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20µm Prepreg Substrates for Ultra-Thin Insulated Single-Layer

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Abstract
Recent increasing demand for miniaturization and multi-functionality of electronic devices has lead to higher PWBs circuit density design, requiring thinner insulation layers, smaller via holes and finer wiring lines than ever before. So that the prepregs used to compose PWBs require better drilling ability and higher insulation reliability in additions to the demands of thinner fabric. To meet these requirements, ASAHI-SCHWEBEL has developed a new type of ultra-thin prepreg capable of forming as thin as 20µm thick single insulation layer by using 10µm thick glass fabric obtained by our proprietary uniform glass fabric spreading method. Furthermore, we have succeeded to render UV-YAG laser drilling ability to resin/glass fabric prepregs without impairing problematic hole-to- hole insulation reliability by chemically finishing the glass fabric with inorganic nano-particles. The values achieved are 50µm via hole capability and no failure after 350 hours at 121℃, 85RH% under 5 volts applied with hole -to- hole length of less than 150µm. The mechanical properties of the developed prepregs, especially rigidity and dimensional stability, are found to be much better than those of other organic substrates. We believe that this new type of prepreg is best suited for not only current but also future PWBs material, such as for buried capacitor laminates containing high dielectric constant compounds.

Introduction
Recent increasing demand for miniaturization and multi-functionality of electronic devices has lead to higher PWBs circuit density design. To make higher PWBs circuit density designs, thinner insulation layers, smaller holes, and finer wiring lines are required.

High circuit density designed PWBs are generally produced by building up single thin insulation layer. Various thin organic films and prepregs have been used for the single insulation layer. In the near future, less than 30µm single insulation layer will be required. Prepregs compose PWBs, have required better rigidity and dimensional stability besides the demands of thinner fabric therefore, glass fabric will continue to be necessary.

With the advancement of PWBs and miniaturization of insulation layers, we have developed and commercialized ultra thin glass fabric. Table 1 shows the history of ultra thin glass fabric.

Table 1 - History of Ultra Thin Glass Fabric

Style	Counts/inch		Weight (g/m^2)	Thickness (µm)
	Warp	Weft		
101	75	75	17	26
104	60	52	19	35
106	56	56	25	39

(The above figures were typical data, but not guaranteed.)

These fabrics exhibit difficulty with micro and laser drilling due to the lack of uniformity of glass filaments density in squares. Also, there has been possibility of layer-to-layer insulation degradation because of the contact of glass filaments with copper foil, considering Figure 1.

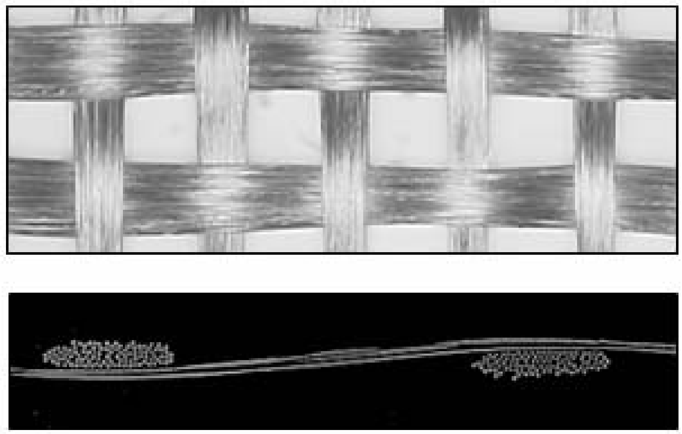


Figure 1 - Surface and Cross Sectional Images of 106 Glass Fabric

To resolve these issues, we have developed and commercialized a physical spreading technique (MS) to uniformly spread and flatten the glass filaments [1]. By using our original physical spreading technique, an ultra thin 10µm glass fabric, called 1017, has been developed to make ultra thin 20µm prepreg substrates. Moreover a surface chemical finishing has been developed to produce a fabric capable of UV-YAG laser drilling without impairing problematic hole-to-hole insulation reliability [2].

Experimental

To achieve 20µm prepreg substrates, development first focused on 10µm fabric and characterizing the resulting board. Three important properties, layer-to-layer insulation reliability, UV-YAG laser drilling ability and hole-to-hole insulation reliability were evaluated.

Designing of Ultra Thin 1017 Glass Fabric

When designing new ultra thin glass fabric, the linear relationship between thickness and weight should be considered, Figure 2. According to this relationship the weight target for 10µm glass fabric should be $10 g/m^2$ (0.295 osy).

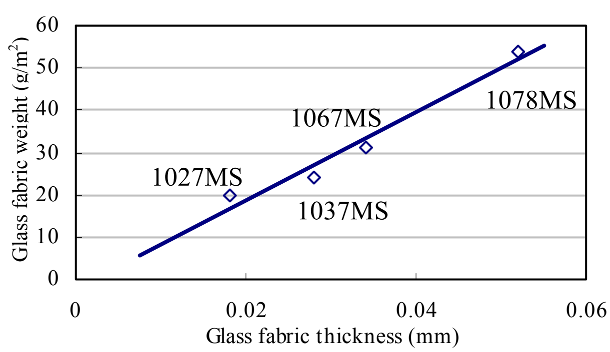


Figure 2 - Relationship Between Thickness and Weight of Ultra Thin Glass Fabric

Next the glass yarn density was determined for the fabric weight. Several types of ultra thin glass fabric were woven using BC1500, BC2250, and BC3000 zero twist glass yarns. After weaving, the physical spreading technique for glass fabric was applied. Finally, by observing the surface and cross sectional microscope images of each trial fabric, the best glass yarn type, glass yarn density and physical spreading conditions was determined.

Properties of Boards Consisting of 1017 Glass Fabric

The boards were made with 10µm glass fabric and FR5 epoxy resin. The strength, modulus of elasticity, coefficient of thermal expansion, heat resistance, water absorption and surface roughness were measured.

Board’s strength and modulus of elasticity were measured according to JISK6911.5.17. Board’s coefficient of thermal expansion was measured according to JISK6911.5.25:

- Board’s heat resistance was observed after dipping in 260 °C solder bath (20sec).
- Board’s water absorption was measured after exposing in 121°C /100RH% batch (1h).
- Board’s surface roughness was measured by surface texture measuring instrument.

Layer-to-Layer Insulation Reliability of Boards

1ply boards were made using the fabric, 5µm thickness of FR4 epoxy resin, and 12µm thick low-profile copper foil (Figure 3). 10mm diameter circles were etched in the copper for the layer-to-layer insulation reliability experiments. The resistance of each sample was continuously measured in the atmosphere of 85°C/85RH%/100V for 1000 hours in-situ. Less than 10^{-7} resistance samples were considered failures. As the controlled experiment, we measured boards consisting of 106 glass fabric equally.

Figure 3 - Experimental Setups for Layer-to-Layer Insulation Reliability Experiments

UV-YAG Laser Micro Drilling Ability of Boards finished with Our Normal and Developmental Finishing

1 ply boards were made using 10µm glass fabric, FR4 epoxy resin, and 12µm thick normal copper foil. 50µm diameter via holes were made using the UV-YAG laser drilling machine model 5150 produced by esi.[3]

Additional 1 ply boards were made using our developmental chemically finished 10µm glass fabric. On this boards imperfect 50µm diameter via holes were made by UV-YAG laser drilling to observe the conditions of each hole by microscope. As the controlled experiment, we measured boards consisting of our normal chemically finished 10µm glass fabric equally.

Hole-to-Hole Insulation Reliability and Water Absorption of Boards Finished with Our Developmental Finishing

15plies boards were made using 10µm glass fabric finished with our developmental finishing, FR4 epoxy resin and 12µm thick normal copper foil. Patterns were etched on the boards with a resist agent. Through holes were drilled at 150µm distances as insulation test samples (Figure 4).

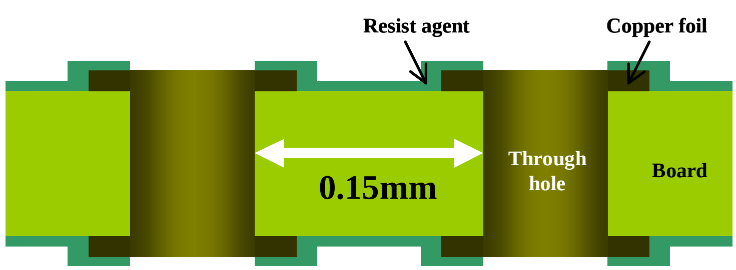


Figure 4 - Experimental Setups for Insulation Reliability Experiments between Each Through Hole

The resistance of these samples was measured continuously for 350 hours in atmosphere of 121°C/85RH%/5V. The water absorption of 15plies boards in 121°C/100RH% after 1week was also measured. As the controlled experiment boards consisting of normal chemically finished 1017 fabric were also measured.

Results and Discussion

Properties of Newly Developed Glass Fabric and its Boards

The developmental target was to make 10µm ultra thin glass fabric to be able to make 20µm prepreg substrates. Resin thickness of 5µm from the edge of glass fabric was necessary to prevent problematic layer-to-layer insulation reliability. Monofilaments diameter of BC type yarn was about 4.1µm so that 10µm thickness glass fabric was the thinnest theoretically.

To achieve this target there were two essential basic technologies. One essential technology was to spread the glass fiber uniformly. Table 2 shows the list of ultra thin glass fabric available with the MS spreading technique.

Table 2 -The List of Spreading Ultra Thin Glass Fabric

Style	Counts/25mm		Weight (g/m²)	Thickness (μm)
	Warp	Weft		
1027MS	75	75	20.0	19
1037MS	70	73	24.0	28
1067MS	70	70	31.0	34

(The above figures were typical data, but not guaranteed.)

The other method was to weave ultra thin glass fiber that had zero twist and would spread with ease. To solve the former task, we developed the proprietary uniform glass fabric spreading technique. And to solve the latter task, a weaving technique by using zero twist glass fiber was developed.

We have applied both of these techniques to development ultra thin glass fabric. The resulting fabric was style 1017. (Table 3).

Table 3 - The Spec of the Fabric

Yarn type		BC3000 1/0
Filament diameter (μm)		4.1
Filament number		50
Counts/25mm	Warp	84
	Weft	84

In the Figure 5, the fabric surface and cross sectional images are shown. And the properties of the fabric are shown in Table 4.

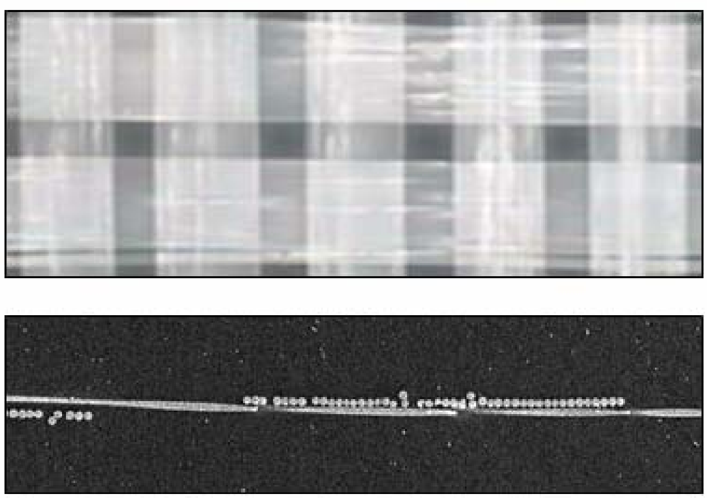


Figure 5 - Surface and Cross Sectional Images of Fabric

Table 4 - Properties of the Fabric

Thickness (μm)		10
Weight (g/m²)		11.4
Strength (N/25mm)	Warp	20.4
	Weft	30.2
Loss of ignition (wt%)		0.19

(The above figures were typical data, but not guaranteed.)

Table 5 shows the properties of boards consisting of the fabric. The rigidity and the coefficient of thermal expansion are sure to be much better than those of ordinary build-up substrates.

Table 5 - Properties of Boards Consisting of the Fabric

Thickness (μm)	20
Strength (MPa)	145
Modulus of Elasticity (GPa)	10.7
Coefficient of Thermal Expansion (ppm/degree)	20
Heat Resistance	Excellent
Water Absorption (wt%)	0.1
Surface Roughness (μm)	2.2

Figure 6 and Figure 7 show the results of layer-to-layer insulation reliability tests on boards made with new and 106 glass fabrics. Only the boards with new fabric that had the same resin thickness from edge of glass fabric and thinner insulation layer could pass the insulation reliability test. There were two reasons:

- Possibility of contact between glass fabric and copper foil decreased due to spreading of the filaments
- Occurrence of air in the glass yarn decreased due to the uniform dispersion of glass filaments.

Therefore it is possible to make ultra thin single layer boards using our developmental fabric without impairing layer-to-layer insulation reliability.

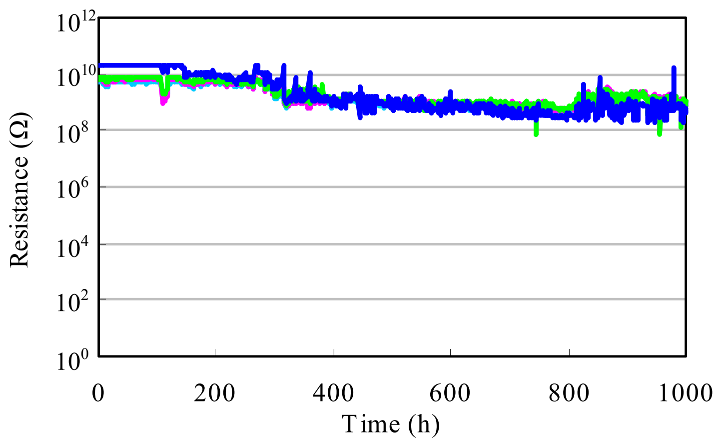


Figure 6 - Layer-to-Layer Insulation Test on Boards of the Fabric

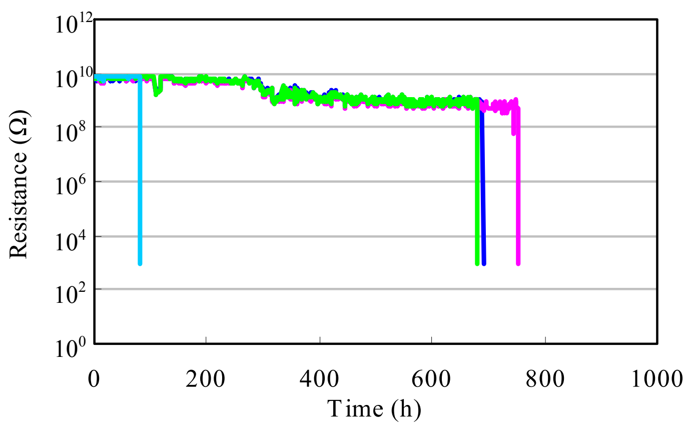


Figure 7 - Layer-to-Layer Insulation Test on Boards of 106 Fabric

Properties of Newly Developed Chemically Finished Glass Fabric and Its Boards

In the near future, micro drilling by UV-YAG laser and finer wiring patterns will be applied to high circuit density designed PWBs. Therefore the improvements of UV-YAG laser drilling and hole-to-hole insulation reliability achieved with the fabric is needed.

Figure 8 shows the cross sectional image of 50µm diameter via hole on 1ply board using the new fabric by UV-YAG laser drilling. From this result, micro drilling for boards of the fabric by UV-YAG laser drilling was possible because of the uniform and small quantity of glass filaments.

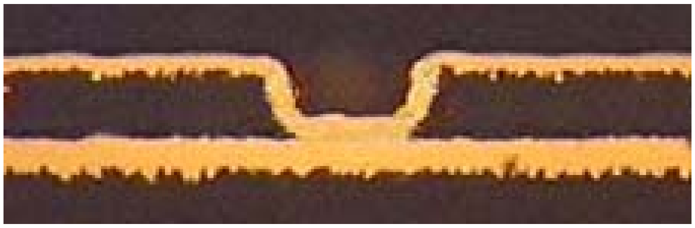


Figure 8 - Via Hole on Board Consisting of 10µm Glass Fabric by UV-YAG Laser Drilling

E-glass composed glass fabric usually has little absorbance for UV-YAG laser (Wavelength = 355nm). It is more difficult to drill glass filaments than resin in the case of using the UV-YAG laser. To improve laser drilling, we developed a glass surface finishing technique using nano-sized inorganic particles, which increased the absorbance of glass filaments for UV-YAG laser. (Absorbance of inorganic particles finished 1017 fabric = 0.2) Table 6 shows the lowest diameter of 50µm via holes for inorganic finished and normally finished fabric. These results showed that UV-YAG laser drill ability was improved by using inorganic nano-sized particle finishing. Plating conditions were also improved.

It is generally known that insulation degradation occurs in high humidity atmosphere because of metal ion migration at the glass/resin interface (CAF phenomenon). This phenomenon tends to increase in high circuit density designed boards.

To resolve this problem, we found that glass surface finishing with inorganic nano-sized particles and special silane coupling reagents could improve reactivity of the glass surface and epoxy resin and decrease water absorption at the glass/resin interface.

Figure 9 and 10 shows the insulation reliability test results of 15 plies boards using newly developed chemically finished fabric. The insulation reliability between each through hole was greatly improved. This improvement was probably due to reducing water absorption at the glass/resin interface. Table 7 showed that this finishing could improve water absorption of boards.

Table 6 - Laser Drilling Ability of Boards Consisting of Fabric Finished with Inorganic Particles

Finishing	The lowest via diameter (µm)
Normal finishing	29
Inorganic particles finishing	16

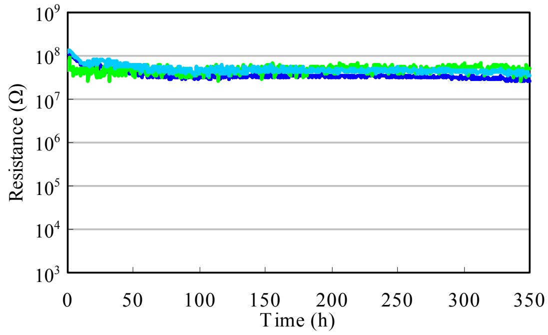


Figure 9 - Insulation Reliability Test on Boards Consisting of Newly Developed Chemically Finished 10µm Glass

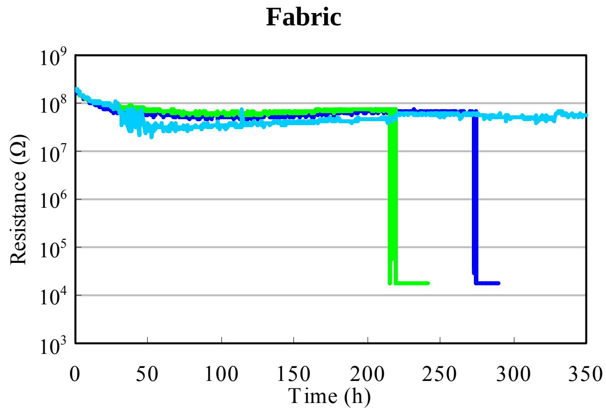


Figure 10 - Insulation Reliability Test on Boards Consisting of Normal Chemically Finished Fabric

Table 7 - Water Absorption of Boards Consisting of Newly Developed Chemically Finished Fabric

Finishing	Water absorption (wt%)
Normal finishing	1.88
Special silane coupling finishing	1.77
Developmental finishing	1.60

1017 fabric finished with this developmental finishing will be well suited for high density electronic devices. Table 8 shows the properties of this developmental fabric.

Table 8 - Properties of Newly Developed Chemically Finished 1017 Fabric

Thickness (µm)		10
Weight (g/m²)		11.8
Strength (N/25mm)	Warp	22.2
	Weft	33.5
Loss of ignition (wt%)		0.40

(The above figures are typical data, but not guaranteed.)

Applications

Applications for Multi-layer Boards

One of the applications of our developmental 20µm prepreg substrates containing 10µm glass fabric is multi-layer board. Actually ultra thin multi-layer boards (6 layers) were developed using our developmental prepregs. Figure 11 shows the cross sectional images by SEM. Thickness and weight of this board were one-third those of 2116 glass fabric.

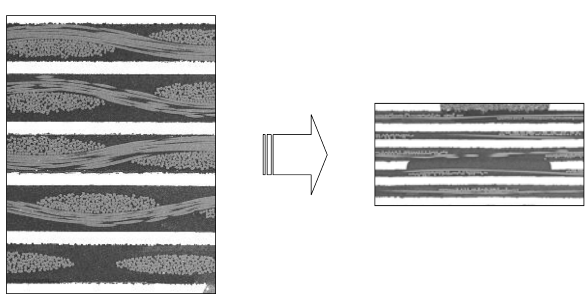


Figure 11 - Cross Sectional SEM Images of 6 Layers Boards Using 2116 and 1017 Fabric

Applications for Buried Capacitance PWBs

Our developmental prepregs containing 1017 fabric can be used for buried capacitance. There are three advantages of using 10μm glass fabric for buried capacitance.

The first advantage is to be able to finish Barium titanate (BTO) particles efficiently which are generally used for high dielectric constant materials on glass fabric by annealing at 500°C.

The second advantage is the thinness of the fabric because electrostatic capacity is inversely proportion to board's thickness.

$$C / A = \varepsilon_0 \cdot \varepsilon_r / T$$

Where:
C = Electrostatic capacity
A = Area of electrode
T = Thickness of dielectrics film
ε_0 = Dielectric constant in vacuum
ε_r = Dielectric constant

The third advantage is the ability to change the industrial process of buried capacitance because our developmental prepregs can be handled more easily than other films due to the glass fabric reinforcement.

15plies boards consisting of 10μm glass fabric finished with BTO particles and FR4 epoxy resin containing 50% BTO volume were made. Table 9 shows the dielectric properties of the board at 1GHz by impedance analyzer.

Table 9 - Dielectric Properties of Boards with Fabric and FR4 Epoxy Resin Containing 50% BTO Volume

C/A (pF/mm^2)	6.2
Dielectric constant ε	17
Dissipation factor tanδ	0.008
Thickness (μm)	25

Conclusions

Our developmental prepregs containing ultra thin glass fabric, which are developed for the first time in the world, contribute to the miniaturization and multi-functionality of electronic devices. Improvements in UV-YAG laser drilling ability and insulation reliability by our developmental chemically finishing, the developmental prepregs will be adapted to future high density electronic devices. Handling can be improved by using organic films or copper foils as carriers. We believe that this new prepreg is best suited for current and future PWBs material, such as buried capacitor laminates containing high dielectric constant compounds.

Reference

1. Y. Kimura, IPC Printed Circuits EXPO 2000 Technical Proceedings S09-1 (2000)
2. K. Arai, The Journal of Japan Institute for Interconnecting and Packaging Electronic Circuits, Vol.13, No.1 (1998)
3. M. Owen, Circuit World, Vol.25, No.2, p35 (1997)

20 μm Prepreg Substrates for Ultra-Thin Insulated Single-Layer

Asahi-Schwebel co.,LTD

Glass Fabrics for PWBs

Advantages of Glass Fabrics

1.Mechanical Rigidity 2.Dimensional Stability 3.Insulation Reliability

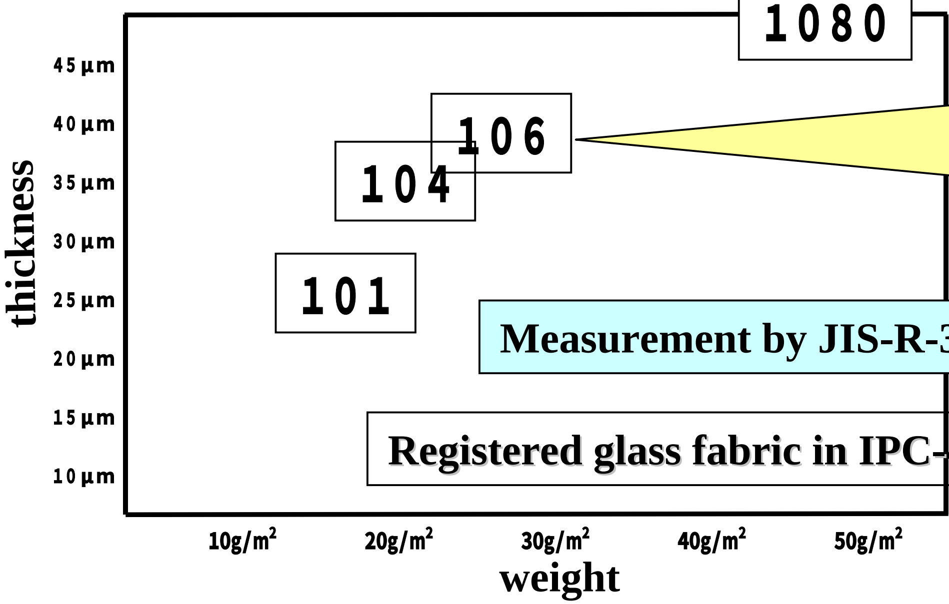
Typical Glass Fabrics' Data

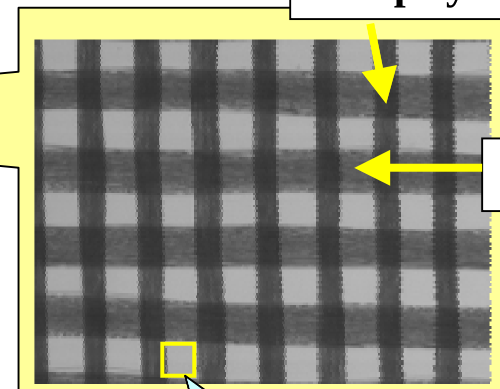
Style		7628	2116	1080
Yarn Type		G75 (9 μm × 400)	E225 (7 μm × 400)	D450 (5 μm × 400)
Thickness	(mm)	0.18	0.09	0.05
Weight	(g/m^2)	210	104	47
Typical Thickness of Prepregs	(mm)	0.2	0.1	0.06

With the advancement of PWBs, thin fabrics have been required.

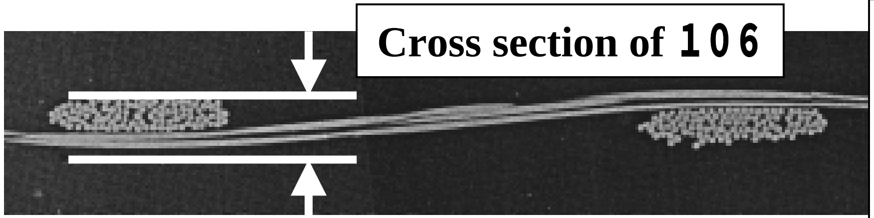
Asahi KASEI GROUP

Ordinary Ultra Thin Glass Fabric





Basket hole
200～300 μm□



Counts of filaments in Z-direciton
warp = 7
weft = 4

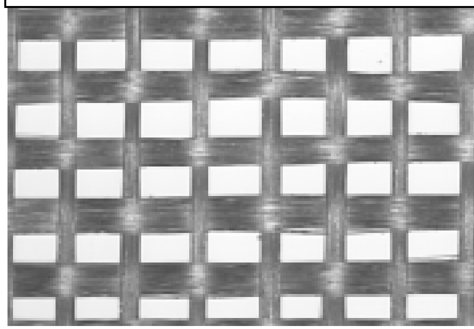
maximum thickness
11×5 μm

55 μm

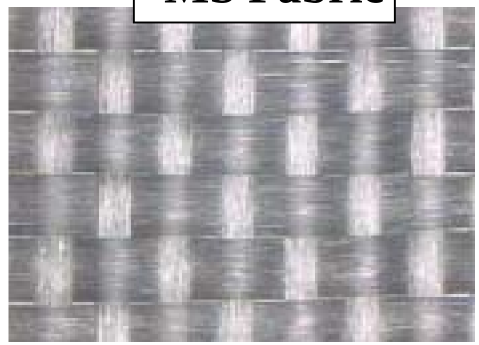
The lack of uniformity in squares and Z direction

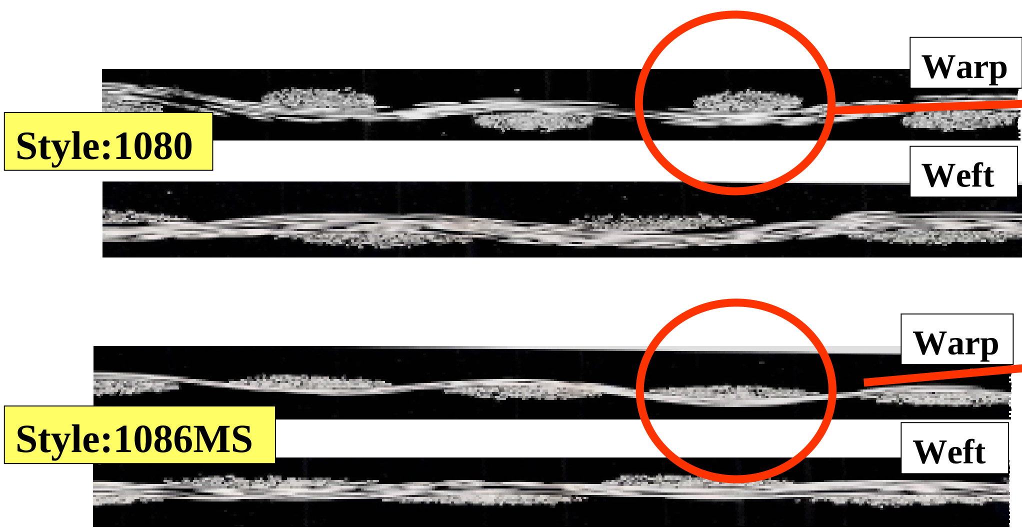
MS Glass Fabric

Ordinary Fabric



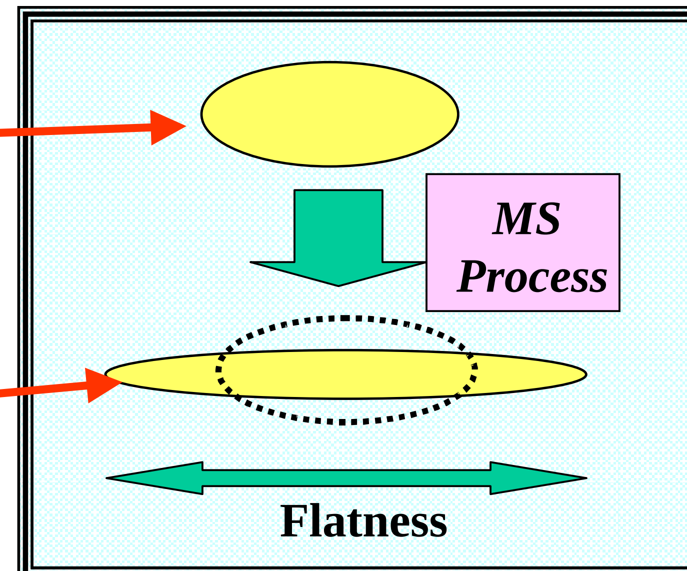
MS Fabric





Features of MS Fabric Laminates

- ∗Laser drilling-ability
- ∗Mechanical drilling-ability
- ∗Dimensional stability
- ∗Warp & Twist etc.



Various types of MS Glass Fabrics

Style		1027MS	1037MS	1067MS	1080MS	1084MS	1086MS
Yarn	Warp	BC1500 1/0	C1200 1/0	D900 1/0	D450 1/0	D450 1/0	D450 1/0
	Weft	BC1500 1/0	C1200 1/0	D900 1/0	D450 1/0	D450 1/0	D450 1/0
Counts /inch	Warp	75	70	70	60	55	60
	Weft	75	73	70	47	53	60
Weight	g/m2	19	24	30	48	48	54
Thickness	mm	0.019	0.028	0.032	0.045	0.045	0.052
Typical Prepreg Thickness	mm	0.03	0.04	0.045	0.05	0.05	0.06

The above values are typical example of many measurements .

Demand for Ultra-Thin Glass Fabric

Forecast of the thinnest prepreg for multi-layer

(μm)

	2004	2006	2008	2010	2012
Class-A	100	100	100	100	100
Class-B	60	60	40	40	40
Class-C	30	30	**20**	**20**	**20**

PWB-markers to lead the latest technology

1027MS

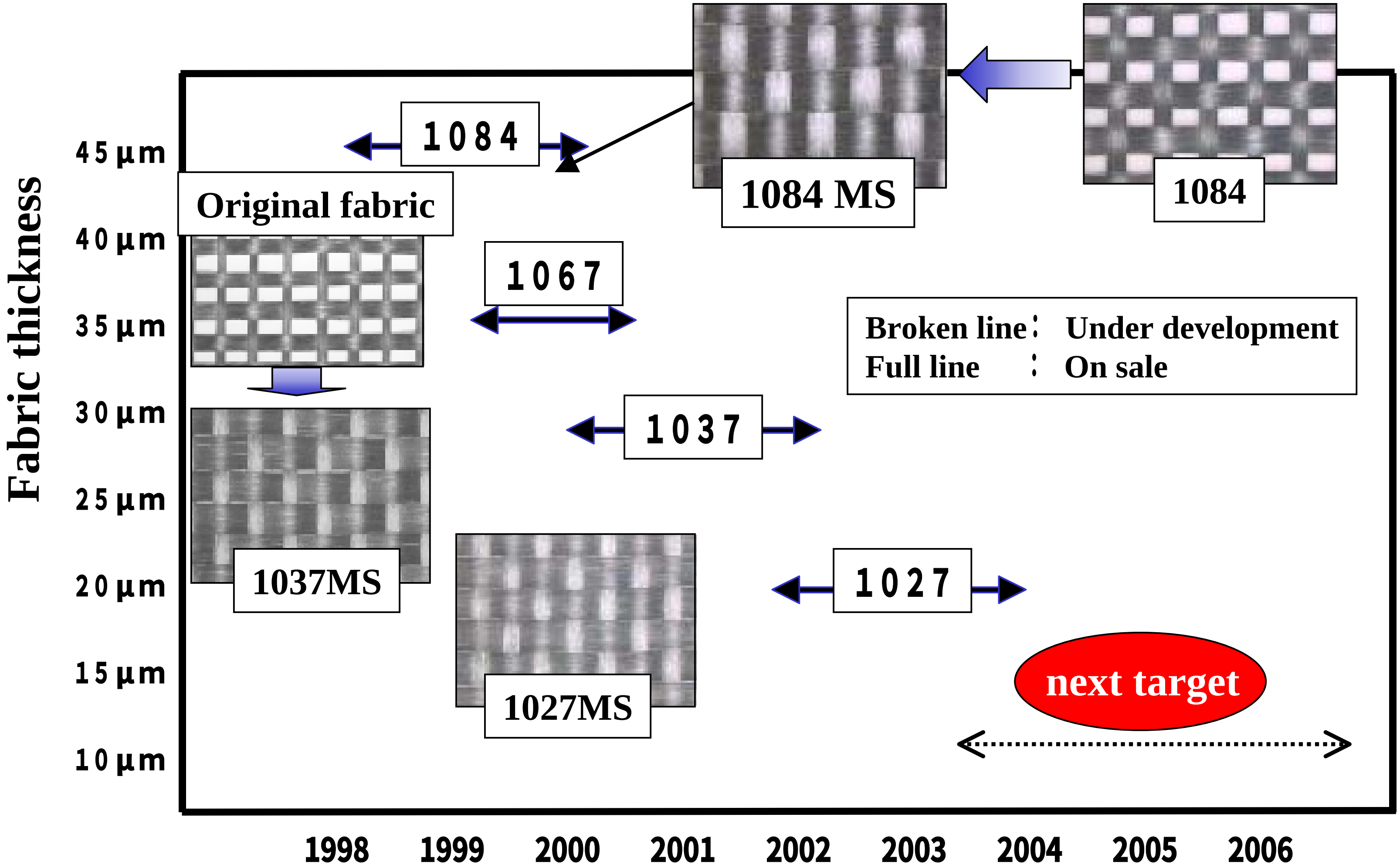
1037MS

From Japan Jisso technology roadmap 2003

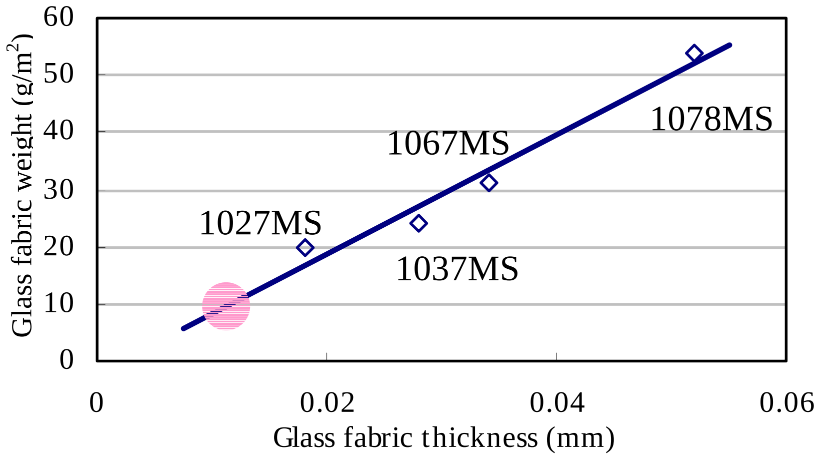
Glass fabrics are indispensable for multi-layer boards to keep the high performance of mechanical properties and insulation reliability.

It is necessary that the thickness of those glass fabrics in the those regions is less than 20 μm.

Our Roadmap of Ultra Thin Glass Fabric



Designing of Ultra Thin Glass Fabrics

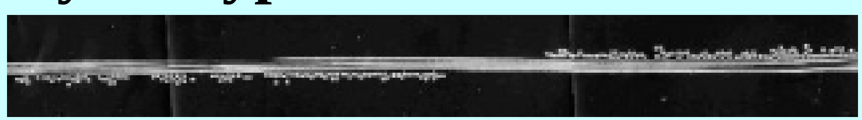


Target (thickness) = 10 μm

Target (weight) = 11 g/m2

Structure of Glass Fabric

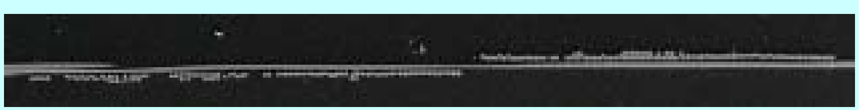
Selection of glass yarn type



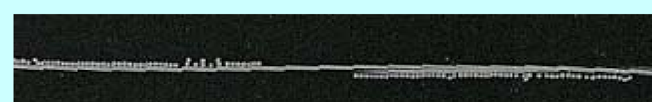
4μm×100

Cross Sectional Image of 1027MS

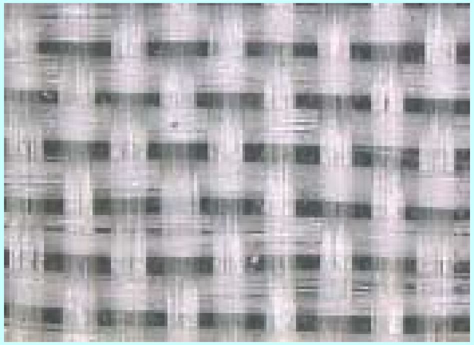
Thinner Filaments

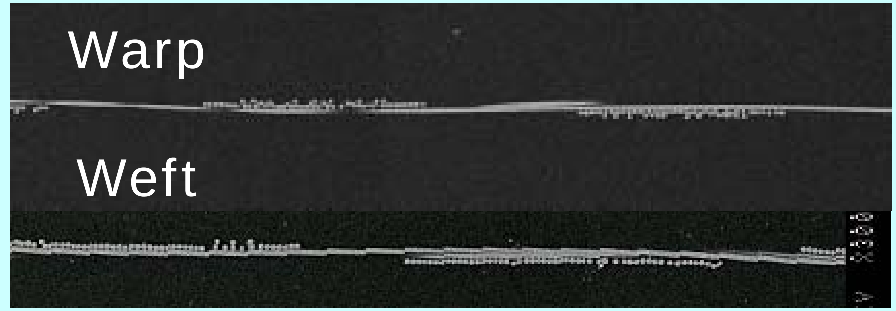


Fewer Filaments



10 µm Ultra Thin Glass Fabric



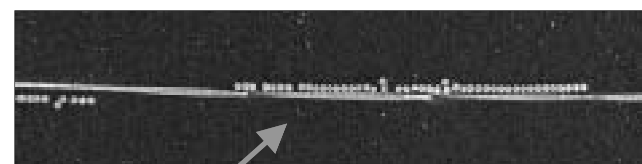


Surface and Cross Sectional Images of Developmental Glass Fabric

Specification of 10 µm Ultra Thin Glass Fabric

Yarn Type		BC3000
Counts / inch (Warp・Weft)		84・84
Thickness	µm	10
Weight	g/m^2	11.4
Strength (Warp・Weft)	N/mm^2	20.4・30.2
Loss of Ignition		0.19

The above values are typical example of many measurements .

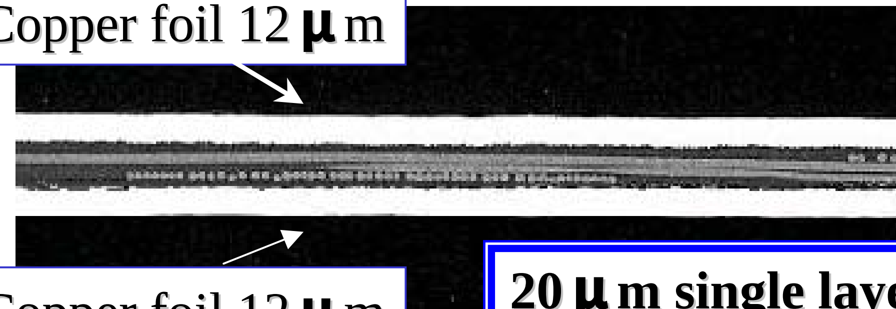


2.5 Filaments in Z direction

10 µm thickness (4 µm × 2.5)

Properties of Boards

Boards Conditions
Resin：FR-5 type epoxy
Copper：12 μm Low-profile



Properties of boards consisting of 10 μm fabric

Thickness (μm)	20
Strength (MPa)	145
Modulus of Elasticity (GPa)	10.7
Coefficient of Thermal Expansion (ppm/degree)	20
Heat Resistance	Excellent
Water Absorption (wt%)	0.1
Surface Roughness (μm)	2.2

The above values are typical example of many measurements .

Newly Developed Chemical Finishing

Improvement of UV laser drilling ability

Improvement of hole-to-hole insulation reliability

Improvement of UV light shielding ability

Nano-sized particle

Special silane coupling reagent

Newly developed chemical finishing

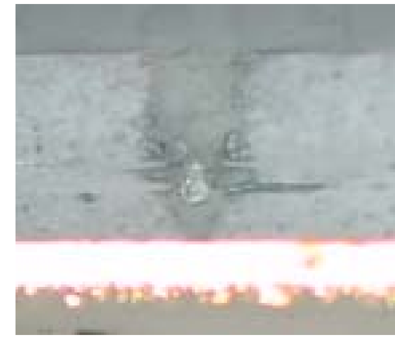
Improvement of YAG Laser Drilling Ability

Increase of laser absorbance

Improvement of

1. **Laser drilling rate**
2. **Plating condition**

Developmental finishing

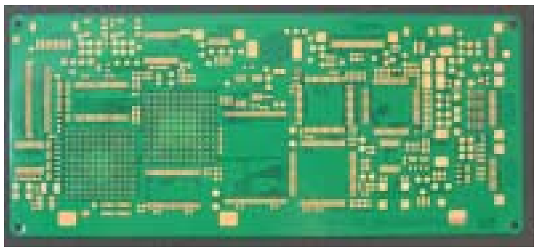


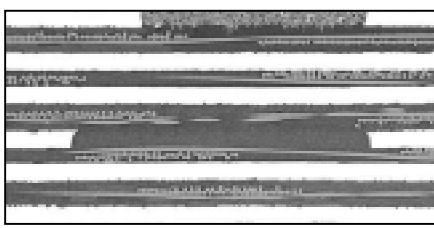
Normal finishing

Laser drilling ability of boards consisting of developmental finished 10 μm fabric
Boards' thickness = 20 μm, Via diameter = 50 μm

Finishing	The Lowest Via Diameter
Normal Finishing	29
Inorganic Particles Finishing	16

Application for multi-layer boards

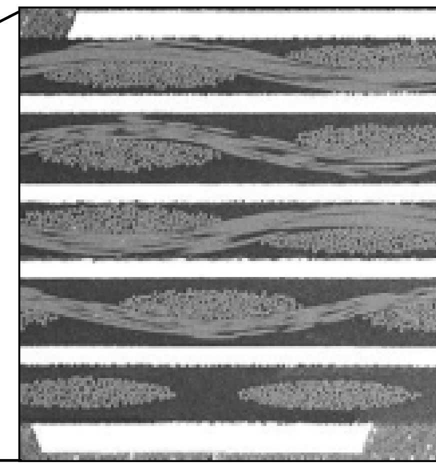




Trial 6 layers board using 10 μm fabric

Thickness and weight became 1 / 3

One-third



6 layers board using 2116 fabric

Conclusion

MS fabrics | Fabrics composed of non- twist yarns

We have developed 10 μm ultra thin glass fabric for the first time in the world.

+ Newly developed chemical finishing

We have developed 20 μm Prepreg Substrates for Ultra-Thin Insulated Single-Layer