Study on the Filament Yarns Spreading Techniques and Assessment Methods of the Electronic Fiberglass Fabric

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Abstract. The filament yarns spreading techniques of electronic fiberglass fabric were developed in the past few years in order to meet the requirements of the development of electronic industry. Copper clad laminate (CCL) requires that the warp and weft yarns of the fabric could be spread out of apart and formed flat. The penetration performance of resin could be improved due to the filament yarns spreading techniques of electronic fiberglass fabric, the same as peeling strength of CCL and drilling performance of printed circuit board (PCB). This paper shows the filament yarns spreading techniques of electronic fiberglass fabric from several aspects, such as methods and functions, also with the assessment methods of their effects.

1. Introduction

The electronic fiberglass fabric, which is woven by fiberglass yarns, is the basic material of the copper clad laminate (CCL), and CCL is the basic material of the printed circuit board (PCB). The developing trend of electronic products is toward thinner, lighter, shorter and smaller, therefore the CCL requires to develop high density, thin multilayer, high Tg, lead-free and halogen-free. The heat resistance and surface smoothness of PCB are getting higher, which makes electronic fiberglass fabric thinner and even more uniform, also have faster resin wettability and higher dimensional stability.

In order to deal with the development trend of downstream industry, the filament yarns spreading techniques of the electronic fiberglass fabric were developed, with improving the performance of treatment agent of electronic fiberglass fabric at the same time. The technique mainly refers to flattening in the production process of electronic fiberglass fabric. When the fabric was soaked with the resin, there was a greater contact area between them. It also improved the penetration rate of electronic fiberglass fabric and resin, and made better combination of fabric and resin. The penetration of resin on the electronic fiberglass fabric became faster with filament yarns spreading. The treatment agent also made the chemical bond between glass fiber and resin more stable, so that the heat resistance of PCB improved. Meanwhile, the surface of the electronic fiberglass fabric became smoother, the gap between the warp and weft yarn became smaller. Fibers and resin in the PCB were relatively uniform, which improved the processability, surface smoothness, dimensional stability and water suppression of the PCB, and made the PCB more reliable[1].

2. Technological process

The electronic fiberglass fabric processed with filament yarns spreading technique called spreading electronic fiberglass fabric, which is a physical process for the common woven electronic fiberglass fabric. Usually high pressure spunlacing was used, which made the warp and weft yarns of the fabric
spread and flat. The protrusion of the overlap of the warp and weft yarns was obviously reduced, and the gap between the warp and weft yarns reduced significantly. It improves the smoothness and dimensional stability of the fabric, permeability and surface peeling resistance of the resin. Thus, it is possible to avoid the defects of different hole wall smoothness and different quality of the conducting hole caused by drilling on gaps of warp and weft yarn of the electronic fiberglass fabric when drilling on the PCB\(^2\).

The basic technological process of electronic fiberglass fabric includes three steps. First step is expanding by expanding wheel after weaving on air-jet loom. At the same time, fabric is rapidly heated and extruded by continuous rollers. Second step is re-coiling and degreasing in high temperature furnace for several hours. Third step is spreading, usually by high pressure water. The spreading machine generates high pressure water and breaks up the weft yarn mainly. So that the space gap between the warp and weft yarn becomes smaller, the air permeability is decreased, and the electronic fiberglass fabric becomes soft, and the penetration performance is improved and even more uniform. After that, the roller setting and proper agent are needed\(^3\).

3. Methods of spreading

Generally the warp yarns are under high tension during the technological process of electronic fiberglass fabric. Tremendous resistance and friction must be overcome whichever method was chosen. The spreading effect of warp yarn is poor than weft yarn. As a result, the surface roughness and smoothness of half cured sheet is not good. The quality of CCL is difficult to meet the requirements of technology, such as ALIVH (arbitrary layer in the via hole technology) and B2it (embedded bump solder joint interconnect technology) of PCB. The half cured sheet made by electronic fiberglass fabric with poor spreading effect could not meet the requirements of high-grade CCL because of bad penetration performance of resin and bad drilling performance. The fiberglass fabric appears to show holes between monofilaments and resistance of ion mobility is poor\(^4\).

Therefore, the spreading effect of warp yarn is the key to measure the spreading methods of electronic fiberglass fabric. At present, the common methods of spreading include the following ways:

3.1. Rollers method

The rollers method is coating electronic fiberglass fabric on the porous rollers by tensive rollers. The plum rollers concentric with the porous rollers were driven by variable frequency motor and put into a tank full of water. The water wave vibration produced by plum rollers was transfer to electronic fiberglass fabric through porous rollers, so that the fibers of warp and weft yarns of electronic fiberglass fabric could spread to achieve spreading effect.

The spreading effect of this method is proportional to the the vibration intensity of wave, and the vibration intensity is proportional to the rotation rate and cube of amplitude. Therefore, the vibration intensity of wave could be enhanced by improving the rotation rate and increasing the number of petals of plum rollers or making petals bigger, thereby increasing the spreading effect. Yet the fiber strength of electronic fiberglass fabric must be considered with the increasing rotation rate and the number of petals. Spreading should not cause hairiness and bias weft, which means the appropriate rotation rate and plum rollers should be selected in case of the hairiness and bias weft could be controlled in the allowed range.

3.2. High pressure spunlacing method

Spunlacing method is spraying high pressure water (soft water) on the both sides of electronic fiberglass fabric through high-pressure pump and nozzle on a spreading machine consisting of several guide rollers, so that the fiber of electronic fiberglass fabric is evenly dispersed. The spreading machine formed the soft water circulation system through the circulating water pump, the two stage filtration system, the replenishment tank and the water tank. The circulating water pump was driven by a variable frequency motor to ensure the dynamic balance of the circulating soft water.

The effect of this method depends on the outlet pressure of high-pressure pump, the nozzle type and the distance from nozzle to the surface of fabric. The selection of process parameters are usually different according to the different types of electronic fiberglass fabric. Generally when electronic
fiberglass fabric is thin, the pump pressure is low, the nozzle flow is smaller, the distance of the nozzle to the surface of fabric should adjust farther to ensure the full spreading effect and avoid to producing a trace of water on the fabric. High pressure spunlacing method have better spreading effect and higher qualified rate of downstream products than rollers method in case of choosing appropriate nozzle type, spray height and spray pressure.

3.3. HDI method
Shanghai Honghe Electronic Material Co., Ltd. developed a efficient spreading method for HDI substrate (high density interconnect multilayer board), which could spread under the condition of fiber tension as low as possible. The width of electronic fiberglass fabric reaches the maximum, and the uniformity is better. This method is processing the desizing fabric by jet-flow with pressure of 0.49Mpa-4.9Mpa (5kg/cm2-50kg/cm2), diameter of 0.1mm-0.3mm, water temperature of 25℃-85℃ and the vibration frequency of 25Hz-50Hz. And then the fabric is formed by pressure rollers of 0.98Mpa-9.8MPa (10kg/cm2-100kg/cm2) and soaked by silane coupling agent finally[5].

This method could reduce the damage of fabric appearance to the lowest level during spreading by matching the supporting belt speed and tension control. An so on, this method has obvious spreading effect especially for thin and ultra thin fabrics. HDI method could make the warp and weft yarns of electronic fiberglass fabric more dispersed, fabric structure more uniform and smooth, gaps around interweave smaller or even disappear. The interweave of fabric becomes more dispersed and the permeability decreased, the penetration performance of resin improved, the width of warp and weft yarns increases, fabric thickness decreased, the uniformity of the thickness increased. CCL has better uniformity, smaller thermal expansion coefficient difference, better size stability, and better performance in the downstream processing.

3.4. Other methods
There are many factors affecting the effect of the electronic fiberglass fabric, and there are many spreading techniques deserved attention and reference in production practice:

3.4.1. Low twist and non twist of electronic fiberglass yarn. The twisting of electronic fiberglass yarn is beneficial to weaving, which makes the yarn having better strand integrity, abrasion resistance and hairiness less. Yet twisting is not beneficial to the spreading of electronic fiberglass fabric. Undoubtedly as the most suggested way, the electronic fiberglass yarn should have low twist or even no twist from the point of view of spreading. That because fiber is easy to spread into flat shape in the later processing stage. Therefore, the low twist and non twist of electronic fiberglass yarn must become the mainstream development trend. However, there is a high requirement for the wetting agent in the spinning stage, and only a few enterprises in Japan could produce it right now.

3.4.2. Low tension in weaving preparation process. It is very important to improve the spreading effect of the warp yarn in the preparation process before weaving due to the warp tension of the electronic fiberglass fabric and the spreading effect of the warp yarn is inferior to that of the weft yarn. Low tension warping and shaft is beneficial to loose yarn, but how to ensure that yarn would not shake after low tension and warp work stably seems important. Therefore, it is necessary to consider that how to control the tension piecewise in tension setting. In order to facilitate the warp spreading, the tension of the warp and the shafts should be as minimum as possible in case of the quality of weaving fabric and the uniformity of yarn tense is guaranteed. At the same time, yarns should not vibrate during warping and shaft.

3.4.3. Expanding in weaving process. The effect of warp yarn spreading could be improved by expanding the electronic fiberglass fabric in the weaving process. The electronic fiberglass fabric will be expanded by a couple of temples (special thread rollers) on both sides of air-jet loom, which could achieve warp yarns spreading effect in weaving. Temples set in the winding end could also play a role in preventing wrinkle in weaving thin cloth and extreme thin cloth.
3.4.4. Healing of electronic fiberglass fabric. The warp and weft yarns of the electronic fiberglass fabric consist of hundreds of monofilament with diameter of several microns, and the surface of the monofilament is adhered with the starch based soakage agent. In case of using starch swelling tide principle when fabric weaving was completed, for a certain period of time in a high humidity environment, the process for electronic fiberglass fabric called "healthing" process in Nittobo. After the heat treatment, the electronic fiberglass fabric is treated by thermal desizing. And the warp and weft yarns become looser, which is more conducive to spread the fiber.

4. Functions of spreading
Compared with the ordinary electronic fiberglass fabric, the spreading electronic fiberglass fabric has advantages in the following aspects:

4.1. Lower air permeability and better uniformity
The direct effect of spreading is that the gap of warp and weft yarns becomes narrow, single yarn width becomes wide, interweave becomes smooth and permeability becomes small and uniform.

4.2. The leaching property of resin improves obviously
The warp and weft yarn of the electronic fiberglass fabric becomes more flat after spreading, and the contact area with the resin increases, so that the penetration rate of the resin is faster and the soaking time is shortened.

4.3. Better affinity with resin
After spreading, the surface area of the warp and weft yarn of the electronic fiberglass fabric is bigger, the penetration property of the resin becomes better. Also the binding and affinity of the fabric and resin becomes better, which could be reflected from the change of the resin content.

4.4. Heat resistance and heat moisture reliability improves apparently
After spreading, the adhesion and affinity of the electronic fiberglass fabric and the resin improves, and the combination of the glass fiber and the resin is more compact, which could effectively improve the thermal stress of the plate and improve the heat resistance reliability of the board.

4.5. Better drilling performance on PCB
After spreading, the distribution of warp and weft yarns tend to be uniform and the space is reduced, which makes the distribution of yarns in the plate more uniform. It is beneficial to drilling performance on the plate, and the hole inner wall becomes smoother and the hole position becomes more accurate.

4.6. Better surface smoothness
The surface of electronic fiberglass fabric becomes smoother through the spreading process and the sheet surface consisting of it becomes more smoother. It could be reflected by the change of surface friction and tensile strength test value of the fabric.

4.7. Better dimensional stability of the plate
The thermal expansion molding shrinkage degree of formed sheet will be reduced after spreading process because of twist loss of the warp and weft yarns, which is equivalent to a certain degree of stress release. It could be reflected from the CTE size of sheet, or the size change of X, Y direction after etching of sheet. It is beneficial to the low pressure forming of the sheet because of its small size change.

4.8. Better resistance to ion migration of PCB
The resistance performance of the ion migration of sheet requires higher along with light and thin and short and small trend of electronic products, also with small hole spacing and small interlayer spacing of PCB and dense of lines. The penetration performance of resin seems better for spreading and
flattening electronic fiberglass fabric. The boundary between electronic fiberglass fabric and resin seems closer and better, which leads the sheet not easy to absorb moisture. Better moisture resistance is helpful to improve the resistance performance of ion migration.

5. Assessment methods
The evaluation methods of the spreading effect of electronic fiberglass fabric are very limited, such as the following methods:

5.1. Air permeability method
The air permeability of fabric is the primary index to measure the spreading effect of electronic fiberglass fabric by the fabric permeability tester. For example, the air permeability of 7628 electronic fiberglass fabric without spreading is 6-8ml/cm2*s-1 in general, and the air permeability of the same fabric after rollers spreading is less than 3ml/cm2*s-1 [6]. The permeability test cost is low and the operation is convenient, but it is an indirect characterization of the spreading effect, which could only reflect the permeability of the whole specimen, but could not express the micro situation of spreading.

5.2. Direct observation method
The sample could be directly observed by magnifying glass or microscope, with measuring the width of warp and weft yarn and the area of interweaving area of warp and weft yarn, also with calculating the uniformity of yarn (especially warp yarn) width. The spreading effect could be compared between different spreading fabrics by measuring the data before and after spreading.

5.3. Penetration performance method
The wetting rate is calculated according to the wetting time of the resin, and the effect of the spreading of different electronic fiberglass fabric could be compared.

5.4. Fabric cross section observation method
The filament distribution of the fabric could be observed and analyzed. For example, most of the weft yarns of the spreading fabric are in the 3 layer, and most of the HDI spreading fiber fabrics are 2 layers, and the warp yarns are less than those of the ordinary spreading electronic fiberglass fabric.

5.5. Surface roughness method
This representation method of spreading is measuring the surface height difference of electronic fiberglass fabric. The three-dimensional data of the sample surface shape and the surface height difference of the data could be measured by scanning laser microscope, as shown in Figure 1. After modifying height difference data as required, the statistical data could be collected. The monofilaments far from the surface of the fabric will interfere the experimental data, so the exclusion of monofilament interference and the correction of height difference data are required to by selecting certain local image regions, as shown in Figure 2.

![Figure 1. 3D surface map of fabric](image-url)
6. Concluding Remarks

There are already several methods to spread filament yarns of electronic fiberglass fabric. However, the assessment methods are still not direct and effective enough. Still there is a lot of work need to do, such as developing the characterization method, measuring the interface of the composites, and building a testing database of surface roughness.

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