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Internal Strain Free & Homogeneous Glass Fabrics for High Performance HDI Boards

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Abstract
A recent trend of increasing circuit density, particularly in the areas of plastic packages and multi-layer boards, has resulted in ceaseless demand of improved mechanical properties for laminates with improved quality and reduced cost. In general, mechanical properties of laminates composed of glass fabrics and thermosetting resin are strongly dependent on the resin shrinkage during thermal cure, asymmetrical structure of the laminates and inhomogeneous structure of the glass fabric made by glass yarns having twist, a presumably main cause of internal strain in the glass fabrics. We conducted in depth studies intended to correlate the characteristics of glass fabrics to the mechanical performance of laminates, and have succeeded in developing new glass fabrics using zero twist yarn. We have combined it with our uniquely developed "MS process", by which a homogeneous distribution of glass fibers in the laminates can be obtained quite easily. Eliminating internal strain by use of twist-free yarn and MS process, these new laminates have proved not only to reduce warp and twist by as much as 50% compared to conventional laminates, but also to improve mechanical properties such as dimensional stability with low standard deviation and C.T.E. by ca. 2ppm. In addition, the new laminates have exhibited excellent micro-diameter drilling capability, such as laser drilling and mechanical drilling with 0.1mm or less in diameter, with less drill bit breakage and uniform via side-wall.

Introduction

The trend in electronic equipment, such as PC and mobile devices, has been toward greater compactness of design and lighter weight. As for the PCBs used for the field of these information and communication device, it is estimated that it will be thin insulation layer, narrow pitches of through holes and fine patterns. In view of these trends, the build-up boards have adopted resin coated copper foil method (RCC) and resin coating method, because those substrates have easy drilling characteristics and small board size[1]. However, there has been much concern that a lack of reinforcement will result in decreased mechanical strength and insulation resistance. Also, because of the trend to Pb-free solder alloy in the packaging process, higher heat condition is added to the board. In this case, the materials for the board demanded high rigidity and low Warp and Twist at the high temperature reflow.

We have evaluated various techniques to improve the performance of laminates made with glass fabrics, including the patented in Japan "MS process" which homogeneously distributes the glass filaments[2]. Laminates made with these glass fabrics are proven to have improved mechanical properties and micro-diameter drill ability equal to RCC laminates. However, further improvement is the distribution of glass filaments is needed to meet the requirements of new high density devices.

To meet the requirements of high density devices, we have developed "AZ Fabric" (ASAHI-SCHWEBEL Zero Twist Fabric). This fabric combines zero twist yarn and special after weaving processing. Zero twist fabric was patent registered in 1996. This fabric reduces internal strain in the fabric by uniformly distributing the glass filaments in both the aspect and thickness directions. This provides laminates with reduced warp and twist, improved mechanical properties such as dimensional stability, and C.T.E. In addition, the new laminates exhibit excellent micro-diameter drilling capability such as laser drilling and less drill bit breakage with mechanical drilling.

Development of Internal Strain Free & Homogeneous Glass Fabrics

Development of a Production Method for AZ Fabric

Previously we attempted to produce fabrics with zero twist yarns. During the production process the glass filaments were easily broken. The resulting fabrics had high levels of surface broken filaments that could not be eliminated. Since these early trials, we have made significant improvements in zero twist fabrics. The main improvements have in the areas of:

- Warping technique - special sizing method developed
- Weaving technique - special air jet loom developed
- Finishing technique - special process to prevent fiber destruction developed

Relation between Glass Fabric and Warp & Twist

The standard yarn currently used in glass fabrics typically has 1 turn per inch (usually Z direction) of twist. Twist is imparted in the yarn to hold the filaments in the fiber bundle together during processing. Twisted yarn has an untwist force. Because the yarns next to each other combine the untwist force, the fabric tends to curl. Generally, with PCBs, glass fabric, resin and prepreg are used as the base material. When resin exceeds the glass transition temperature, the repeated heating process allows movement in the board. And then, it is thought that residual stress of glass fabric is released, and distortion occurs inside the board. The potential twist moment of the yarn (Mt) is shown in the following equation:

$$Mt = (B\cos 2a + C\sin 2a)/R$$

Where:
a= Helix angle of twist yarn
B = Bending rigidity
C = Torsional rigidity
R = Radius of helix envelope cylinder

This equation means that as the twisted yarn bends in a spiral, fabric becomes cylindrical, and warp occurs in the board. Theoretically, reducing yarn twist will restrain this phenomenon. Zero twist yarn is the most effective method to reduce Mt. In this case when a=0, then Mt=0 and R=8 . So, with glass fabric, curl does not occur with zero twist yarn. As a result, it is estimated that distortion can be reduced inside the PCB.

Homogeneous Glass Fabrics

Ordinary glass fabrics have the plain weave structure whose warp and weft yarns rise and fall alternately. Figure 1 shows the photomicrograph of ordinary glass fabric, style 1080. As Figure 1 shows, it is considered that glass fabrics have three different domains in nature. The first domain is of two yarns area (area-1), the second is of one yarn area (area-2), and the third is of no glass fiber area called basket holes (area-3). Generally, those domains are distributed in the glass fabric by the influence of yarn width and twist. It is necessary for the glass fiber laminates to have the glass filaments uniformly distributed.

The fabric (that we have successfully developed by a special method) uniformly distributes the glass fiber in the aspect and thickness directions. Figure 2 shows the photomicrographs of the development glass fabric and a conventional fabric, also shown are electron microscope photographs of the cross sections. Figure 3 shows the distribution of the warp yarn's width. The AZ glass fibers are easily spread out and uniformly distributed in the fabric, and glass distribution of aspect direction and thickness direction equalized. So crimp and thickness are reduced.

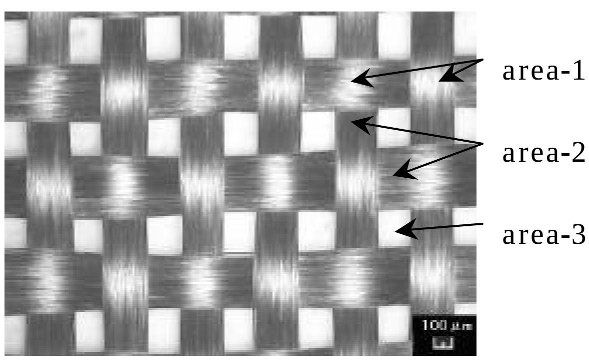
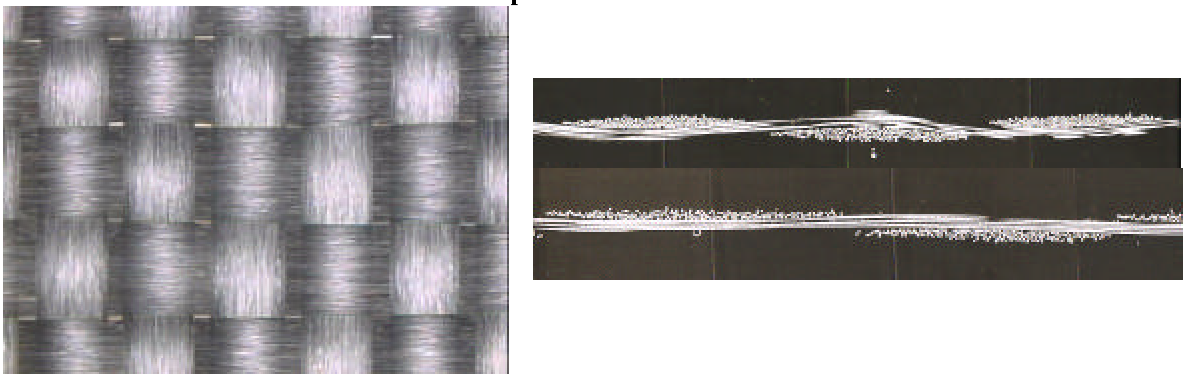
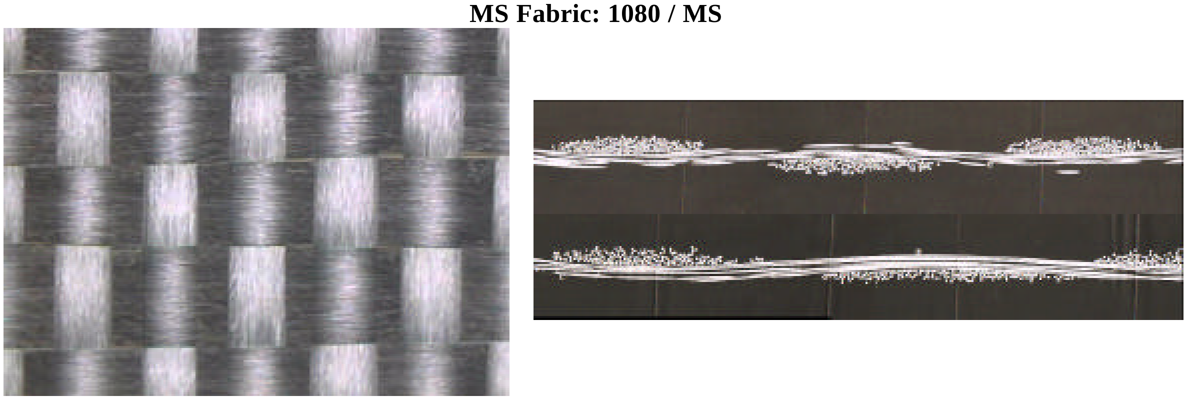


Figure 1 - Ordinary Fabric Structure

Developed Fabric: 1080 / AZ



MS Fabric: 1080 / MS



Conventional Fabric: 1080 / AW

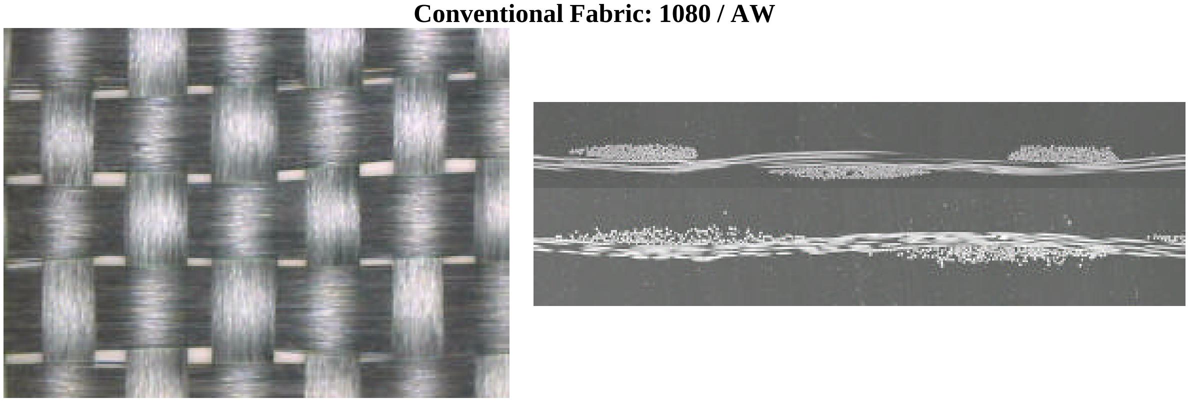


Figure 2 - Surface and Cross Section

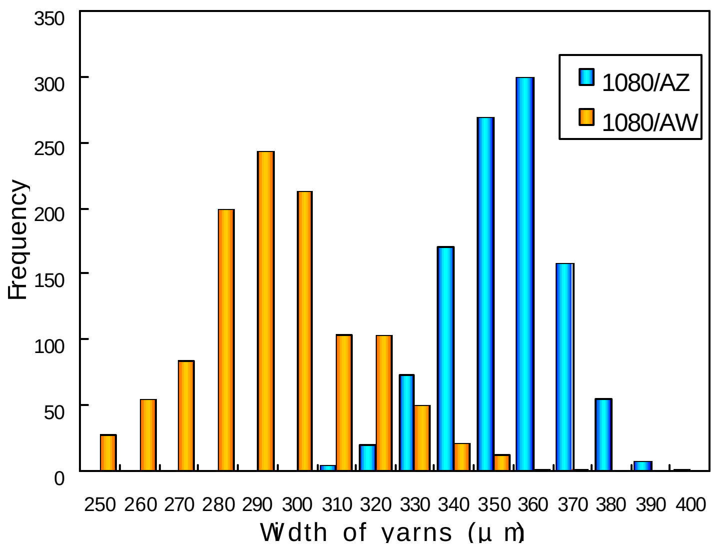


Figure 3 - Distribution of Warp Yarn's Width

Variety of Newly Developed Glass Fabric

Table 3 shows a basic characteristic of the new fabric and conventional fabric. For the new fabric, thickness is thinner and air permeability is lower. Additionally, we are developing ultra thin glass fabrics. The glass fabrics that consist of zero twist yarns can combine uniformity and thinness. Figure 4 shows the cross section of an ultra thin fabric. Glass fibers in the yarns are equal to one line and the thickness is about 10μm.

Table 3 - Various Styles of AZ Fabric

Style Process	1116 AZ	1116 MSW	1116 AW	1080 AZ	1080 MSW	1080 AW`	1017 AZ
Yarn	D225	D225	D225	D450	D450	D450	BC3000
	1/0 0Z	1/0 1Z	1/0 1Z	1/0 0Z	1/0 1Z	1/0 1Z	1/0 0Z
Filament (μm)	5	5	5	5	5	5	4
(counts)	400	400	400	200	200	200	50
Counts/inch (Warp×Weft)	60 x 58	60 x 58	60 x 58	60 x 47	60 x 47	60 x 47	84 x 84
Thickness	0.084	0.084	0.089	0.042	0.047	0.050	0.011
Permeability ($cm^3/cm^2/s$)	4	5	12	29	59	83	120

* AW; The process to spread out fibers for resin wettability
* MSW; MS + AW process
* The above figures are typical data, but not guaranteed.

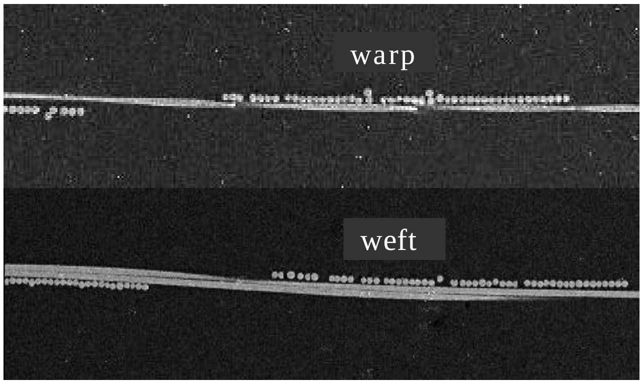


Figure 4 - Cross Section of 1017/AZ

Mechanical Characteristic Evaluation of the Board

It became clear by experiments that the board with the new fabrics showed superior characteristics. For the mechanical characterization, 100µm glass fabrics, FR-4 resin prepregs and 12µm copper foils were used in the experiment.

Warp and Twist

Test pieces are 1-layer boards. After etching, Warp and Twist was measured based on JIS-C-6481. Figure 5 shows the results. The new fabric laminates reduce Warp and Twist by as much as 50% compared to conventional fabric laminates. As a result, it was possible to reduce the Warp and Twist in four sheets of new fabric to the same level as with eight sheets of conventional glass fabric.

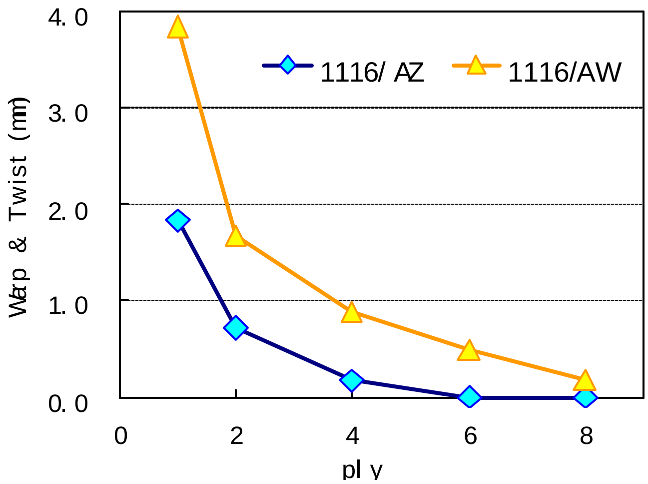


Figure 5 - Warp and Twist

Dimensional Stability

Test pieces are 1-layer boards whose size is 340mm x 340mm. Base point, after copper foil etching, first heating (170?/30min.) and second heating (170?/30min.) were evaluated. Figure 6 shows the results. The new fabric laminates improve the dimensional stability and reduce standard deviation, because the glass fibers are uniformly distributed in the glass fabric. By reducing the undulation the hardness and aspect direction are improved.

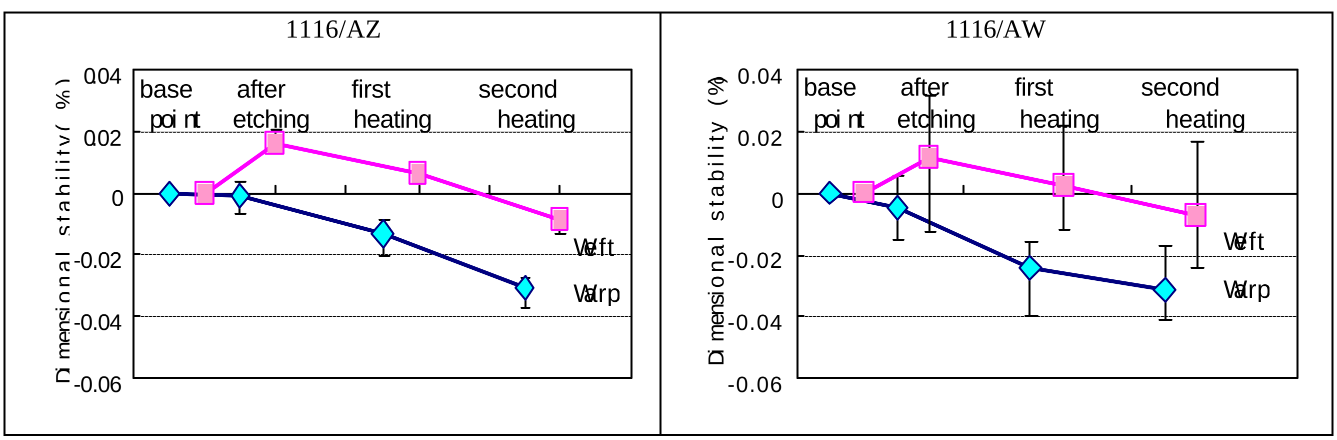


Figure 6 - Dimensional Stability

Coefficient of Thermal Expansion (CTE)

Test pieces are 1-layer boards 3mm in width. C.T.E. in the y direction is shown in Figure 7. Crimp of fabric is reduced in the boards, which used the new fabric, and the reinforcement ability of the aspect direction improves.

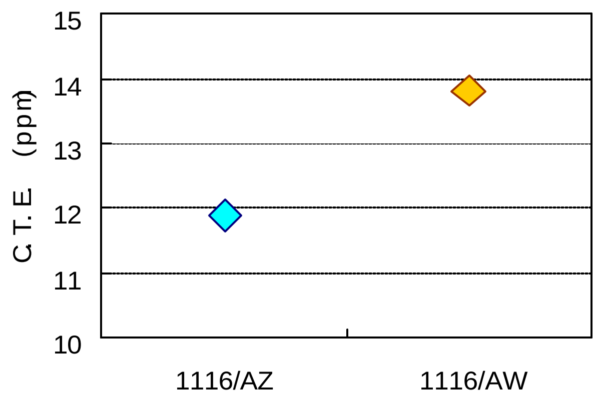


Figure 7 - CTE

Drillability

Drillability was measured by using 50µm fabrics' in laminates.

Mechanical Drilling

As for mechanical drillability, location of drilling through holes precision and wear of the drill tip were evaluated. Test pieces were 2-layer boards. The drilling condition was drill rotation speed of 160krpm with 0.075-diameter drill. Figure 8 shows the standard deviation of the drilled hole-locations and Figure 9 shows the distribution of hole-locations. Figure 10 shows a photomicrograph of the drill tip after processing. In the new laminates hole position precision improved more than 10%. Drill tip wear was reduced and consistent. There was less resistance to drilling.

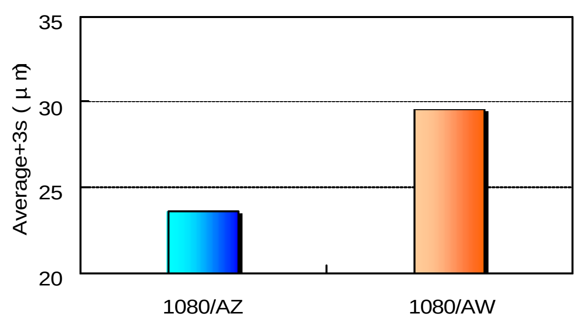


Figure 8 - Accuracy of Hole Location

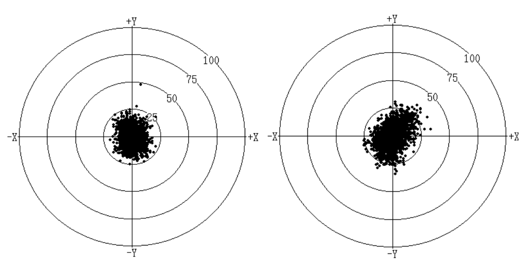
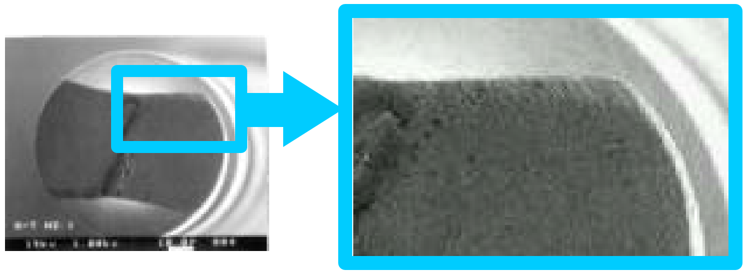
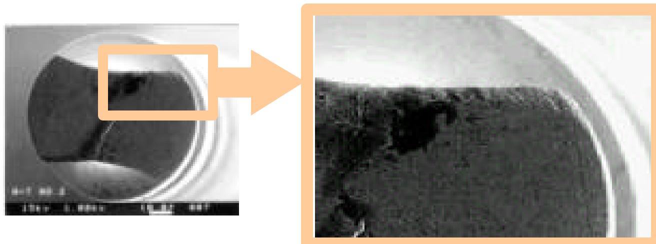


Figure 9 - Distribution of Hole Location



1080/AZ



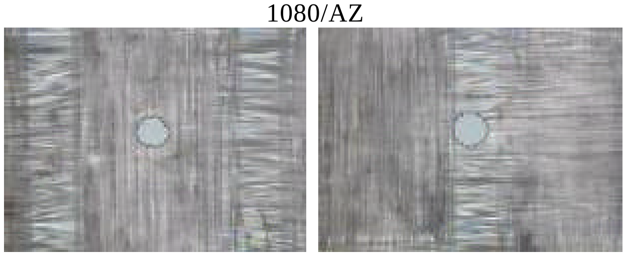
1080/AW

Figure 10 - Wear of the Drill Tip

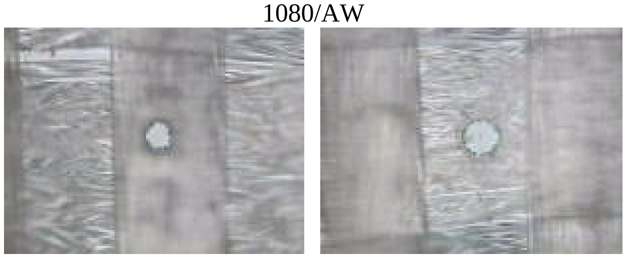
Laser Drilling

Test pieces were 1-layer, with the evaluation substrate laminated on each side of 0.1mm thickness core board, covered overall with black oxidized 35µm copper foil. The laser drilling condition was a 0.1mm via diameter, frequency of 100Hz and pulse energy of 0.6W. Figure 11 shows photographs of the laser via hole's diameter of one yarn area and two yarns area. In Figure 11, the new fabric laminate has a clean and consistent laser drilled via hole. Figure 12 shows that the via hole's shape of two yarns area in new fabric is uniform, and the difference in diameter of two yarns area and one yarn area is smaller than in the conventional fabric, because of the homogeneous structure of the fabric.

1080/AZ



1080/AW



Two yarns area One yarn area

Figure 11 - Via Hole's Surface Photograph

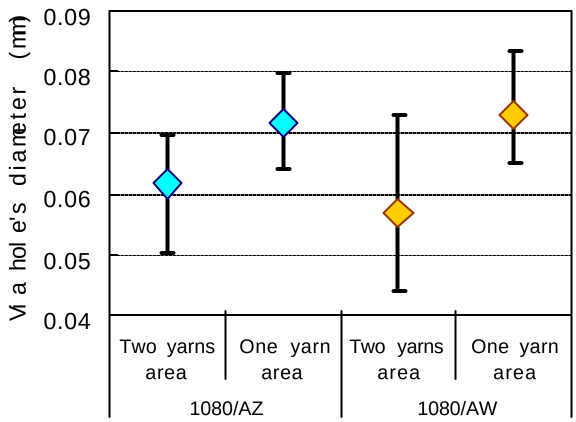


Figure 12 - Via hole's Diameter

Conclusion

We have successfully developed a method to produce fabric, using zero twist yarn, and uniformly distributing the glass filaments. The new fabrics are available in conventional fabric styles. The new fabric can be summarized as follows:

- The fabric exhibits reduced internal strain and the glass filaments are uniformly distributed not only x-y direction, but also z direction.
- Laminates made with the fabric have reduced levels of Warp and Twist, and improved mechanical properties such as dimensional stability and C.T.E.
- Laminates have exhibited excellent micro-diameter drilling capability, such as laser drilling and mechanical drilling with less drill bit breakage.

Reference

1. Tarja Rapala-Virtanen, Circuit World, Vol.29, No.1, p16 (2002)
2. Y. Kimura, IPC Printed Circuits EXPO 2000 Technical Proceedings, S09-1 (2000)

Internal Strain Free & Homogeneous Glass Fabrics for HDI Boards

Shinji Yoshikawa

ASAHI-SCHWEBEL CO.,LTD.

Technology & Development

Abstract

Conventional Glass fabric

The standard yarns have 1 turn per inch of twist.

We developed the glass fabrics that consist of zero twist yarns.

【AZ fabric Asahi-Schwebel Zero twist fabric】

AZ fabric *will be able to improve…*

- ***Warp & Twist*** → **about 50% decrease**
- ***C.T.E.*** → **about 2ppm decrease**
- ***Dimensional stability.*** → **low standard deviation**
- ***Laser and Mechanical.*** → **well-rounded holes**
- ***Drillability.*** **low wear of the drill tip**

Background

Trends of the PCBs

Mother Board
- multifunctional
- high density
- compactness of design

Substrate
- thin insulation layer
- narrow pitches
- fine patterns

Demands for the Glass Fabric

◎Mechanical strength

→ Warp & Twist, Dimensional Stability, Low C.T.E.

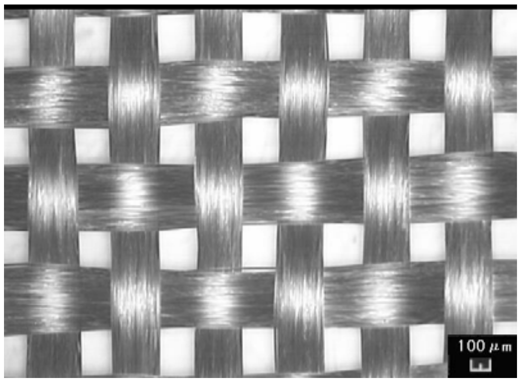
◎Drillability

→ Well-rounded holes, Low wear of the drill tip

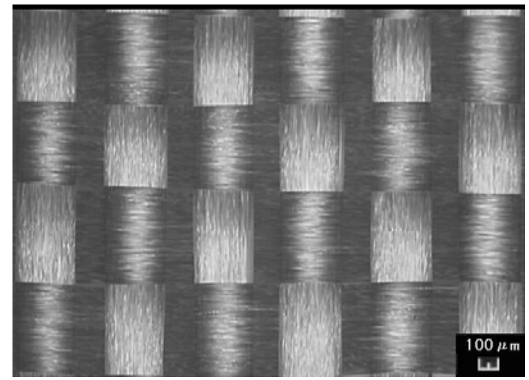
○ More Thinner ○ Insulation reliability … etc.

One of our solution method

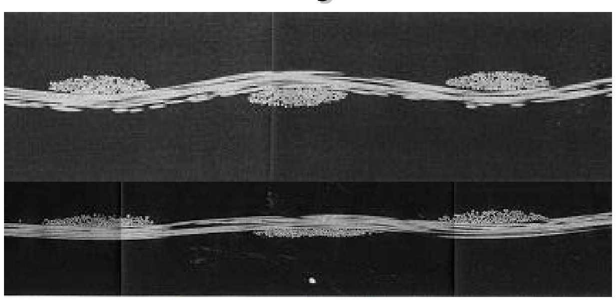
MS fabric

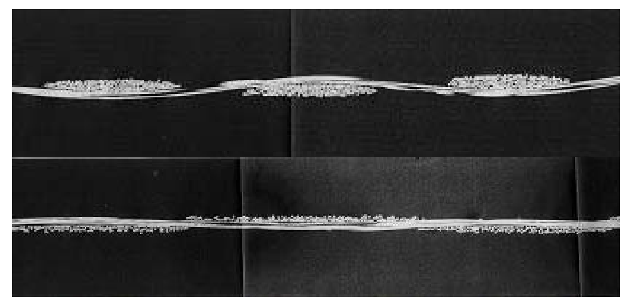


Ordinary fabric



MS fabric





- The glass filaments are uniformly distributed.
- Crimp and thickness are reduced.

What's the AZ fabric ?

What's the AZ fabric ?

Surface and Cross Section

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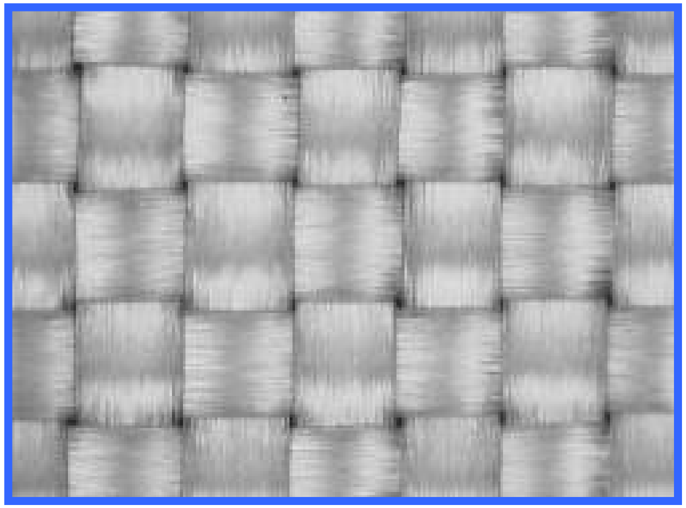
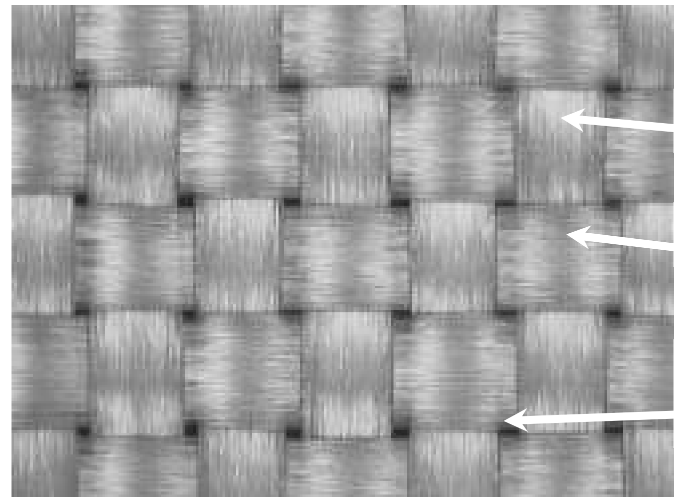
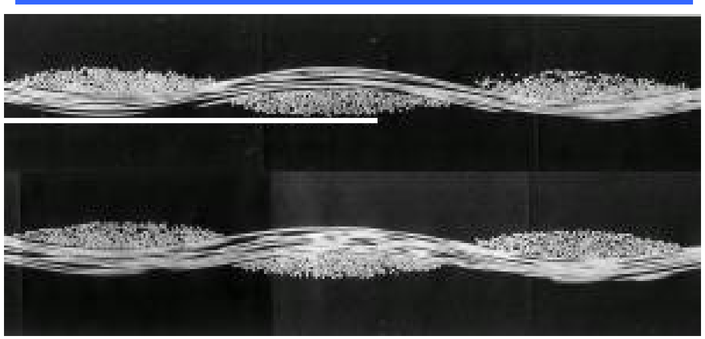
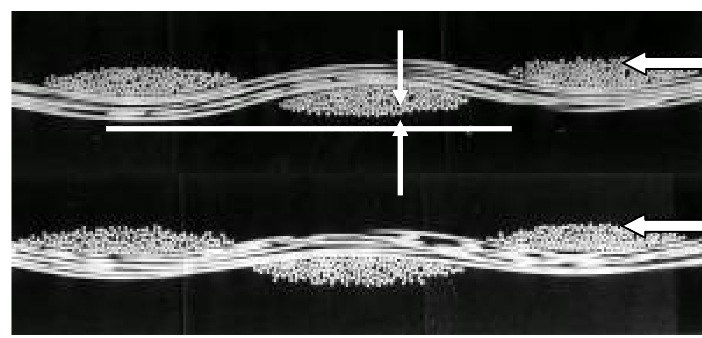
1116/AZ



1116/AW







What's the AZ fabric ?

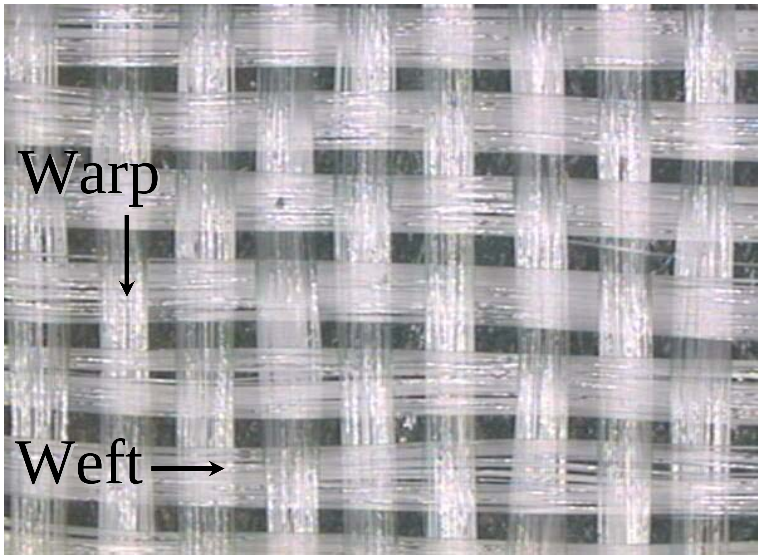
Various styles of the AZ Fabric

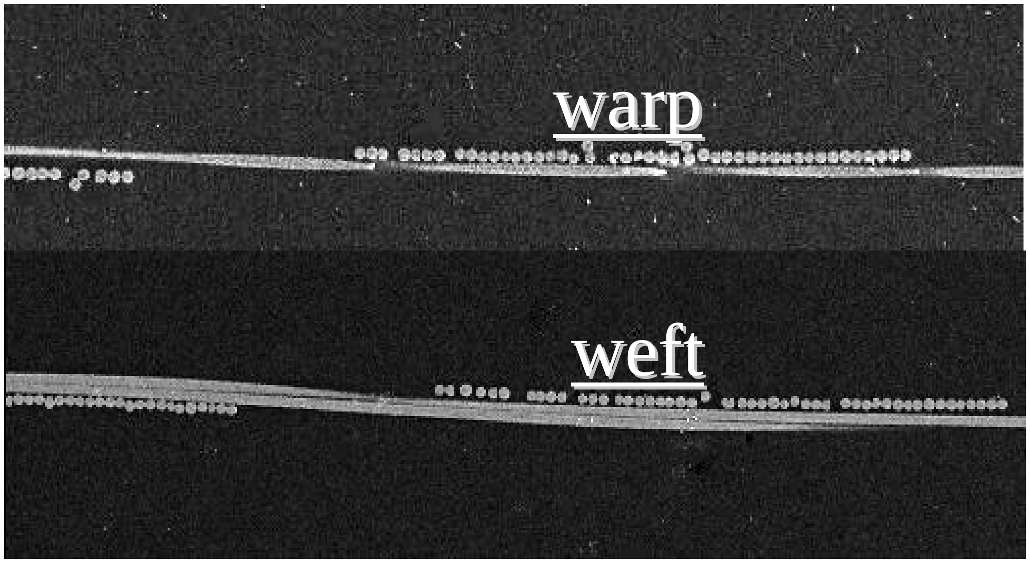
	100µm			50µm			Trial
Style	1116	1116	1116	1080	1080	1080	1017
Process	AZ	MSW	AW	AZ	MSW	AW	AZ
Yarn	D225 1/0 0Z	D225 1/0 1Z	D225 1/0 1Z	D450 1/0 0Z	D450 1/0 1Z	D450 1/0 1Z	BC3000 1/0 0Z
Filament (µm)	5	5	5	5	5	5	4
(counts)	400	400	400	200	200	200	50
Counts/inch (Warp× Weft)	60×58	60×58	60×58	60×47	60×47	60×47	84×84
Tickness (mm)	0.084	0.084	0.089	0.042	0.047	0.050	0.011
Permeability ($cm^3/cm^2/s$)	4	5	12	29	59	83	120

* The above figures are typical data, but not guaranteed.

What's the AZ fabric ?

Ultra thin fabric





Surface and cross sectional images of ultra thin fabric.

Using zero twist thin yarns,
we get 10μm AZ fabric.

Characteristics of the Board

AZ fabric

Characteristics of the Board

* Internal Strain Free => Warp & Twist
* Lower Crimp => C. T. E.
* Homogeneity => Dimensional Stability

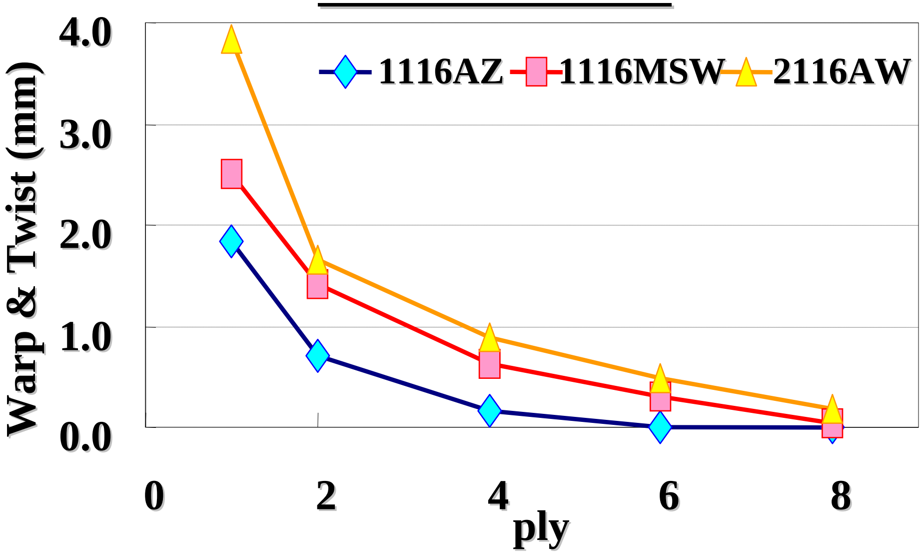
Drillability

Large characteristic improvements are expected by using AZ fabrics.

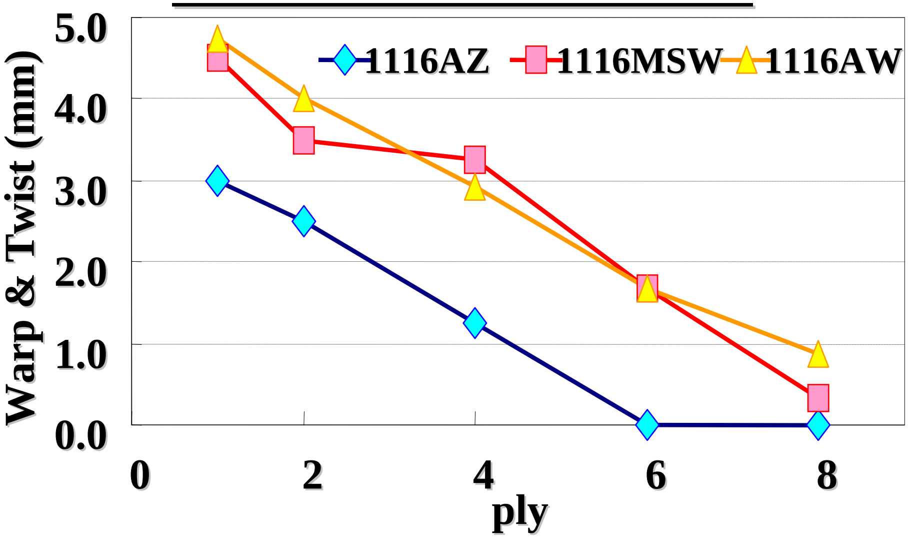
Internal Strain Free

Warp & Twist

Normal state



After heat treatment



Test Conditions

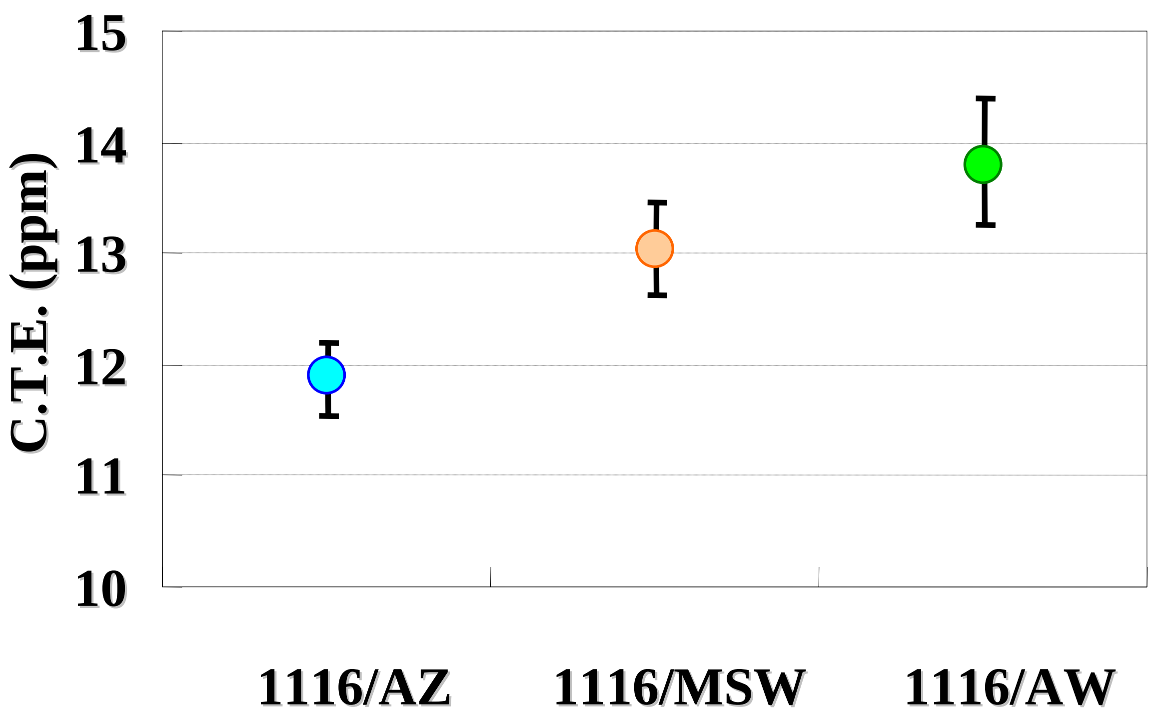
・Test Piece : FR-4　　・Size : 50mm×50mm

・Evaluation: Before heating,　After heating (260℃-30sec dipping in solder)

* The above figures are typical data, but not guaranteed.

Lower Crimp

Coefficient of Thermal Expansion



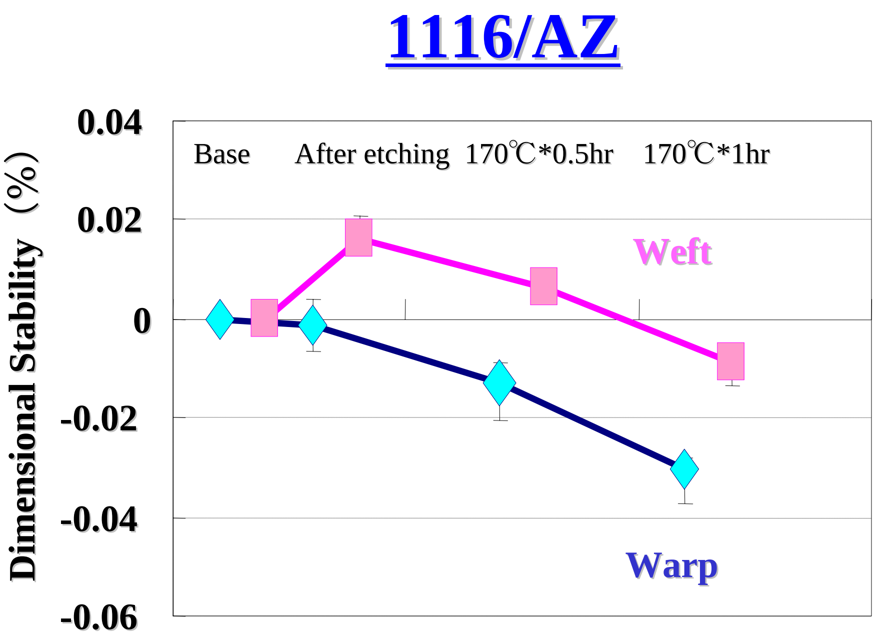
Test Conditions

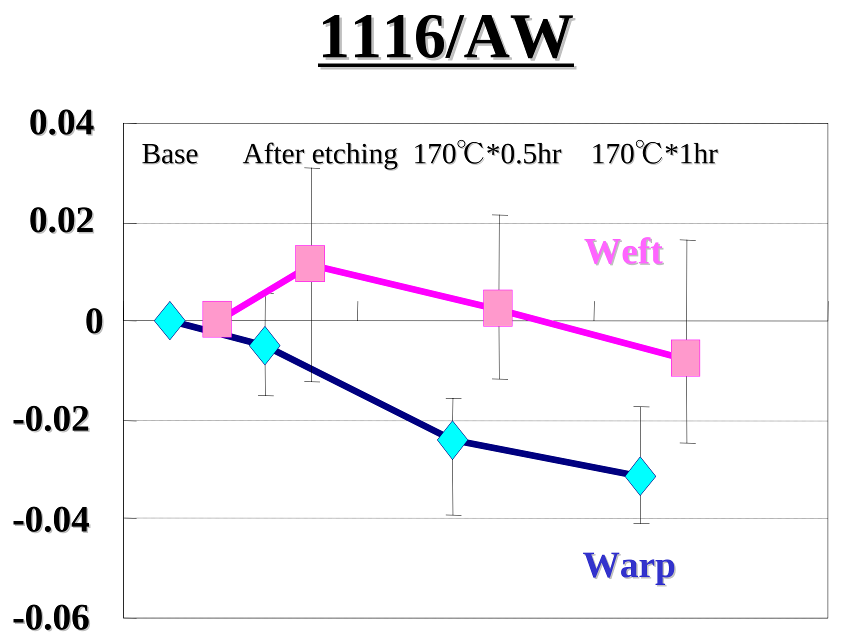
Test Piece : 1 Ply FR-4
Thickness : 0.10-0.11mm
Width : 3mm
Tension : 50mN
Temperature rise rate : 5deg/min.
Temperature range : 50-100℃

* The above figures are typical data, but not guaranteed.

Homogeneity

Dimensional Stability





Test Conditions

・**Test Piece : 1 Ply FR-4 1/3oz. Cu** ・**Size : 340mm×340mm**

・**Evaluation: Base point, After etching, 170℃×0.5hr, 170℃×1hr**

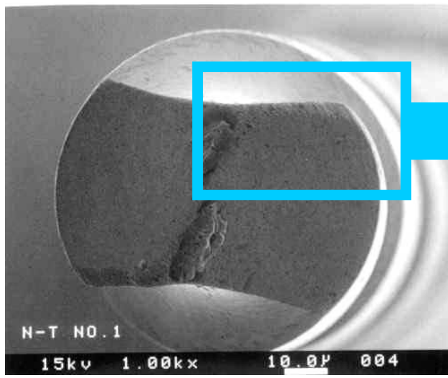
＊ The above figures are typical data, but not guaranteed.

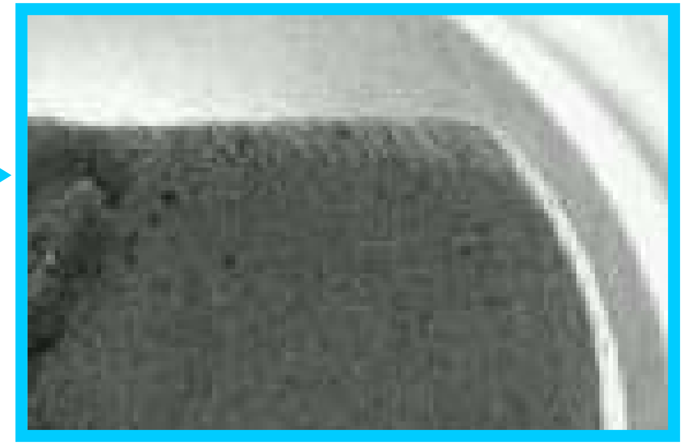
Homogeneity

Drillability -Mechanical Drilling-

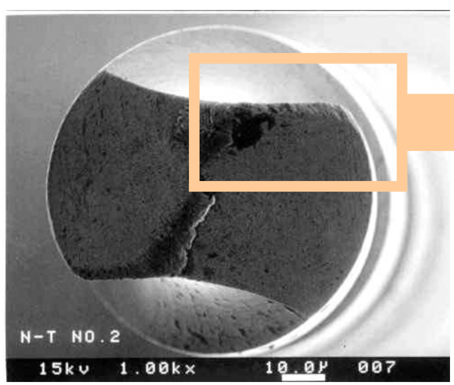
Edge of the drill (Observation of the drill tip) 50μm type

1080/AZ





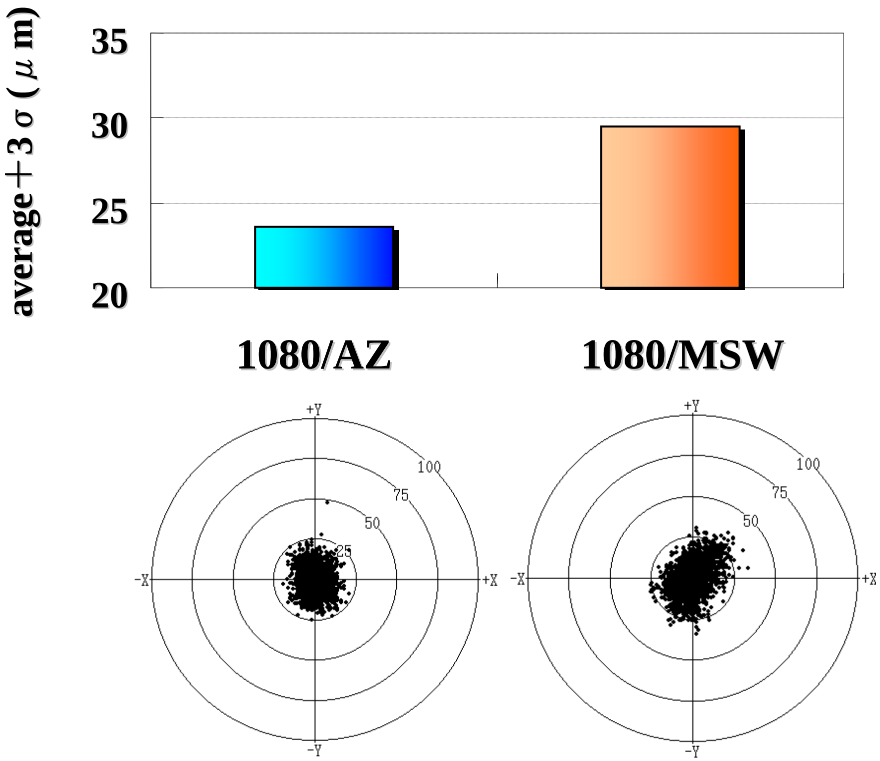
1080/MSW



Drill tip wear

Drillability -Mechanical Drilling-

Hole position precision (50 μm type)



Test Conditions

- Test Piece : 4ply FR-4
- Drill diameter : 0.075mm φ
- Drill rotation speed : 160krpm
- Evaluation : 2000hits

* The above figures are typical data, but not guaranteed.

Homogeneity

Drillability -Laser Drilling-

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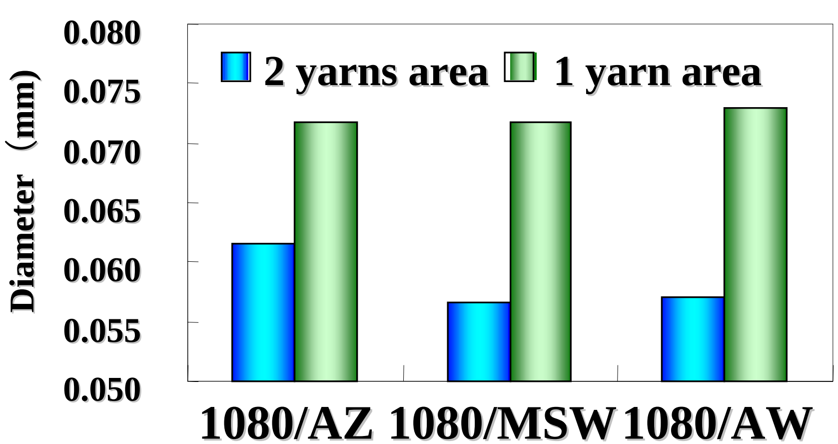
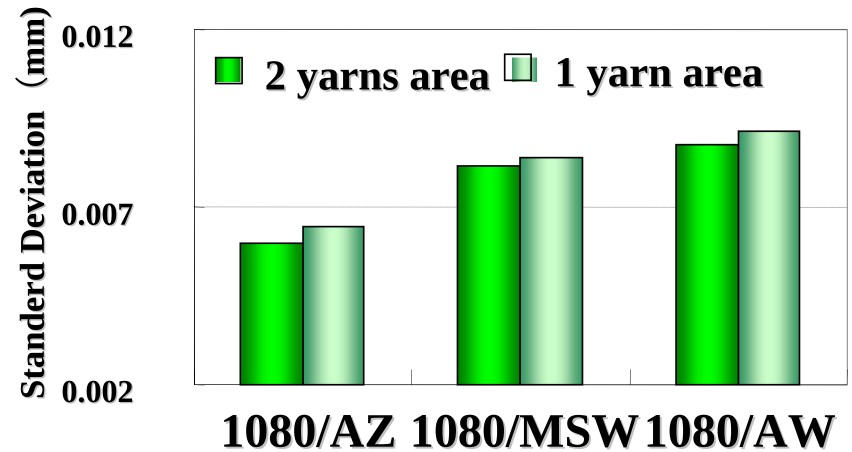
Average Diameter

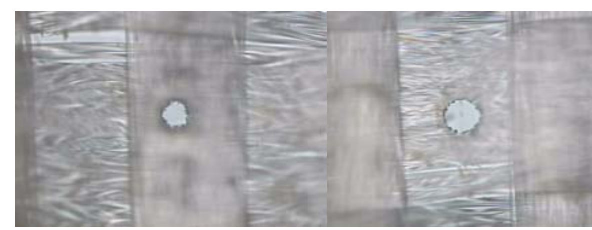


Deviation



1080/AZ

1080/MSW



1080/AW

* The above figures are typical data, but not guaranteed.

Conclusion

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Zero Twist Yarn "MS process" etc.	→	**AZ fabric** Asahi Zero twist fabric

- Eliminating internal strain in the fabric.
- Improvement of fiber distribution in the laminate.

AZ fabric ***will be able to improve…***

Warp & Twist.	→	**about 50% decrease**
C.T.E.	→	**about 2ppm decrease**
Dimensional stability.	→	**low standard deviation**
Drillability.	→	**both laser & mechanical**