Discussion on the features of No-Flow prepreg

1 Introduction

In recent years, with the electronic products' fast developments to small, high-performance and multi-functionalization, multi-layer rigid-flex board, step board, cooling plate's processing technology is rising. In order to prevent flowing glue in the rigid-flex joint、the step slot,etc., pure prepreg often be as a connecting materials,it is difficult to meet the requirement of the rigid-flex joint plate because of pure prepreg's poor stability. As a result, many PCB manufacturers are looking for other alternative materials for bonding between rigid boards and flexible boards, and the currently preferred replacement material is a Non-Flow Prepreg.

It has bigger difference for Non-Flow Prepreg and ordinary FR-4,so we can not simply apply conventional FR-4's processing experience. For example, since the Non-Flow prepregs often require opening windows operations, the Non-Flow prepregs must have good toughness and machinability. "Non-Flow" is the largest characteristics of Non-Flow prepreg,if using the ordinary FR-4 lamination conditions when laminate Non-Flow prepregs, because of small glue flow,it will appear white spots and other defects in the line spacing of the board or the surface filling capacity.

This paper combined with experimental verification,it is detailed analysis of the characteristics of Non-Flow prepreg,and provides numbers of recommendations for Non-Flow prepreg processing.

2 Non-Flow Pprepreg Brief

2.1 Demand Analysis of Non-Flow Pprepreg

The report pointed out that the demand of rigid-flex plate,step PCB board will increase year by year, as shown in Fig. 1.

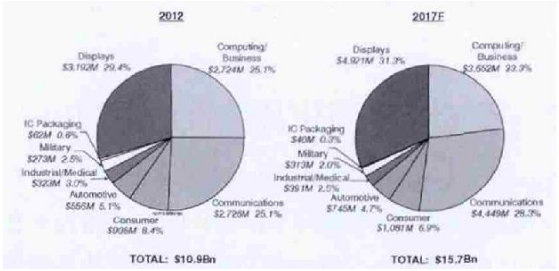


Fig 1 Demand change of rigid-flexible plate,step PCB board

2.2 Kinds of Non-Flow Pprepreg

At present, there are two kinds of common Non-Flow Prepreg: ordinary *Tg* and high *Tg*. When high *Tg* FR-4 material is used for step board or rigid-flex plate, high *Tg* Non-Flow prepregs are typically used for lamination. If the general plate has no *Tg* requirement, the ordinary *Tg* Non-Flow prepreg will be commonly used for lamination in the industry. If the board has halogen-free requirements, you need to use halogen-free Non-Flow prepreg to match and use.

A company in China has developed a high-performance Non-Flow prepreg(SP120N) in order to meet the needs of the fields such as step board and rigid-flex joint board. It has been gradually got the market recognition since it was entered into the market in 2007.

2.3 Features Brief of Non-Flow Prepreg

"No-flow" is the largest characteristic of the Non-Flow prepreg. This kind of plate has strict requirements to the flow ability of Non-Flow prepreg, to prevent flowing glue in the rigid-flex joint, the step slot, etc..From the melt viscosity curve of view of Non-Flow prepreg and conventional ordinary FR4 prepreg, the melt viscosity of the Non-Flow prepreg is higher than that of the ordinary FR-4, and the lowest melt viscosity is 10-100 times higher than that of the ordinary FR-4, as shown in Fig.

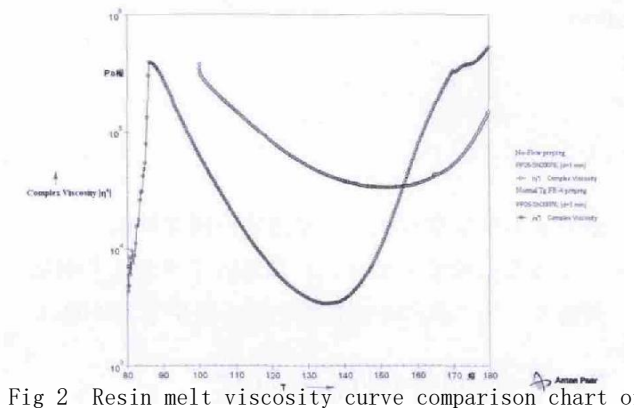


Fig 2 Resin melt viscosity curve comparison chart of Non-Flow prepreg and conventional ordinary FR4 prepreg

In addition, since Non-Flow prepreg often require opening window operations, the Non-Flow prepreg must have good toughness and machinability.

3 Discussion on the features of No-Flow prepreg

Since Non-Flow prepreg has bigger difference from the ordinary FR-4 prepreg, the experience of the ordinary FR-4 prepreg can not be simply applied when Non-Flow Prepreg is used. This paper analyzed and discussed the characteristics of Non-Flow Prepreg from

the aspects of Non-Flow Prepreg index, melt viscosity curve, glass transition temperature curve, mechanical processing and press-fit method. Some suggestions were provided for the application of Non-Flow Prepreg.

3.1 Non-Flow Prepreg index

GT is an important index to evaluate the fluidity of ordinary FR-4 prepregs at high temperature. Prolong GT of prepreg can increase resin flow ability at high temperature, thus enhancing resin's wetting and filling capacity. However, Non-Flow Prepreg is not easy to fall out of powder, and the fluidity of the resin at high temperature can not be judged by the GT. To this end, it was established test method of Non-Flow Prepreg's resin fluidity in IPC-TM-650.

As shown in Fig.3, two 1-inch holes were punched in the sample, the sample、laminated board、release film and pad were placed in two thin steel sheet, and the laminate was placed on a sheet maintained at 171℃±2.8 ℃ in the pressing machine, Immediately clamping mold and make pressure to 1380kPa±70kPa. After at least 20 min at full pressure, remove the pressure and remove the laminate.

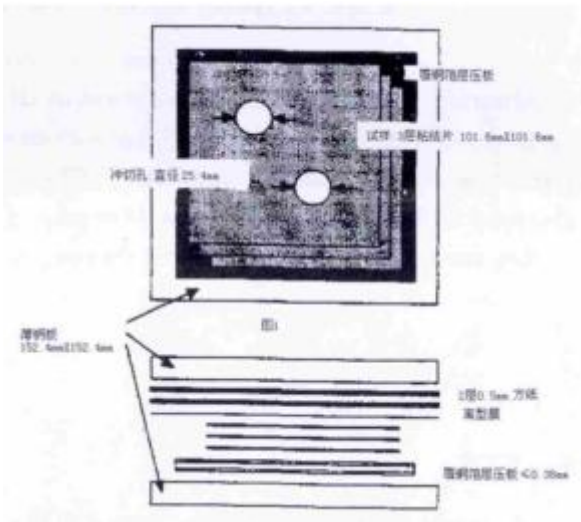


Fig 3 Test method for excess glue

After the resin flowed, the diameter of the hole became small, and measured the diameter of the hole. The hole average diameter when punched, subtract the hole diameter after pressing, that is Non-Flow Prepreg's resin fluidity, the unit is mm.

3.2 The Resin Melt Viscosity Curve at Different Heating Rate

When the melt viscosity curve of ordinary FR-4 material was tested, the melt viscosity curve became wider and the lowest melt viscosity became smaller as the heating rate

increased. "No flow" is the largest flow characteristics of Non-Flow Prepreg, Whether the resin melt viscosity curve of Non-Flow Prepreg has the same law or not ?

Select SP120N, the resin melt viscosity curve when testing different heating rate.As shown in Fig. 4.

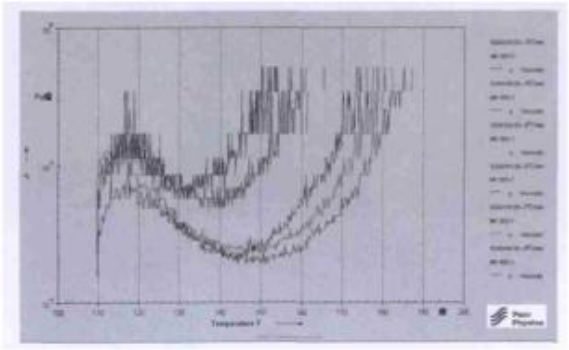


Fig 4 the resin melt viscosity curve in different heating rate

From Fig. 4, the melt viscosity curve of the Non-Flow Prepreg is widened and the lowest melt viscosity becomes smaller as the temperature rise rate was increased during the test. Therefore,although Non-Flow Prepreg has "non-fluidity", the resin fluidity of the Non-Flow Prepreg will increase as the temperature rise rate was increased.

3.3 Glass transition temperature curve

The earliest non-flowing prepreg was a thermoplastic rubber-filled epoxy system or an epoxy system synthesized from partially cross-linked acrylic acid. With the advancement of technology, "non-fluidity" is before the material in the formation of B-order form, It is achieved through chemical way to control molecular weight distribution.Choosing SP120N and a company's V material,and they were pressed into sheet separately,then test the glass transition temperature of the sheet. The results are shown in Table 1.

Table 1 *Tg* Test Result

Test Item	Test Conditions	Unit	No.	Test Result
Tg	DSC	℃	V	103.66/162.07
			SP120N	126.57

Glass transition temperature test curve, As shown in Fig.5,Fig.6.

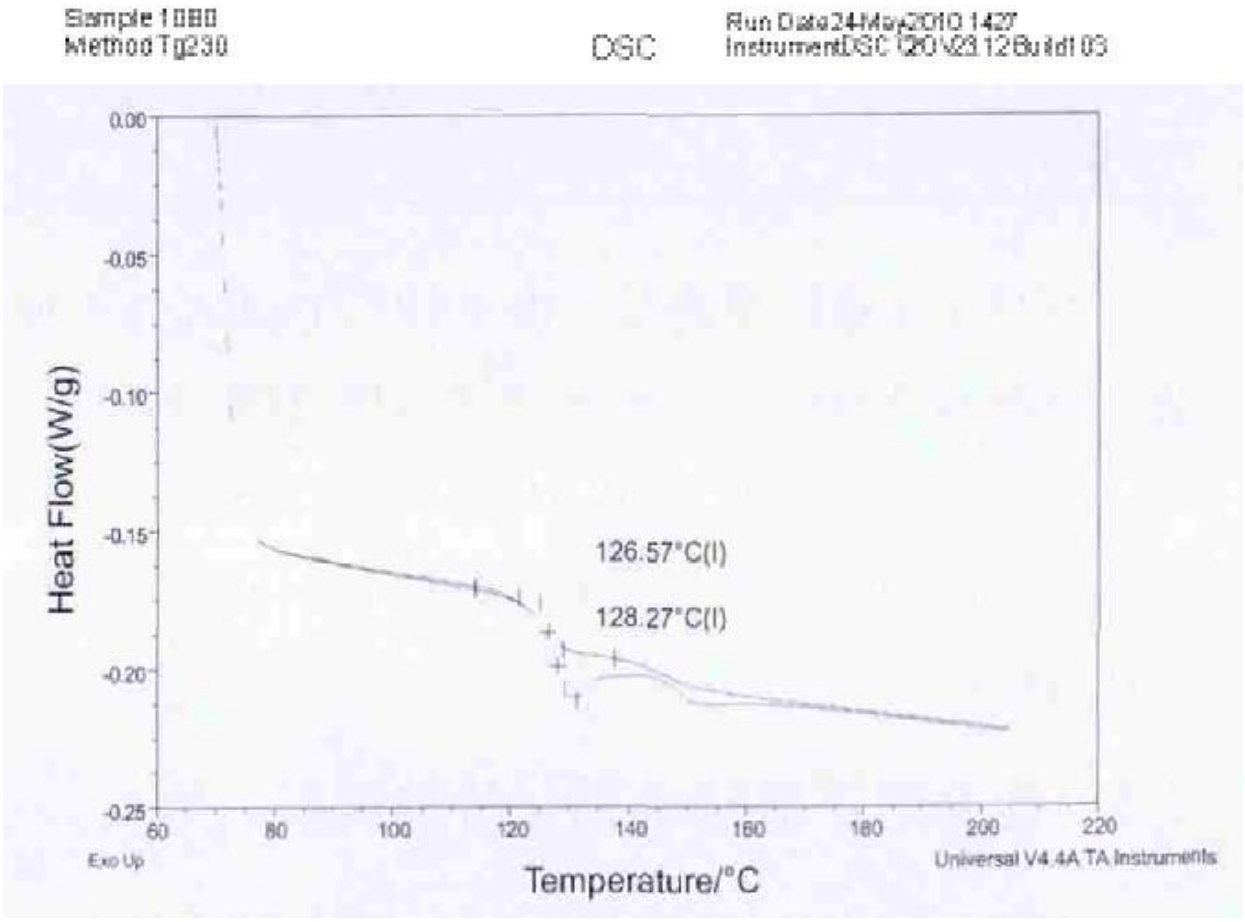


Fig.5 SP120N Tg test curve

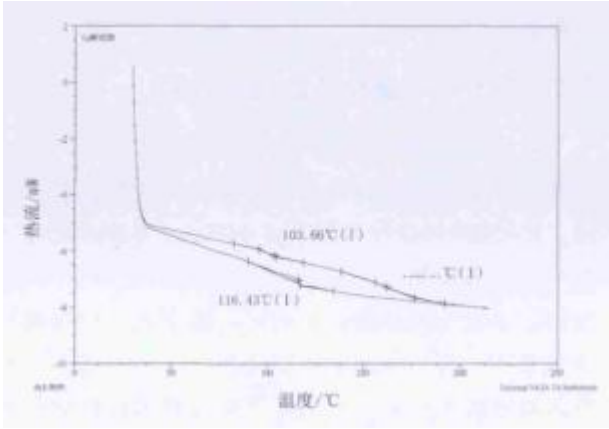


Fig.6 V material test curve

From above test results, SP120N's *Tg* test curve has only a *Tg* test peak, but V material *Tg* test curve appeared *Tg* double peaks phenomenon.

3.4 Non-Flow prepreg mechanical processing

In the combination of cooling plate and PCB, due to the different shape of PCB and cooling plate, opening window area often have components, cooling plate window position does not want any resin outflow. As the Non-Flow prepreg of connecting material, it is necessary to pay attention to the machinability during opening window operation. If the

edge of the window position for Non-Flow Prepreg has crack, because of its poor fluidity, where prone to substrate cracks and voids, there is the risk of stratification.

Choosing 1080 prepreg with SP120N and ordinary FR4 material , using the same punching tools and parameters, have punching test and assess the hole wall quality. As shown in Fig. 7, Fig. 8.

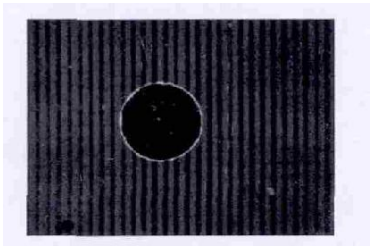


Fig.7 SP120N (1080prepreg) hole wall quality

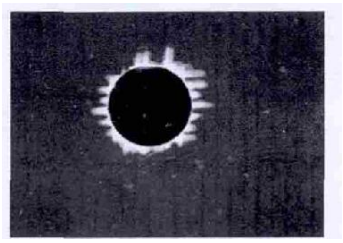


Fig.8 Ordinary FR4 material (1080 prepreg) hole wall quality

From the above test results, SP120N Non-Prepreg's hole wall has good quality ,without hole wall whitening phenomenon after punching the hole; ordinary FR-4 material's hole wall appeared glass yarn crack and hole wall whitening phenomenon after punching holes.

3.5 Non Flow Prepreg's pressing method

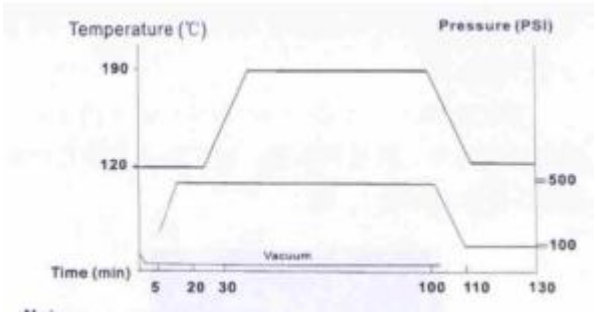
From the R & D principle,the Non-Flow prepreg is epoxy system modified, by adding a low-flow polymer in the formula,through B-order chemical reaction to reduce the fluidity of the product itself. The early as rigid-flex board and step board's connecting material -pure prepreg,mainly is the acrylic system materials. As the two materials' reaction system is not same, Non-Flow Prepreg's pressing way can not simply apply pure prepreg's fast-pressing way, otherwise easily lead to board layer blast because of material curing is insufficient.

3.5.1 Fast-Pressing Method

The comparison of the experimental results with SP120N was carried out using fast pressing (Table 2) and fast heating pressing bonding (Fig. 9). The board structure was 3 × 1080 (RC = 64%) + CCL substrate (e.g.S1000-2).

Tale 2 Pressing Way

	Tep./℃	Time	Pressure/MPa	Time
Pre-Pressing	180	10s	2.76	10s
Forming	180	10min	2.76	10min



Note: Heat-up rate:3.0-5.0℃/min(70-130℃)

Cure time: >30min(170-180℃)

Note: Heat-up rate:3.0-5.0℃/min(70-130℃)

The heat resistance of the materials was measured under the two kinds of pressing methods. The results are shown in Table 3. Fig. 10 and Fig. 11.

Table 3 The Heat Resistance Test Result

Pressing Method	Test Conditons	Times	Test Result
Fast-pressing	288℃/10s	1 times	NG (layer bubbling, Fig.11)
Convention		3 times	OK (Fig.10)

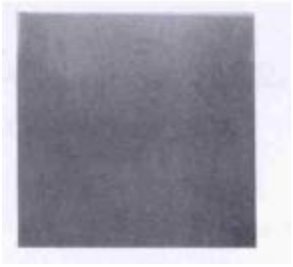


Fig.10 SP120N Substrate OK

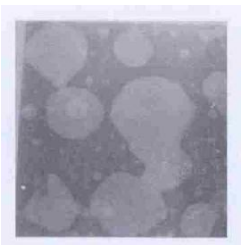


Fig.11 SP120N Substrate layer bubbling

From the above experimental results, SP120N Non-Flow Prepreg's compression method can not simply apply pure prepreg's fast-pressing method,otherwise easily lead to heat resistance became deteriorated because of material curing is insufficient.

3.5.2 Special Pressing Method

According to the flow curve of the resin melt viscosity for Non-Flow Prepreg and the ordinary FR4 prepreg,we can see the melt viscosity of the Non-Flow prepreg is higher than that of the ordinary FR-4, and the lowest melt viscosity is 10 to 100 times higher than that of the ordinary FR-4, and the melt viscosity of the Non-Flow Prepreg is higher than that of the conventional FR-4.In order to better wetting and bonding, must provide high pressure,otherwise easily to cause cavity of Non-Flow prepreg.

The contrast experiment of the different compression procedure was carried out with SP120N.The structure of the board was as follows: 3 × 1080 (RC = 64%) + CCL Substrate (e.g.S1000-2).

The parameters of the lamination program are shown in Table 4.

Table 4 Heating rate verification test

	Heating rate（80~130℃）	Pressure（one step presssure）
Procedure1	1.6℃/min	1.72 MPa
Procedure2	4.0℃/min	2.76 MPa

The heat resistance of the material under both pressing procedures was tested. The results are shown in Table 5.

Table 5 The Heat Resistance Test Result

Pressing Method	Test Conditions	Times	Test Result
Procedure1	288℃/10S	1 times	NG（layer bubbling）
Procedure2		3 times	OK

From the above experimental results, because SP120N Non-Flow Prepreg has low fluidity,the method is different from the ordinary FR-4 material,and can not simply apply the ordinary FR-4 material compression method, otherwise easily lead to heat resistance became deteriorated because Non-Flow prepreg and bonding interface's cavity.

3.6 Non-Flow prepreg's flowing glue when pressing

When Non-flow prepreg is applied to the rigid-flex joint plate and the cold plate, neither the cold plate window region nor the junction of the rigid-flex joint plate is intended to flow excessively. But it is necessary for the basic flow-fill line when pressing. From the rheological point of view, that is, resin melting and bonding surface, as long as the air to the edge, no longer flow. As the joining material of the rigid-

flex joint plate and the step plate, Non-Flow prepreg is not truly "non-flow" from the viewpoint of the resin melt viscosity curve of Non-Flow prepreg. Since Non-Flow prepreg also has a certain degree of liquidity when it be pressed,then liquidity is whether like ordinary FR-4 prepreg or not,the flowing glue of the board edge is bigger than the middle position of the board ?

SP120N and V two kinds of Non-Flow prepregs were used to conduct comparative experiment, and investigate the flow glue in different positions of the plate. Experimental designing structure, such as: 1 × PI film + 1 × 1080 (RC=64%) + 1 × electrolytic copper.

After laminating the PI film and the Non-Flow prepreg, poles were punched in different positions of the sample using a punch, as shown in Fig. 12 and 13.

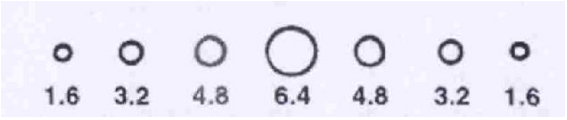


Fig.12 Punching Pole Graphics(Unit:mm)

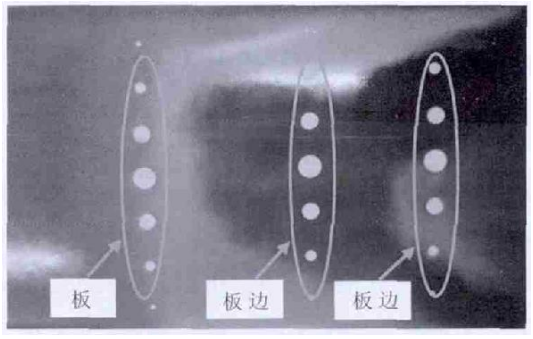


Fig.13 Experimental Punching Pole Position

Then PI film、Non-Flow prepreg and the copper foil were laminated to form a test and pressed. Pressing conditions, as shown in Table 6.

Table 6 Pressing Conditions

Item	Heating rate(70~130)℃	Curing Time	Pressure
SP120N	3.5℃/min	＞30min(170℃以上)	2.76/MPa
V		＞60min(185℃以上)	

The flowing glue quantity of Non-Flow prepreg after laminated was measured, as shown in Table 7.

Table 7 Flowing glue quantity of board

Item	Flowing glue quantity/mm			Substrate Quality
	Board Edge 2	Boar Edge 1	Middle of Board	
V	1.3487	0.5482	0.2983	OK
SP120N	0.2987	0.2838	0.2453	OK

From the above test results, there is a difference in the amount of flowing glue between the edge and the middle position of the plate after laminating non-flow prepreg; the amount of glue in the edge position after pressing V material is far greater than the middle position; After pressing SP120N prepreg,the edge and the middle flow glue quantity is small, only has little difference.

4 Conclusion

Non-Flow prepreg has a very low flowability, which is obviously different from the ordinary FR-4. Based on the above analysis, the characteristics of non-flow prepreg are as follow:

Because it is not easy to drop out of powder for Non-Flow prepreg, GT index can not be used to judge the high temperature resin curing fluidity of Non-Flow prepreg. To monitor the quality of the non-flow prepreg, a test method of non-flow prepreg resin fluidity is required;

Although the non-flow prepreg has "no flowability", with the increase of the heating rate during the test, the resin melt viscosity curve of the non-flow prepreg becomes wider and the minimum melt viscosity becomes smaller, and the fluidity of the resin also becomes large.

As the non-flow prepreg of the joint material, it need pay more attention to the machinability during opening windows operation. SP120N Non-Prepreg's hole wall has good quality ,without hole wall whitening phenomenon after punching the hole; ordinary FR-4

material’s hole wall appeared glass yarn crack and hole wall whitening phenomenon after punching holes.

From the above test results,

From the R & D principle,the Non-Flow prepreg is epoxy system, Non-Flow Prepreg’s pressing way can not simply apply pure prepreg’s fast-pressing way and ordinary FR-4’s pressing way, otherwise easily lead to board layer blast because of material curing is insufficient.

Non-Flow prepreg also has a certain degree of liquidity when it be pressed,there is a difference in the amount of flowing glue between the edge and the middle position of the plate. The flowing glue quantity is different when different Non-Flow prepreg of different manufacturers were pressed.