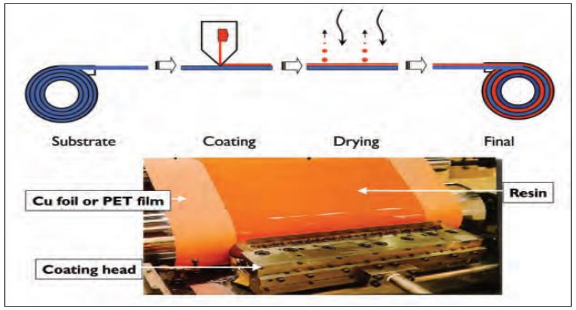


<u>The process</u>

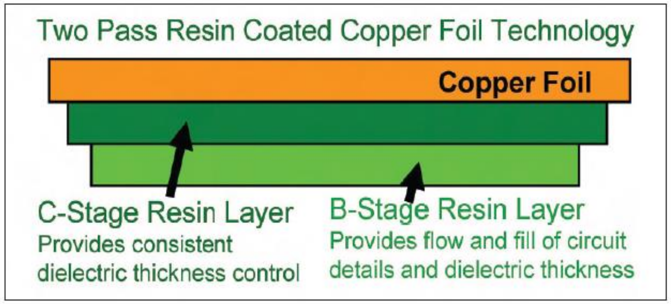
- Epoxy-resin suitably blended
- Filler material in the form of glass cloth
- General Copper foil of required thickness : ~ 9µm, 18µm, 35µm, 70µm

Non-Reinforced Materials-Resin Coated Copper (RCC) Foil

- The limitations of fiberglass-reinforced dielectrics look for alternative dielectric solutions. Problems with laser drilling (poor hole quality and long drilling times), thickness of woven fiberglass.
- To overcome these issues the copper foil was utilized as a carrier for the dielectric so it could then be incorporated into the PCB.
- Copper goes through a coating head and the resin is deposited on the treated side of the copper, Then goes through drying ovens for curing, or continue to B staged to fill the areas around the internal circuitry and bond to the core
- After coated the first layer, coated again in second layer to ensure minimum thickness between layers. With all the benefits of RCC foil, always there are concerns over the lack of reinforcement in terms of dimensional stability and thickness control. Dielectric thin layers as 25 microns are available allowing for very thin multilayer products.
- RCC foils always cost more than the equivalent prepreg, but can actually result in a less expensive product when laser drilling time is taken into consideration. When the number of holes and size of the area increase, the improved throughput of laser drills is more attractive.



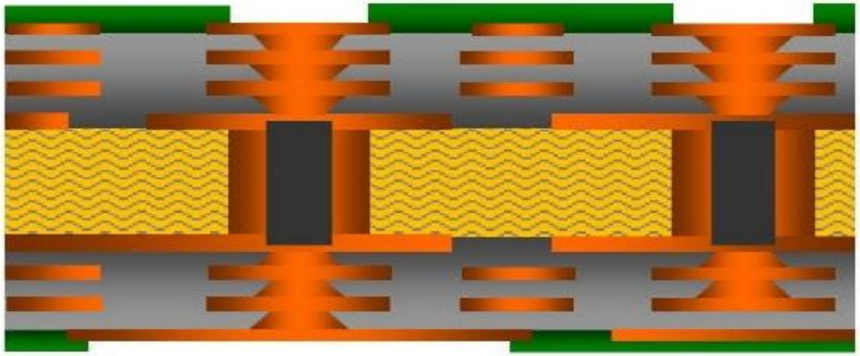
Roll to roll process



Two-stage product

Build-up Technology

- The development of ultra-thin stacked chip scale packaging (UT/CSP) become essential to increasing functionality and higher memory capacity with more complex and efficient memory architectures in small form factor packages
- In the packages, the wafer must be thinned, the conventional die attach (DA) paste material and the assembly method cannot be applied to handle such thin dies.
- The alternative is build-up technology, one core and copper layers which are isolated between them by glue.
- Wafer-level thin adhesive films combined with the corresponding lamination technique provides an alternative solution. However, thinner substrate may cause poor connection reliability due to warpage increased at soldering process. To solve this problem, new thermosetting resins having low coefficient of thermal expansion (CTE), high modulus and high glass transition temperature were investigated.

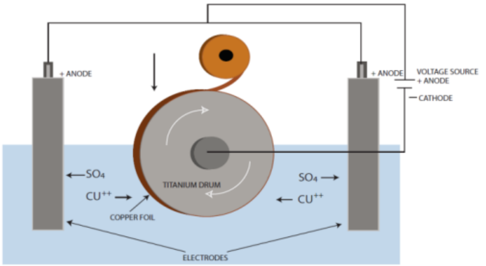


Copper Foil Process Non-Reinforced Materials

<u>Two types of copper substrate</u>: <u>Electrodeposited copper, standard foil (ED), or “Rolled“ (RA).</u>

The difference between them is the fabrication process and the treatment on the backside to enhance bonding adhesion.

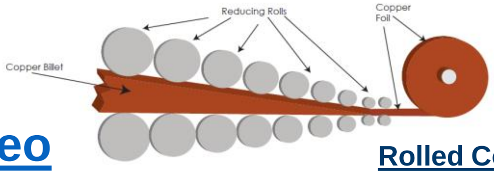
- **<u>Electrodeposited (ED) -</u>** Copper material is dissolved and electrolyzed by means of high current density in the electrolytic equipment. Copper component contained in electroplating solution is deposited on cathode surface of Titanium drum. Video
- During the drum is rotating, thickness of the deposited copper will be increased, then the copper with required thickness is peeled and wound by winding roll.



<u>Electrodeposited Copper Manufacturing Process</u>

- In order to give a required characteristics for Printed Circuit Board (PCB), this machine treats copper chemically and electrochemically by multiple immersion and washing for accomplishment. This machine is consisted of unwinder, treatment tanks, dryer, rewinder and all the related parts continuously to treat Matte side and Shiny side of the copper foil.
- **<u>Rolled - annealed copper (RA)</u>** is made by rolling an ingot to very thin foils. The grain structure is horizontally oriented. The rolling causes stress in the foil and must be heat annealed to remove the stress. This causes rolled-annealed copper to have about 1/2 the peel strength of electrodeposited copper. This means rolled-annealed copper performs better at frequencies above 13GHz.

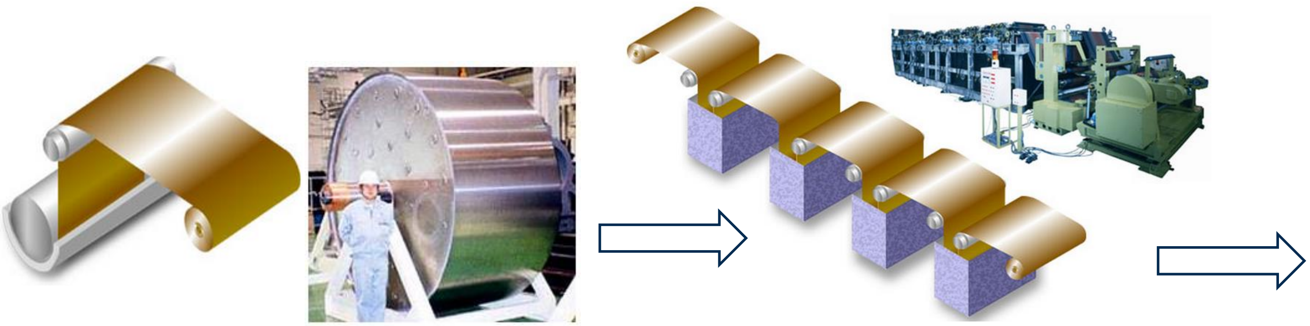
Video

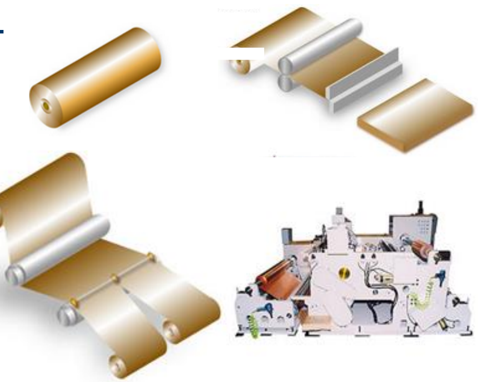


<u>Rolled Copper Manufacturing Process</u>

Copper Foil Process Non-Reinforced Materials

Copper foils are being made thinner for finer lines and spaces, profiles are being reduced to improve imaging and to encourage higher frequency. Foil should be extremely smooth, to reduce signal losses at GHz frequencies.



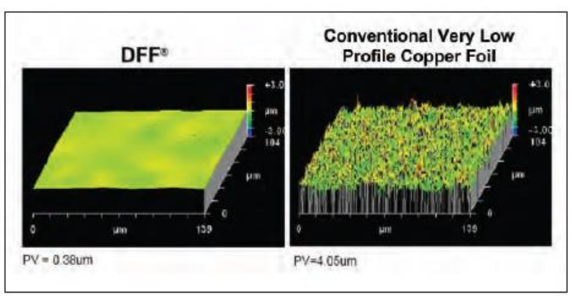


** Various surface treatments that can be applied to copper foil: copper or copper-oxide Thermal Barriers: coating of zinc, nickel, or brass.

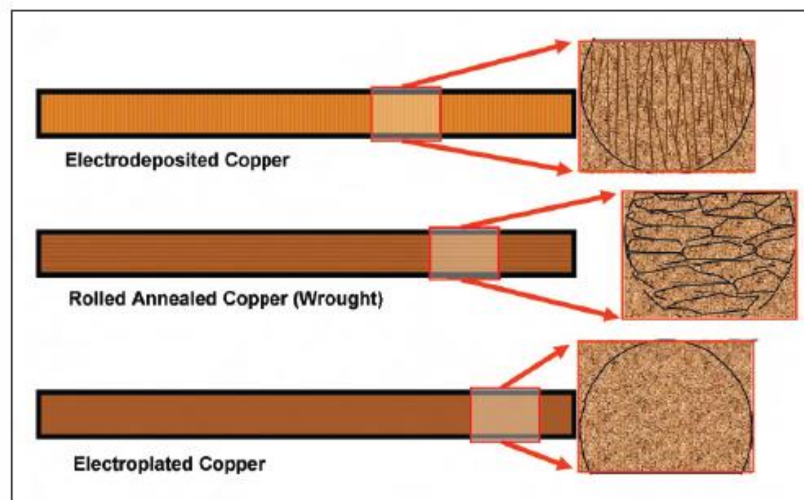
** The coating can prevent thermal or chemical degradation of the foil to resin bond during manufacture of the laminate.

** Special minuscule anchor nodules and chemical treatment to improve adhesion, peel strength and bonding to prepregs

DFF- Dual Flat Foil



Main types of copper foil

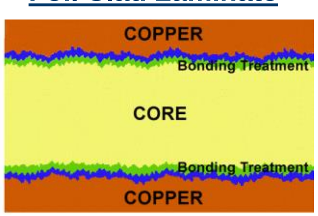


Copper Foil Process - Non-Reinforced Materials

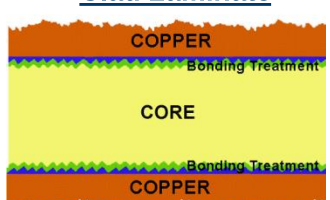
Copper foil used for serves several functions

- Power handling requirements, thin copper won't handle as much power as thicker copper, and too much power routed through a small cross section could result in overheating and burnout.
- Impedance and line loss are affected by the cross sectional area of the copper foil.
- Size and spacing of the copper traces that must be etched on the various layers, very fine lines and narrow spacing will require thinner copper.
- Heat dissipation that must be handled by the copper especially in inner layers, more capacity it has to dissipate heat.
- Other factors such as inner layer bonding which might require special copper properties or finishes.
- Surface roughness of the foil will impact the loss characteristics of a transmission line.
- If copper foil is used for foil lamination the finish on the copper is critical and must be compatible with the resin system employed.

Standard Foil Clad Laminate



DST Foil ® Clad Laminate



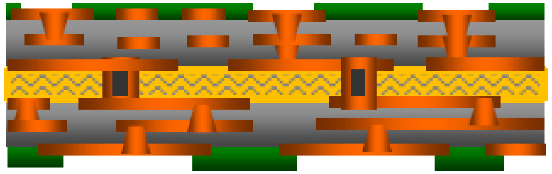
Drum Side Treated Foil

Build-up Warpage Reduction

- As VLSI (Very-Large-Scale Integrated) technology evolves toward smaller features, the most important problem for the application of coreless substrates for high-end BGAs is warpage reduction during a reflow process.
- PTFE- Teflon and Liquid Crystal Polymer (LCP) are low-loss material with excellent RF performance up to mm-wave frequencies, but these materials are more expensive than other organic materials, have high CTE and difficulties in multilayer processing.
- The change is to use glass cloth perpreg low loss and low warpage, as a coreless substrate stack material 50um thickness 400mm X 250mm size.
- **Semi-Additive primer (SAPP) is used to increase the adhesion between the flat copper and prepreg**.
- Material used in IC substrates are usually halogen-free, low CTE, replaced with new method that developed. New method is to fasten the coreless substrate during manufacturing by fastening the frame with low-cost of high performance.
- **Polyimide, BT** - e.g. MCL E-700G, E-679FG **Hitachi Chemical**, HL830HS, HL832NS of **Mitsubishi Gas Chemical** or **ABF** core GX13 or GX92 **Ajinomoto Build-up Film**.
- Ajinomoto is now working on next generation materials with high Tg, low Dk and low CTE to meet the low loss and performance
- The new materials are also targeting the needs of coreless build-up substrates.

NaNya Technology Roadmap

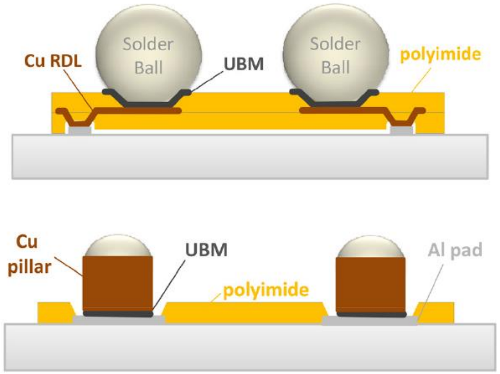
CSP structure



Polyimide – (PI) mass production since 1955

Thermosetting or Thermoplastic

- Thermal stability, good chemical resistance, excellent mechanical properties, and characteristic orange/yellow color.
- Tend to be insoluble and have high softening temperatures, good adhesion with metal layer
- Glass fiber reinforcements have high tensile strength, maintained during continuous up to 452 °C and for short excursions as 704 °C.
- Polyimide materials are lightweight, flexible, not affected by used solvents and oils, also resist weak acids.
- Used as electronics flex boards - flexural moduli 3,000,000 psi.
- Semiconductor industry uses polyimide as a high-temperature adhesive, as an insulating and passivation, as a layer in the manufacture of digital semiconductor and MEMS, in chips as a mechanical stress buffer, and as photoresist.
- Advantages: Good Chemical Resistance, Thermal Stability, High Heat Resistance, Flame Retardant, High Strength, Solvent Resistant, High Stiffness.
- Disadvantages: Difficult to process, High temperatures required, Limited resistance to hydrolysis, High costs.



SPTS Schematic Polyimide as layer

BT - Glass Clothes Copper Clad Laminate (CCL)

Include additional polymerization type with two main components B (Bismaleimide) and T (Triazine Resin), cyanate ester and polyimide.

Blends of various ratios designed to yield improvement.

- Low cost organic substrate compared to Teflon and LTCC, stable multilayer packaging, high-performance, ease-of-processing and available. All-in-one solution for high frequency designs, the choice for electronics packaging.
- Stability is 4 times higher than that of polyimide. Good for rigid substrates compared to FR4 based epoxy, and more advanced and higher-performing from resin-based Bismaleimide-Triazine (BT)
- **Moisture absorption and diffusion behavior have a significant impact on package reliability,** In BT/glass laminates all moisture will be absorbed by the BT resin
- <u>Cured BT Resin Features:</u>

  High heat resistance (Glass transition temperatures: 225~330°C)

  Excellent long-term resistance of 160~230°C

  Excellent thermal shock resistance

  Lower dielectric constant and dissipation factor

  High Cu ion migration resistance

  Excellent mechanical properties

  Excellent chemical resistance

  Excellent abrasion resistance

In fact the standard substrate material for BGA's and CSP laminates. Since BT material is considered as low-cost substrate, it is suitable in all applications where FR4 are used today.

<u>Companies involved</u> : Mitsubishi Gas Chemical, Hitachi Chemical, Asahi APPE Technology
Nelco International, Matsushita Electric (Panasonic), Sumitomo Bakelite and more…..

MGC - Mitsubishi Gas Chemical - BT

The newest progress about Base Material used for IC Package Substrate in Japan

- The rapid development of IC package substrate, drive IC package substrate with copper clad laminate (CCL), class of products with high technological content and high added value. improves the security in the IC package substrate
- Mitsubishi Gas Chemical Company BT resin substrate material (more than 60% in the world), and come from behind of Matsushita Electric company (Panasonic) in order to improve the security in the IC package substrate.
- Plate surface appearance of brown, an epoxy-modified BMI / CE Resin
- Conventional types for IC package: **HL830, HL832 become specifically for IC package substrate resin-based body (supporting CCL, prepreg)**
- Other typical: HL820, HL810, HL870, HL 870M, HL 950, HL 955.
- Six new markets for the IC package on the basis of HL832 CCL varieties, good lead-free soldering, different in Young's modulus, rigidity, thermal expansion, tensile strength and peel strength. Species thinner CCL HL832HS (HS) prepreg thickness of the thinnest is 30 microns, **The insulating layer is made of two prepreg stacked together**.
- **The reason - mainly in the composition of the epoxy-modified BT resin filler.**

Copper Clad Laminates	Prepregs	CCL Thickness	Prepreg Thickness
CCL-HL832NX Type A	GHPL-830NX Type A	0.06, 0.1, 0.15, 0.2-0.8(0.1step), 0.25, 0.35, 0.45mm	0.03, 0.035, 0.04, 0.045, 0.05, 0.06, 0.07, 0.1mm

MGC - Mitsubishi Gas Chemical - BT

Performance characteristics of various Trademark

CCL brand		Prepreg Trademark	Features	Use	
覆銅板牌號		半固化片牌號	性能特點	用途	
CCL-HL832		GHPL-830	常規 IC 封裝用標準型的 CCL。是應用時間最長的品種 Conventional IC packages with standard type CCL	BGA、PGA	
CCL-HL832NB		GHPL-830 NB	無鹵化，其他性能同 CCL-HL832 Halogen-free, with other properties	BGA、PGA	
CCL-HL832EX（New Material）		GHPL-830 EX	適應無鉛化的新型 CCL。有無機填料；高剛性、低熱膨脹率 CCL. Inorganic filler High rigidity, low thermal expansion	BGA、PGA	
CCL-HL 832HS	Type LT	GHPL -830 HS	高剛性的基板材料。適應無鉛化；可直接進行 CO_2 鐳射的通孔加工 Highly rigid CO2 laser machining	倒晶片安裝的 IC 封裝	Flip chip mounting IC package
	Type HS	GHPL -830 HS	高剛性、薄型化的基板材料。適應無鉛化；可直接進行 CO_2 鐳射的通孔加工 High rigidity and thin CO2 laser directly through	有薄型化、高密度要求的 IC 封裝	For thin & high Density requirements IC package
CCL-HL832TF		GHPL -830 TF	耐韌性優良的薄型基板材料。適應無鉛化； Excellent toughness resistant thin, Lead-free adaptation	CSP、存儲卡	CSP Memory card
CCL-HL832NX		GHPL -830 NX	無鹵化，其他性能同 CCL-HL832 HS，有優異的浸焊耐熱性、高剛性、低熱膨脹率 Excellent differentiation dip soldering heat resistance high rigidity, low thermal expansion	BGA、CSP、倒晶片安裝的 IC 封裝	BGA, CSP Flip chip mounting IC package

Mitsubishi Gas Chemical - BT

Main performance comparison of various IC packages to be in BT resin substrate material

			單位 Unit	HL832	HL 832NB	HL 832EX	HL832 HS(LT)	HL832 HS(HS)	HL 832NX	HL 832TF
Surface potential	表面電阻		Ω	$5\times10^{14-16}$	$5\times10^{14-16}$	$5\times10^{14-16}$	$5\times10^{14-16}$	$5\times10^{14-16}$	$5\times10^{14-16}$	$5\times10^{14-16}$
Volume resistivity	體積電阻率		Ω-cm	$5\times10^{12-14}$	$5\times10^{12-14}$	$5\times10^{12-14}$	$5\times10^{12-14}$	$5\times10^{12-14}$	$5\times10^{12-14}$	$5\times10^{12-14}$
Insulation	絕緣電阻		Ω	$5\times10^{13-15}$	$5\times10^{13-15}$	$5\times10^{13-15}$	$5\times10^{13-15}$	$5\times10^{13-15}$	$5\times10^{13-15}$	$5\times10^{13-15}$
CTE	玻璃化溫度	TMA	℃	210	220	210	215	215	215	210
		DMA	℃	180	190	185	185	185	190	185
Hot Swollen Swell Department Number	熱膨脹係數	X 方向	ppm/℃	15	14	14	13	14	14	14
		Y 方向	ppm/℃	15	14	14	13	14	14	14
		Z 方向 $\alpha 1/\ \alpha 2$	ppm/℃	55 /220	45 /160	45 /160	35 /140	45 /160	30 /120	45 /120

Mitsubishi Gas Chemical - BT types

Another BT Materials for IC Plastic Package List

Commodity	CommDescription	Grade	Manufacturer	Origin	MI	Density	Application
BT Copper Clab Laminate	standard BT material	HL832	MGC	JAPAN			IC plastic packages (PGA, BGA)
BT Copper Clab Laminate	standard BT material	HL830	MGC	JAPAN			IC plastic packages (PGA, BGA)
BT Copper Clab Laminate	High stiffness materials	HL832HS	MGC	JAPAN			Substrates for FC-PKG
BT Copper Clab Laminate	Thin materials	HL832TF	MGC	JAPAN			Substrates for CSP and memory cards
BT Copper Clab Laminate	Low DK	HL832MG	MGC	JAPAN			Substrates for RF modules, power amplifier modules, bluethooth modules
BT Copper Clab Laminate	Halogen Free BT mateials	HL832NX	MGC	JAPAN			Full Green IC packages
BT Copper Clab Laminate	Halogen Free BT mateials	HL832NB	MGC	JAPAN			Full Green IC packages
LE Sheet (Alumimum Sheet)	Entry Sheet or Mechanical Drilling	LE300	MGC	JAPAN			0.25mmΦ
LE Sheet (Alumimum Sheet)	Entry Sheet or Mechanical Drilling	LE400	MGC	JAPAN			0.2~0.25mmΦ or High Layer count
LE Sheet (Alumimum Sheet)	Entry Sheet or Mechanical Drilling	LE800	MGC	JAPAN			0.075~0.1mmΦ

Panasonic - Matsushita Electric Company

IC package substrate - MEGTRON series, developed to achieve high capacity and high speed transition.

- In order to meet the next generation of ultra-thin package, Matsushita Electric Company's developed FC lamination method which the multi-layer package substrate is CCL.
- In Japan Matsushita Electric Company's products now occupies the first place in the overall market share of such products (about 80%) the CSP substrate CCL and 20% of Japanese market demand.
- Process improved the accuracy of plate thickness and can be controlled within ± 0.5%, to meet specific customer needs. CCL thickness of the product specification, there are 20μm, 30μm, 40μm, 50μm, 60μm, 100μm and so on. Matsushita Electric has two series of four varieties in terms of IC package substrate, Each IC package with CCL each species significant performance characteristics and a clear application markets, respectively

Polyphenylene ether (PPE)
Modified ring
Epoxy resin

main tree
Lipid composition

Product
licensing

Main performance
characteristics

	主要樹脂組成	產品牌號	主要性能特點
“METRON” 系列	聚苯醚（PPE）改性環氧樹脂	MEGTRON3 R-5715（SL）	低 Dk、耐熱性及低吸濕性優異、BGA 焊球的拉脫強度高
		MEGTRON3 R-5715（ES）	與 R-5715 （SL）基本性能同等，並且還具有高彎曲彈性模量、低膨脹係數
“GX” 系列	高性能環氧樹脂	R-1515 T	低膨脹係數、高彎曲彈性模量、無鹵化
		R-1515 B	低膨脹係數、高彎曲彈性模量、薄型化、UV 遮蔽性優異

Low Dk, excellent heat resistance and low moisture absorption, BGA solder balls High pull-off strength

Substantially equal performance, and further Having High flexural modulus , low CTE.

Low CTE, high flexural modulus, non-halogenated

Low CTE, high flexural modulus, thin, Excellent UV shielding

High performance
Epoxy resin fat

Panasonic - Matsushita Electric Company

The main performance IC package substrate material

			Unit	Test method				
			單位	試驗方法	R-1515 B	R-1515 T	R-5715 SL	R-5715 ES
Volume resistivity	體積電阻率		MΩ-m	JIS C6481	6.5×10^{6}	1.0×10^{7}	6.5×10^{7}	—
Surface potential	表面電阻		MΩ	JIS C6481	2.9×10^{8}	2.9×10^{8}	1.3×10^{9}	—
Insulation	絕緣電阻		MΩ	JIS C6481	8.7×10^{7}	8.3×10^{7}	7.0×10^{8}	—
glass transition	玻璃化溫度（Tg）		℃	TMA	180	187	173	—
			℃	DMA	205	228	203	—
Thermal expansion IN Z	熱膨脹係數	X 方向	ppm/℃	TMA	12	11	14	—
		Y 方向	ppm/℃	TMA	12	12	15	—
		Z 方向 $\alpha 1/\alpha 2$	ppm/℃	TMA	30/140	27/140	61/260	27/140
Permittivity	介電常數	1MHz		JIS C6481	5.2	5.2	4.4	4.5
		1GHz		IPC TM-650	4.8	4.6	4.1	—
Dielectric loss	介質損失角正切	1MHz		JIS C6481	0.012	0.012	0.008	0.007
		1GHz		IPC TM-650	0.011	0.009	0.013	0.013
Peel strength	剝離強度(Cu:18 μm)		kN/m	JIS C6481	1.0	1.2	1.5	1.0
Absorbent	吸水率		%	JIS C6481	0.12	0.20	0.11	—
Thermal stratification time	熱分層時間（T288）		分	IPC TM-650	> 120	17	30	—
Tensile strength	抗張強度（縱）		MPa	JIS C6911	—	23	27	—
Bending strength	彎曲強度		KN/cm^2	JIS C6481		47	62	
Heat Conduction	熱傳導率		W/mk	鐳射 flash 法		0.64	0.32	
Heat resistance	耐熱性 (>)		MPa	JIS C6481	280℃60 分	260℃60 分	250℃60 分	250℃60 分
Flame retardant	阻燃性（UL94）			JIS C6481	V-0	V-0	V-0	V-0

Panasonic - Matsushita Electric Company

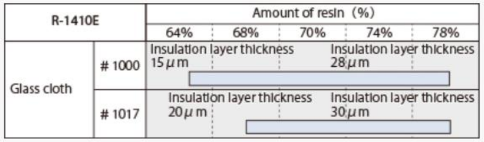
Laminate R-1515E Halogen Free & Narrow Pitch IC Substrate Materials (Black type or natural)

Preperg R-1410E

Ultra-thin circuit board materials R-1515E

MEGTRON GX

Laminate(Black) **R-1515E** Prepreg(Natural color) **R-1410E**



General properties

Item		Test method	Condition	Unit	MEGTRON GX R-1515W	MEGTRON GX R-1515A	MEGTRON GX R-1515U	MEGTRON GX R-1515D	MEGTRON GX R-1515E
Glass transition temp(Tg)		DMA*3	A	°C	250	205	275*1	275*1	270*1
CTE x-axis	below Tg (α1)	TMA*4	A	ppm/°C	9-10	12	0.5*1	3.5*1	9*1
CTE y-axis					9-10	12	0.5*1	3.5*1	9*1
Flexural modulus	25°C	JIS C6481	25°C	GPa	35	27	32	30	33
	250°C		250°C		21	10	14	11	18
Peel strength	35μm	IPC TM-650 2.4.8	A	kN/m	1.2	1.3	–	–	–
	12μm				0.8	0.9	0.7	0.7	0.9
Dielectric constant	1GHz	IPC TM-650 2.5.5.9	C-24/23/50	–	4.8	4.8	4.4	4.7	4.7
Dissipation factor	1GHz			–	0.015	0.015	0.010	0.010	0.011
Resistivity	Volume	IPC TM-650 2.5.17.1	C-96/35/90	MΩ-cm	1.0E+09	1.0E+09	1.0E+09	1.0E+09	1.0E+09
	Surface			MΩ	1.0E+08	1.0E+08	1.0E+08	1.0E+08	1.0E+08
Flammability		UL	C-48/23/50	–	94V-0	94V-0	94V-0*2 (equivalent)	94V-0*2 (equivalent)	94V-0*2
Decomposition temp(Td)		TGA	A	°C	390	390	400	400	390

*1=0.1mm
*2=0.2mm The other sample thickness is 0.8mm.
*3 R-1515W,R-1515A:Measurement in bending mode.
R-1515U,R-1515D,R-1515E:Measurement in tensile mode.

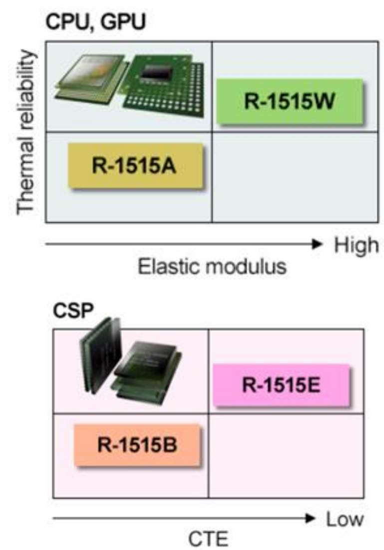
Panasonic - Matsushita Electric Company

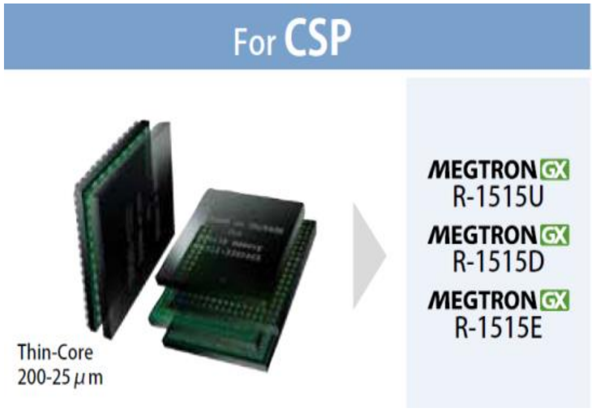
The main performance IC package substrate material

- IC package substrate thinning is very focused High temperature to maintain high performance rigid plate, R-5715 ES ("MEGTRON" series) showed **good adaptation of this thin IC package substrate under high heat required**.
- Main Features: reduce the warpage in thin package substrate, corresponding to the small-diameter mechanical drilling, halogen-free, ensure the flame-retardant antimony free (UL94V-0).
- CCL for IC package substrate Matsushita Electric improved glass transition temperature, elastic modules and thermal expansion properties which help in reducing the warpage.
- IC package CCL breed "GX" series improved performance value. Three types developed to be applied for thin package board CCL (R-1515 T, R-1515 B, R-5715 ES).

Panasonic properties of materials

Panasonic part number material

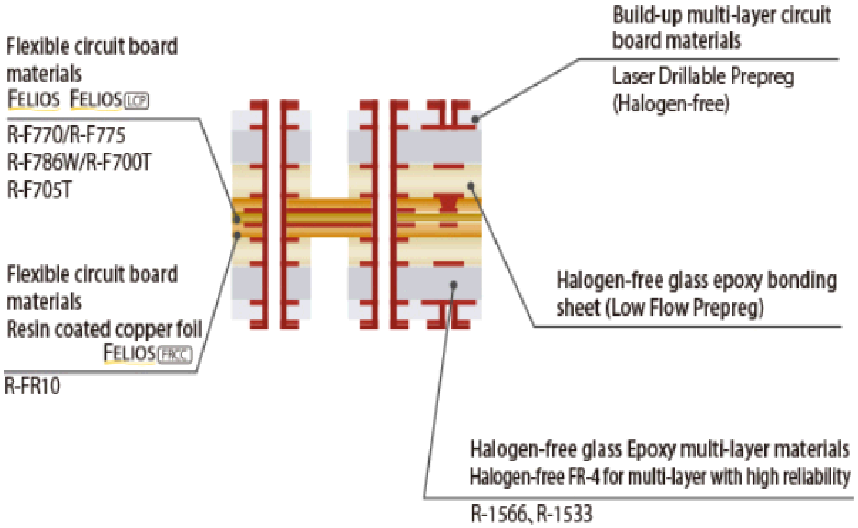


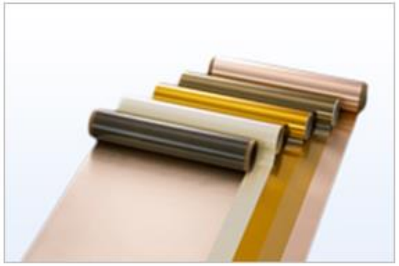


Panasonic - Matsushita Electric company

Flexible material - Felios type

Layer composition of rigid-flex board and suggestion of materials



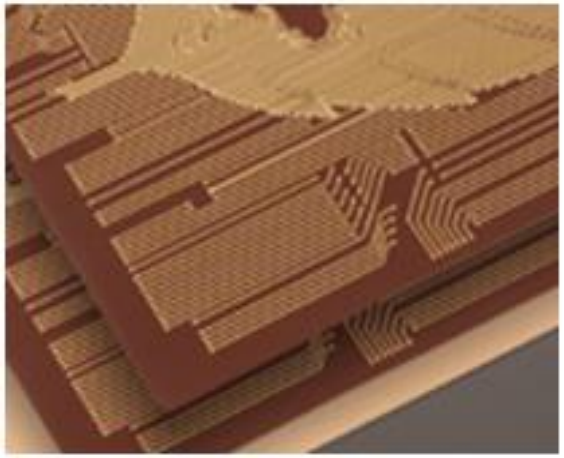


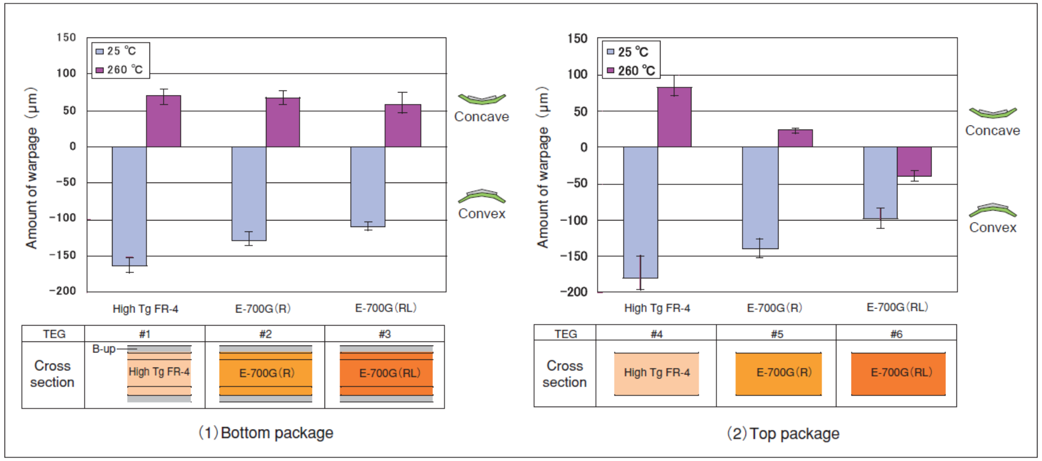
Resin coated copper foil FELIOS FRCC

Flexible Circuit Board Materials for Mobile Products "FELIOS" series

Hitachi Chemical - MCL - E-700G(R)

- Material for substrate MCL-E-700G(R) series type **S-Glass**, high heat-resistant for thin packages having a build-up structure with low warpage based on High -Tg Glass Epoxy.
- Low CTE in X, Y directions and high elasticity modulus, meets flammability standard UL94V-0 without using halogen.
- Generally a method to decrease CTE and increase the modulus of elasticity is to load a large amount of inorganic filler, but this method causes many problems at the drilling process because of overloading on drill bits.
- Thermosetting resins based on ring structure containing nitrogen show high elasticity, low thermal expansion and high incombustibility. However, these resins face many problems, including lack of solubility.
- Hitachi Chemical solves this problems by introducing substituent for solubility that reactive in low temperature.
- Can be applied to build-up structures by semi-additive process, and can support narrow and high density wiring.





Hitachi Chemical - MCL - E-700G(R)

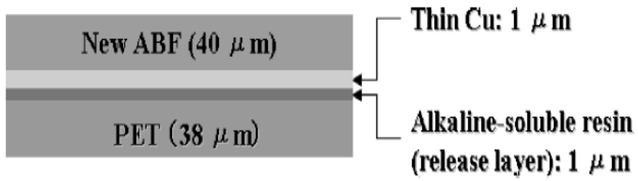
Properties of MCL-E-700G（R）and E-700G（RL）

Property		Condition	Unit	E-700G(R)	E-700G(RL)	High Tg FR-4
Glass transition temperature		TMA(tensile)	℃	250-270	250-270	165-175
		TMA (compression)		220-240	220-240	165-175
		DMA		295-305	295-305	200-220
Thermal decomposition temperature		TGA(Td5)	℃	400-420	400-420	340-360
Coefficient of thermal expansion	X, Y	α1(tensile)	ppm/℃	7-9	5-7	13-15
		α2(tensile)		5-7	5-7	10-12
		α1(compression)		10-12	8-10	13-15
		α2(compression)		4-6	3-5	10-12
	Z	α1(compression)		15-25	15-25	23-33
		α2(compression)		90-120	90-120	140-170
Copper foil peel strength		12 μm(Std)	kN/m	0.9-1.1	0.9-1.1	0.8-1.0
Modulus of elasticity		A	GPa	32-34	34-36	23-28
Heat resistance	T-288	TMA	min	＞60	＞60	＞60
Heat resistance of the package		260℃ reflow	cycle	＞20	＞20	＞10

List of characteristics

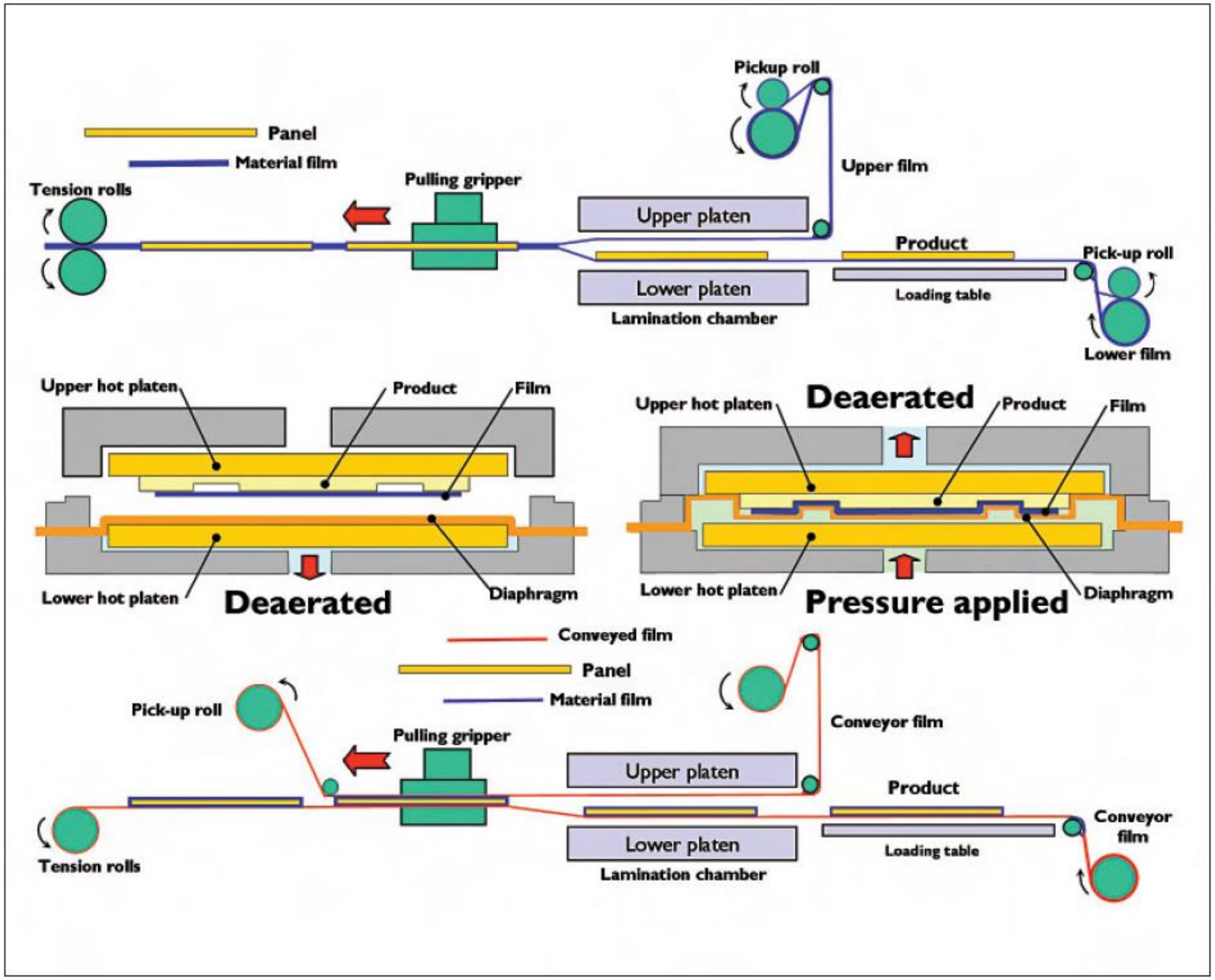
Ajinomoto Buildup Film (ABF)

- Ajinomoto build-up films (ABF) layers are widely used as package substrates. The increasing demand for electronic devices with advanced functions, package substrates are required to be miniaturized with high-density circuit wirings.
- New ABF combination, low CTE, high Young's modulus, demonstrated as a high-tech resin coated copper (RCC) film for fine line formation. **ABF materials are improved with the progress of IC.**
- Very thin copper transfer film and ABF-prepregs which are glass-cloth materials impregnated with ABF resin compositions, are proposed for use as core materials, especially for CSP substrates.
- These new applications can achieve the high adhesion between the copper and insulating layers.
- The material is a series of very thin film dielectrics made with **epoxy/phenol hardener**, **cyanate ester/epoxy, and cyanate ester with thermosetting olefin.**
- The epoxy type is also available halogen-free, the thin film (15 – 100um thick) is supported by a 40um PET film and protected by a 16um OPP cover film.
- **The material is vacuum laminated in special machines using.**



Construction of ABF-RCC (cross section).

Ajinomoto Buildup Film (ABF)



Details of the material flow through the vacuum laminator and the lamination step

Process:

1. Surface preparation of core dielectric and copper
2. Dry core (130° C for 30 min)
3. ABF auto-cutting, remove cover film, and placement
4. ABF vacuum lamination and metal hot-press
5. Remove PET film and post-cure (170-190° C for 30 min.)

ABF films, like the liquid dielectrics and dry films, have to be semi-additively metallization.

The conditions and steps will determine the resulting copper peel strengths

Ajinomoto Build-up Film (ABF) New RCC

- Coating and drying the alkaline-soluble resin (1μm thick, release layer) on PET (38μm thick), and depositing 1μm thick copper layer on the release layer by vacuum evaporation.
- Thin copper transfer film was hot laminated with the new 40μm thick ABF to get the RCC.
- Cure conditions for the ABFGX13: 180 degC for 90 min, for the new ABF; 190degC for 90 min
- New ABF-RCC process similar to SAP:

  * Lamination of the ABF-RCC to the core board with through holes (TH) and circuit patterns

  * Curing of the new ABF

  * Removal of the PET film

  * Laser drilling for via formation

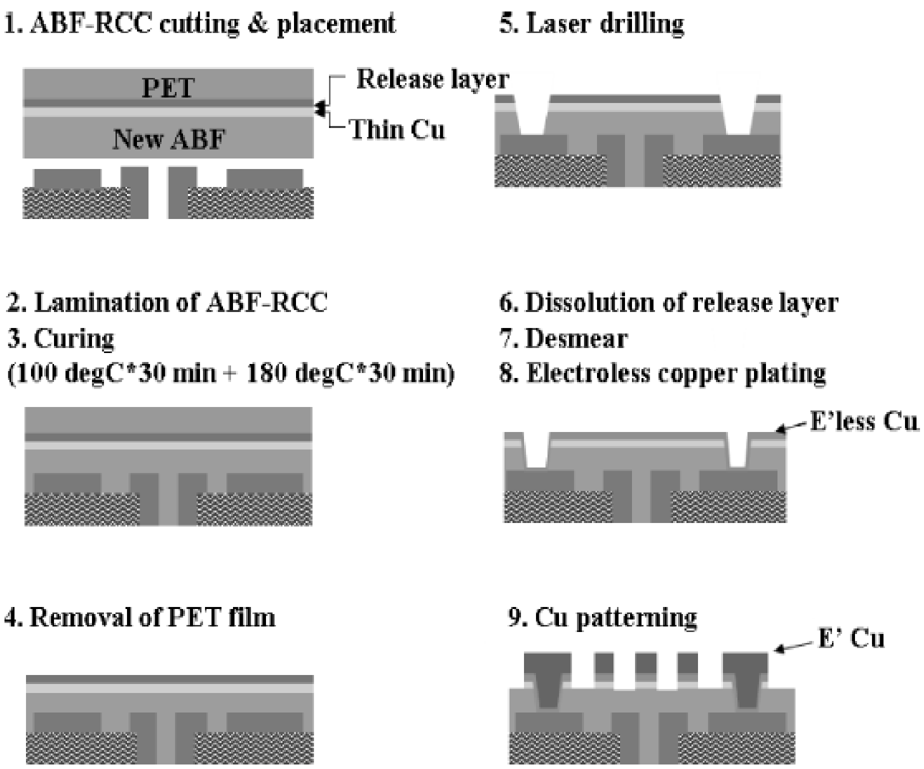
  * Dissolution of release layer

  * Desmear for cleaning the via bottoms

  * Electroless copper plating

  * Patterning

Advantages of this process: during via laser formation the release layer on the thin copper prevents residues of seed layer.



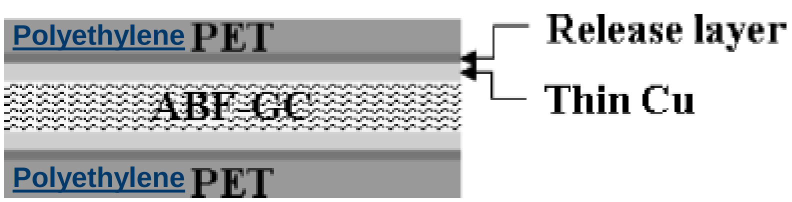
Manufacturing process using ABF-RCC

Ajinomoto Build-up Film (ABF) New RCC

- **CCL (Copper Clad Laminate) Consisting of ABF-Glass Cloth (GC) and Thin Copper Transfer Film/AGL-1020**

- Consists of thin copper transfer films and prepregs

- Resin composition of prepreg is similar to that of ABF and has the specific feature of high adhesion to smooth copper



Construction of AGL-1020

- Reliability tests showed the robust interface between ABF-GC and smooth copper, which seems promising for future fine-line core boards.

- Combining the copper transfer film with a new ABF, low CTE, high Young's modulus and low DK can provide material with high adhesion and very fine patterns - ABF-RCC, ABF-GC.

Test condition	Unit	AGL-1020
CTE x-y (25–150 degC) (tensile TMA)	ppm/degC	13
CTE x-y (150–240 degC) (tensile TMA)	ppm/degC	8
Tg (tensile TMA)	degC	180
Tg (DMA)	degC	190
Dielectric constant (Cavity perturbation, 5.8 GHz)	–	4.5
Loss tangent (Cavity perturbation, 5.8 GHz)	–	0.017
Flame retardancy (UL94)	–	≒ V0

General characteristics of AGL-1020

ABF-GX13GC - GC-prepreg for Build-up dielectric

◆ ***The Feature of GX13-GC***

- Lower CTE (x-y:23ppm)
- High Young's Modulus (over 11GPa)
- Decreasing the Warp of PCB
- Vacuum Laminator Applicable
- SAP (Semi-Additive Plating) Applicable
- Almost same process conditions as GX13 applicable

Adaptable to Coreless and Thin-core Package!!

◆ ***GX13-GC : 3 layers construction***

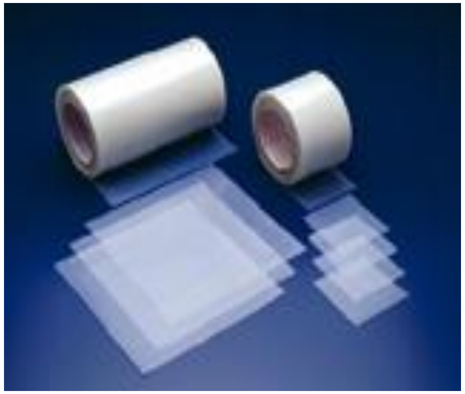
Base film
(38um release PET)

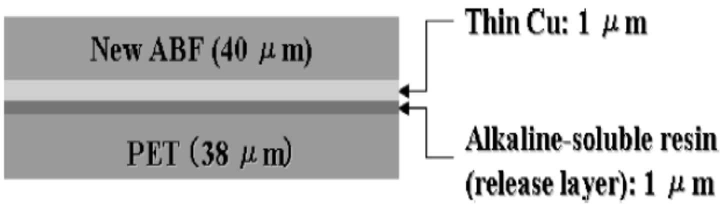
Total thickness of GX13-GC: 50 - 70 um
Glass Cloth :1027 (16um)

Separation film
(15um OPP)

Ajinomoto Buildup Film (ABF)

- PCBs using ABF is a semi-additive process (SAP) including the lamination and curing of the ABF resin composition.
- Laser vias, and a desmear process using an alkaline permanganate (strong oxidizing properties) solution to form micro anchors on the ABF surface prior to electroless copper plating as a seed layer for thicker electrolytic copper plating.
- This process provides high adhesion strength (peel strength) between the insulating layer and the plated copper by roughening the surface of the insulating layer. But this effect prevents very fine line formation of less than L/S = 15/15µm.
- Dielectric material and a manufacturing process can produce high adhesion strength with a smooth interface between an insulating layer and a conductive layer that strongly desired for future fine line formation.
- Additional ABF materials GXT31, GZ41 and GY11 for high speed transmission in IC.



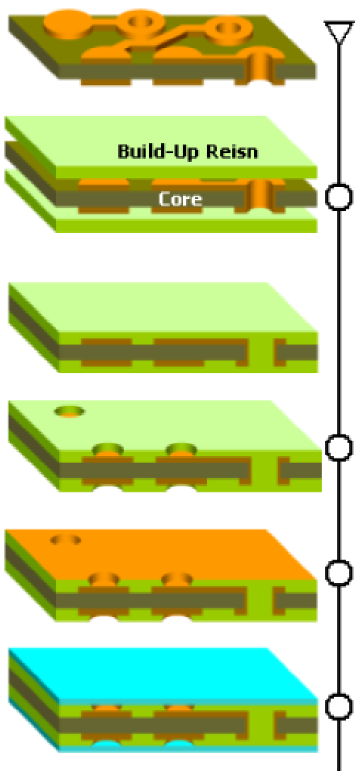


Ajinomoto ABF Laser Drillable Films

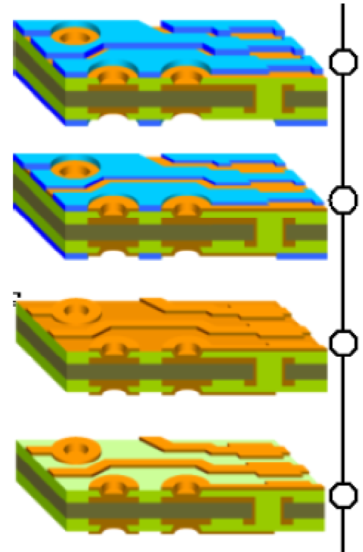
Hydrofluoric

ABF type	SH9k	GX3	GX13	GX60	GZ9-2	GZ11	GZ20	GZ30	TB
Resin	Epoxy	Epoxy-HF	Epoxy	Epoxy + phenol	Cyanate ester + epoxy	Cyanate ester + epoxy	CE + epoxy	CE+ epoxy	Cyanate ester + Olefin
Solvent residue (wt% ave)	2.8	2.8	2.8	3	2.0	2.0	1.7	1.7	3.2
Vacuum Lamination	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum viscosity (poise/^{0}C)	1400/145	1400/145	1400/145	3000/136	3100/104	3100/104	3200/90	9500/90	5500/106
Cure (^{o}C x min)	180 x 90			190 x 90					
CTE x-y (25-150^{0}C) (tensile TMA)	95	46	46	39	36	35	28	21	52
CTE x-y (150-250^{0}C) (tensile TMA)	180	120	120	114	105	100	75	58	- -
Tg (tensile TMA)	178	156	156	163	170	173	177	190	150
Tg (DMA)	200	177	177	185	195	201	210	205	190
Young's modulus (GPa)	4.0	4.0	4.0	5.1	4.9	4.9	7.1	7.8	4.9
Tensile strength (MPa)	93	93	93	104	109	109	130	125	86
Elongation (%)	5.0	5.0	5.0	3.6	3.5	3.5	2.8	2.3	2.1
Dielectric constant @ 5.8 GHz	3.4	3.1	3.1	3.3	3.2	3.1	3.1	3.2	3.0
Loss Tangent @ 5.8 GHz	0.022	0.019	0.019	0.025	0.009	0.012	0.010	0.008	0.006
Water absorption (100^{0}C, 1 h (wt%)	1.1	1.1	1.1	1.1	0.8	0.8	0.7	0.6	0.5
HAST L/S=20/20 um (130^{0}C, 85%, 3.3V)	>200h	>200h	>200h	>200h	>200h	>200h	>200h	>200h	>200h
Flame retardancy (UL94)	V0	V0	V0	V1	V1	V1	V1	V0-V1	- -
SIO_2 amount (wt%)	38	38	38	40	38	38	50	60	40
Status	Mass	Mass	Mass	U.D.	Mass	Samples	Samples	U.D.	U.D.

Coreless Manufacturing Substrate using ABF

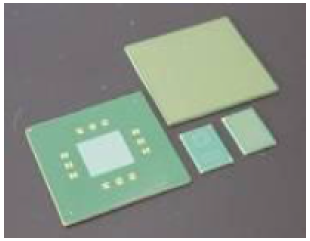


1. Preparation of core-boards Cu surface treatment & pre-drying (130-190degC*30min)
2. ABF placement on both side and vacuum lamination & metal hot-press
3. Pre-cure in a hot air clean over, 180degC*30min
4. Via formation by CO2 or UV-YAG laser
5. Desmear & E'ls Cu plating and drying (100-150degC*30min)
6. Dry Film lamination

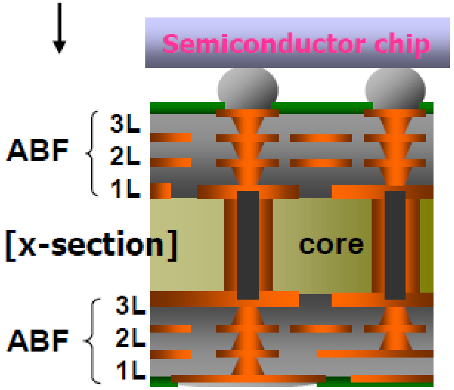


7. Dry Film patterning (exposure and development)
8. Electro Cu plating
9. Removal of Dry Film Pater formation by SAP (Semi-Additive Process)
10. Flash etching & annealing (Full-cure)

Repeat for multilayered BU



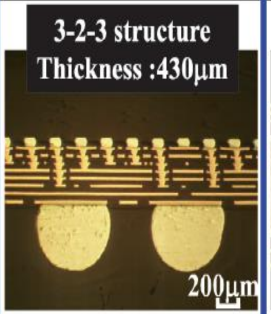
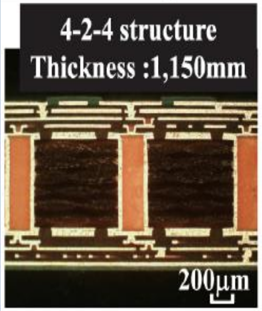
[package]



Low Warpage Coreless Substrate for IC Packages

- Coreless substrate is excellent for fine patterning, small via pitches, and transmission property, and it is a promising IC packaging method for the next generation.
- Multilayer build-up substrate contain two or more build-up layers either side of a core with stacked vias.
- Coreless eliminates the core in the substrate and utilizes only build up materials to interconnect between the chip and PCB board. Attractive cheap option to meet the very low z-height, means lighter substrate, smaller, very short interconnection in fine line width, and good power integrity. However may cause poor connection reliability due to warpage increased at soldering process.
- Coreless has three advantages compared to buildup substrate:
  1. High wiring design flexibility owing to fine via pitch.
  2. Power source improvement because of low impedance.
  3. Large signal integrity.

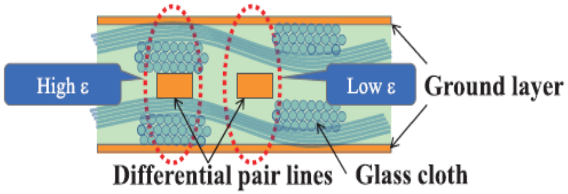
  Disadvantages - doesn't includes high rigidity layer.
- Today, coreless substrates have been used in limited applications such as small size of CSPs, The desire is to develop coreless for large **BGA 20mm squares**.

Properties	Coreless	Bulidup
Cross-sectional view of structure		
Patterning scale	Fine	Rough (Core layer)
Via pitch	Small	Large (PTH)
Transmission	Excellent	Poor (Core layer)
Warpage	Large(Low rigidity)	Small

Low Warpage Coreless Substrate for IC Packages

- The most important problem for the application of coreless substrates for high-end BGAs is warpage reduction during a reflow process.

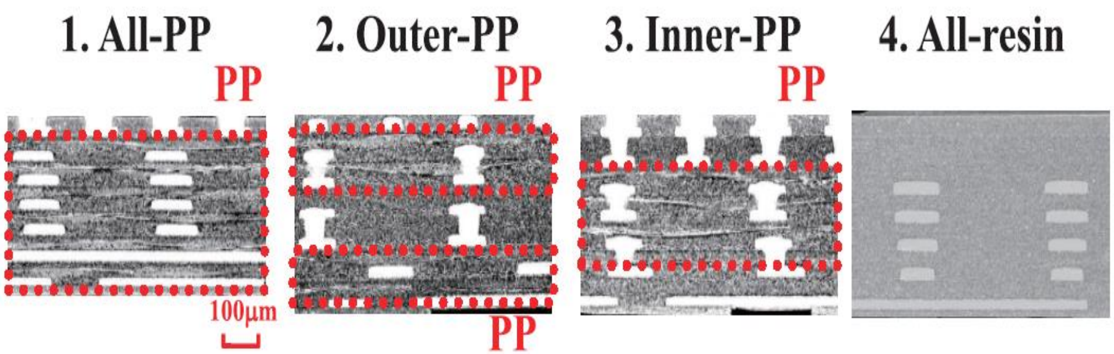
<u>Fujitsu test</u> - in order to improve the rigidity of coreless substrate



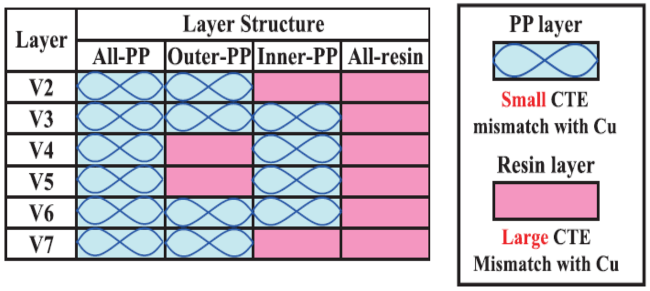
- Includes prepreg adhesion resin sheet that reinforced by glass cloths,
  But due to the lack of homogeneity in the glass areas, recommended to use a minimum number of preprege.

- Two kinds of dielectric materials, **prepreg (resin impregnated with glass Cloths) GX-13GC and resin GX-13**.

- 4 kinds of coreless substrates with different layer structures,
  The coreless substrates area was **42.5**mm squares, **0.4mm** thickness, pitch = **50µm**, total number of elements = **810,000**.



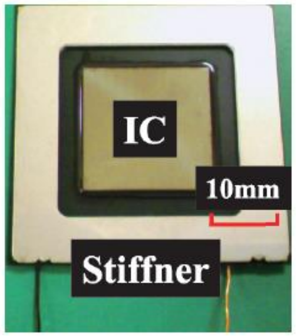
<u>Cross-sectional images of substrates.</u>



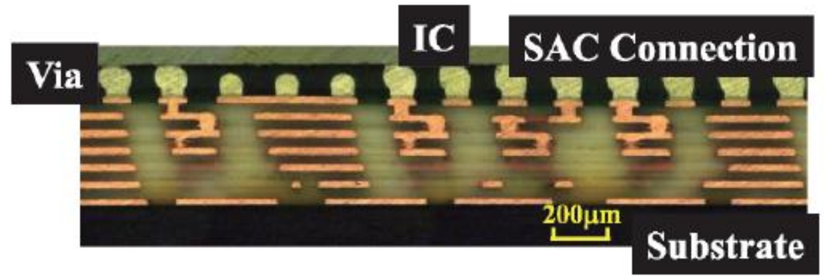
<u>Schematic figure of layer structures.</u>

Low Warpage Coreless Substrate for IC Packages

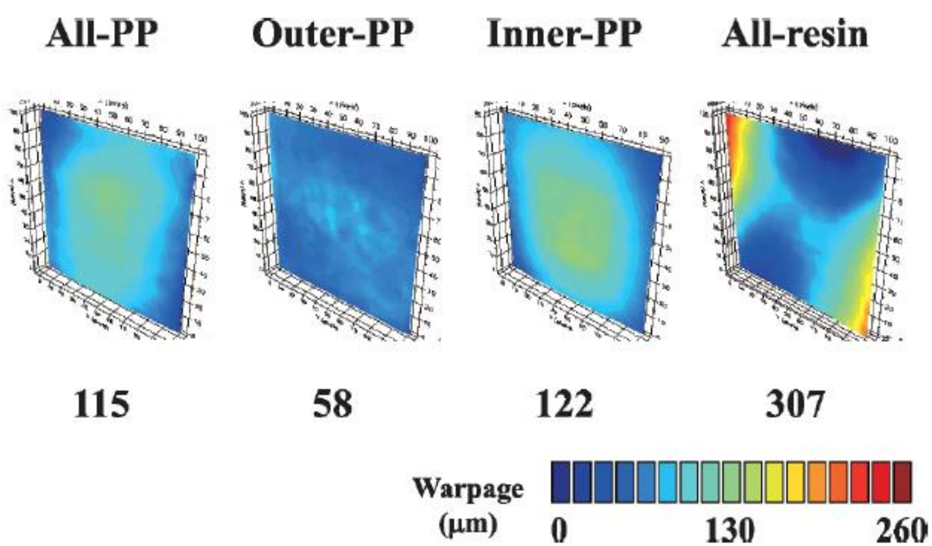
- **Fujitsu test**



External view of the IC-mounted coreless substrate



Cross-sectional view of the IC-mounted coreless substrate



Warpage measurement results

Effective factors for high reliability are not only low warpage at the solder melting point, but also small temperature-dependent warpage during cooling process.

Sample	IC assembly test results	Warpage (μm)
All-PP	Passed	115
Outer-PP	Passed	58
Inner-PP	Failed	122
All-resin	Failed	307

IC assembly test results

Taconic - Polytetrafluoroethylene (PTFE or Teflon®)

- Complex, high density, multi-layer digital boards have been manufactured toward smaller plated- through-holes, thinner dielectrics, finer lines/ spaces, and higher layer counts. Digital substrates have kept pace with these developments by transitioning to higher temperature resins to provide better plated-through-holes reliability, thickness and DK control impedance.

- Significant development in PTFE-based material technologies to meet the mechanical and thermal stability requirements for complex multi-layer boards. In the past these types of base materials were mainly used in military applications.

- Taconic has engineered two PTFE-based substrates with enhanced technical properties:

<u>TLE-95</u> substrates are manufactured in thicknesses from .004" (0.1mm) with a dielectric constant of 2.95 +/- 0.05. this for complex multi-layer microwave and high-speed digital circuit boards.

<u>TLC</u> substrates are specifically designed to meet the low cost, manufactured in thickness .0145" (0.37 mm) with Er=2.70, and .020" (0.50 mm)

** Both materials exhibit excellent mechanical and thermal stability, Higher peel strengths and cost less than traditional PTFE substrates.

New cellular communication systems are being upgraded from 450MHz to 900MHz and 1.8 GHz, **TLE-95**, and particularly **TLC** substrates, deliver high performance and high reliability at a cost.

- The PTFE/woven glass substrates exhibit exceptionally low moisture absorption, and require little conditioning during fabrication to eliminate trapped process chemicals in drilled holes which improved reliability in plating holes.

- Outdoor applications such as direct broadcast satellite televisions LNB´s, PCS/PCN antennas, automotive radars, and other benefit from PTFE/glass low moisture absorption.

orbotech
The Language of Electronics

THANK YOU