Improvement of material properties of printable adhesive

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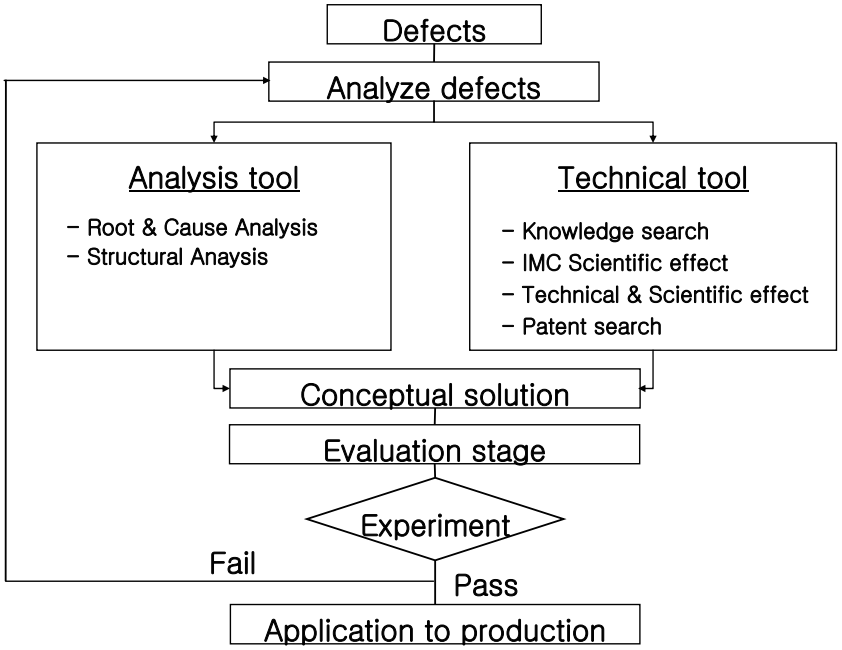
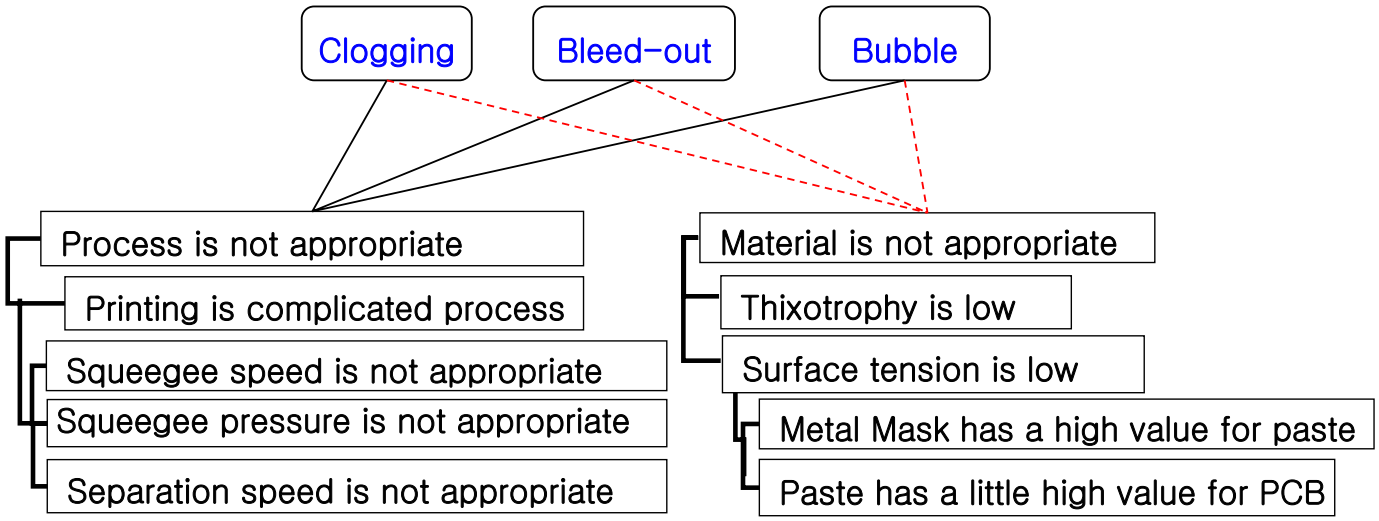
Problem Solving Scheme

Factors for the defects are revealed through Analysis and Technical tools. Then, appropriate solutions are suggested, which will be verified by experiments.



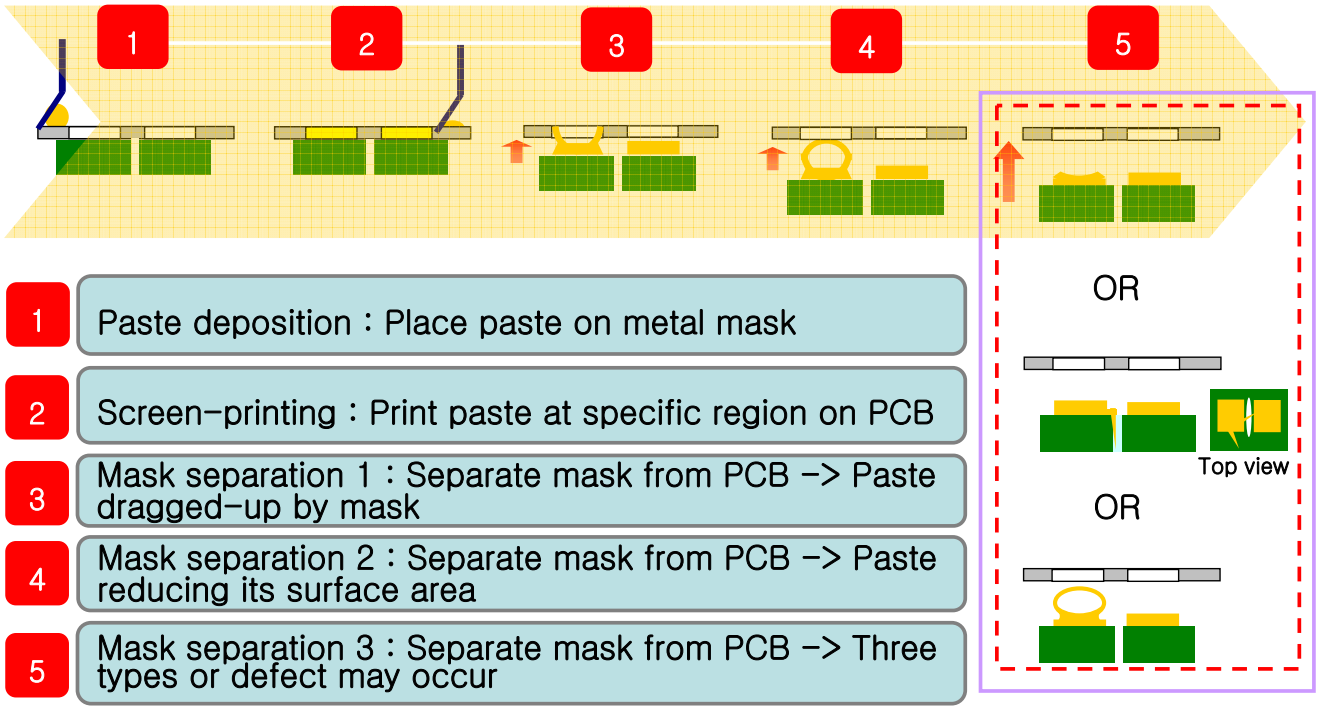
Analysis Tool – Root & Cause Analysis

Defect factors are considered in aspect of process and material itself: process factors, such as screen-printing parameters (squeegee speed, squeegee pressure and separation speed) or material factors, such as thixotrophy or surface tension.



Analysis Tool – Process view (Structure Analysis)

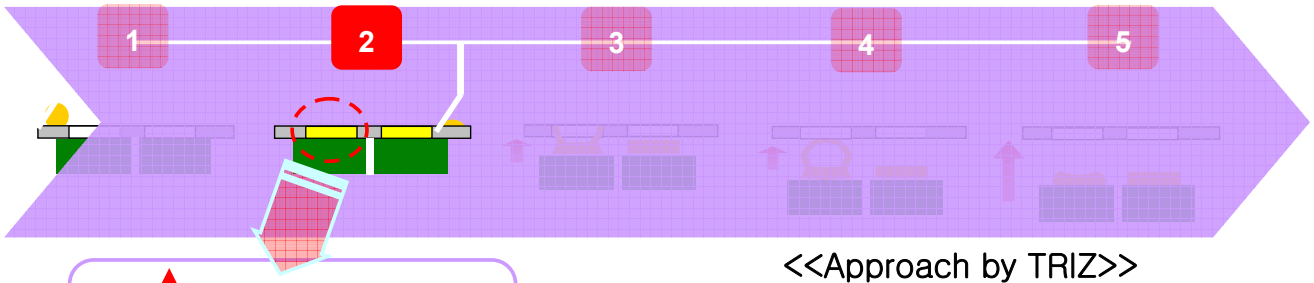
Different types of defects occurred during printing processes

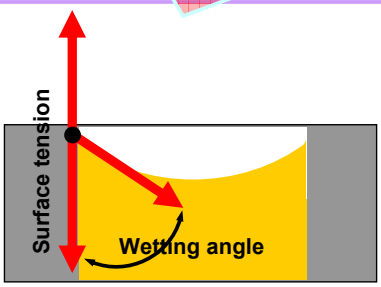


1. Paste deposition : Place paste on metal mask
2. Screen-printing : Print paste at specific region on PCB
3. Mask separation 1 : Separate mask from PCB -> Paste dragged-up by mask
4. Mask separation 2 : Separate mask from PCB -> Paste reducing its surface area
5. Mask separation 3 : Separate mask from PCB -> Three types or defect may occur

Analysis Tool – Process view (Structure Analysis)

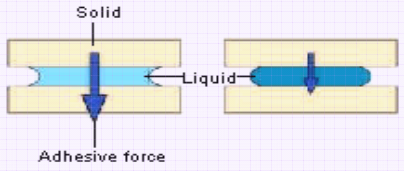
Surface tension of paste affects the wetting behavior on metal mask



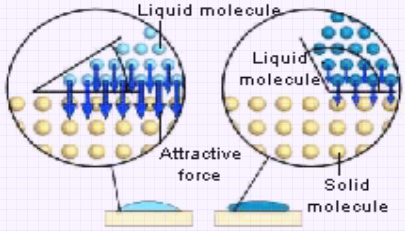


Change in the wetting angle changes the magnitude and the direction of the surface tension forces

<<Approach by TRIZ>>



Wetting angle affects the adhesive force between two solids



The smaller the wetting angle, the stronger the solid molecules attract the liquid molecules

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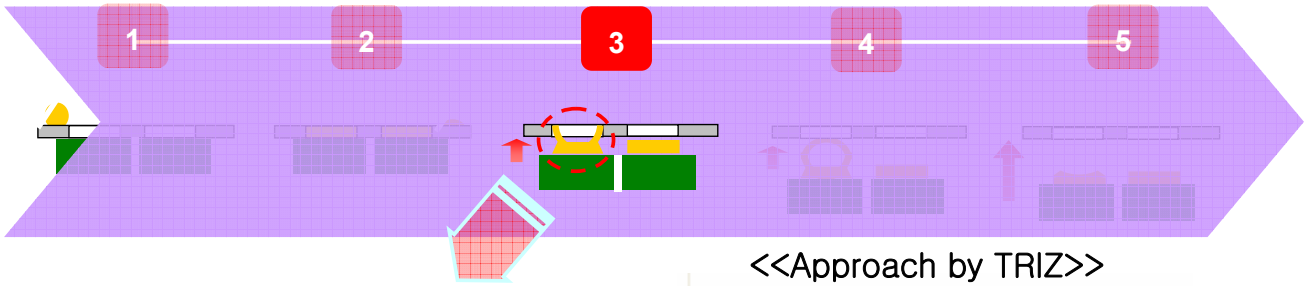
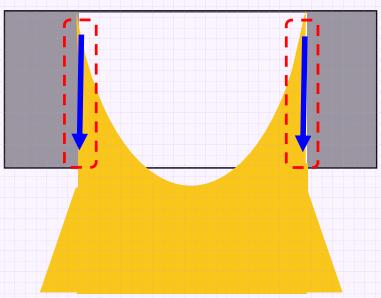
Analysis Tool – Process view (Structure Analysis)

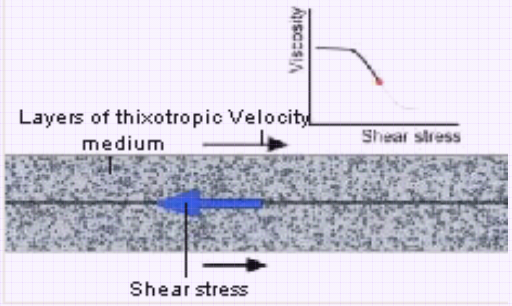
Shear stress applied on paste drags up paste with low surface tension





Shear stress is applied on paste at the side wall of mask

<<Approach by TRIZ>>



Shear stress affects the viscosity of a thixotropic medium

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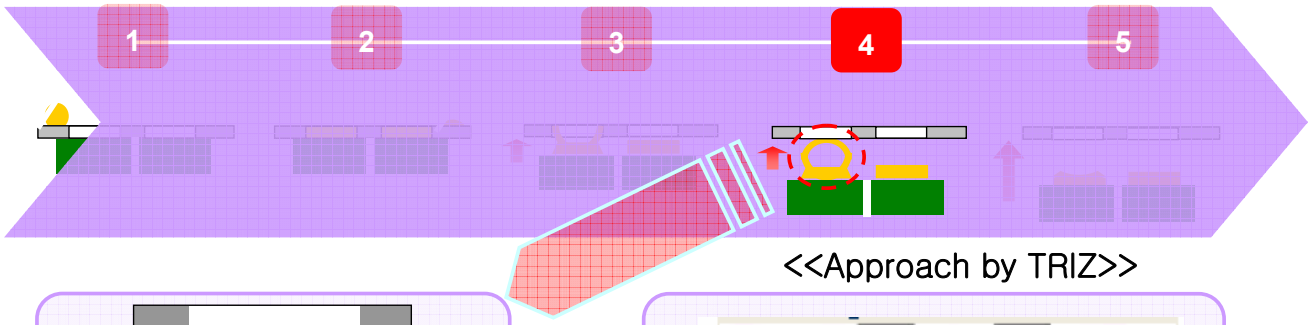
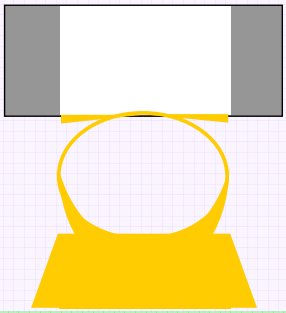
Analysis Tool – Process view (Structure Analysis)

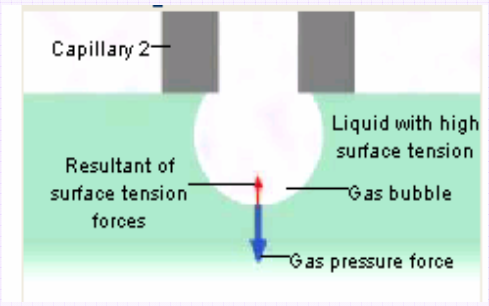
Paste forms a bubble after mask separation



<<Approach by TRIZ>>



Surface tension of paste affects the detachment of gas bubble through mask aperture



Surface tension affects the forces on the liquid–gas interface in a capillary

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Analysis Tool – Process view (Structure Analysis)

It is revealed that the process steps 3&5 generate undesirable effects, the defect. Squeegee pressure and squeegee speed must have fixed parameters constrained by customers. Therefore, only the separation speed is the adjustable factor in order to improve the defects

<< Useful Function and Undesirable Effect of Process >>

Process step	Function	Undesirable effect
1. Paste deposited on mask	Paste is placed on mask to be printed	None
2. Squeegee moves down onto mask	Squeegee is located onto mask to print paste	None
3. Squeegee presses / moves paste	–Press with appropriate pressure / move at appropriate speed –Deposit paste onto desired area of PCB	– Mask warped if the pressure is too high – Clogging & Bubble generated if the pressure is too low – Paste deposited insufficiently if the speed is too high – Low processibility if the speed is too low – Clogging, bleed–out and bubble generated reciprocally depending on the pressure and speed occasionally.
4. Squeegee lifts up	Give the space where mask can be separated up from paste and PCB	None
5. Mask separation	Separate mask from paste deposited on PCB	– Clogging, bleed–out and bubble generated reciprocally depending on separation speed very often.

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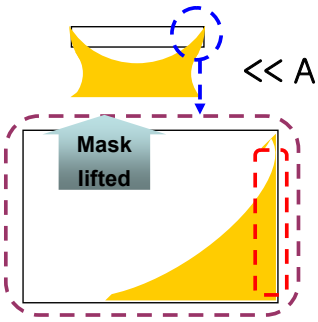
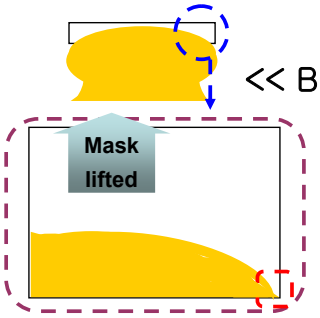
Technical Tool – Material view (Knowledge search)

Surface tension difference between mask and paste affects a wetting behavior of paste implying that surface tension of “A paste” is lower than that of “B paste” (Surface tensions of masks are the same):





- Relationship of surface tension among mask, A Paste and B Paste :

$$|\text{Mask} - \text{A Paste}| > |\text{Mask} - \text{B Paste}|$$

$$\approx \text{A Paste} < \text{B Paste}$$

- In order to have less wettability of paste on mask but better wettability on PCB, relationship of surface tension should be :

$$\text{Mask} < \text{Paste} < \text{PCB}$$

However, their relationships in real are :

$$\text{Paste} < \text{PCB} < \text{Mask}$$

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Technical Tool – Material view (Knowledge search)

There are some causes of clogging, bleed-out and bubble, which are assumed to be as follows:

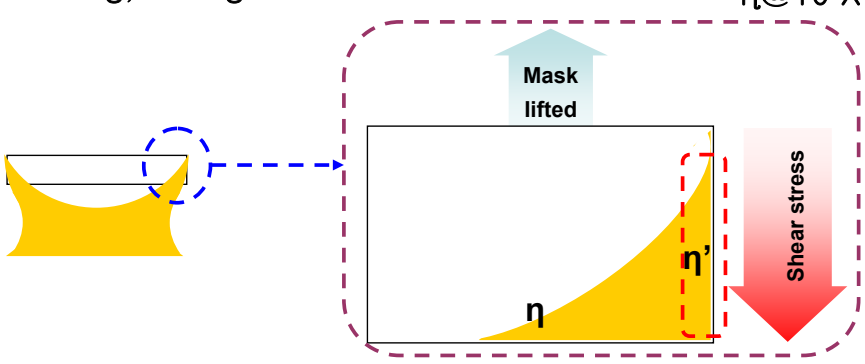
- Thixotropy

Reversible reduction in viscosity of some media under the influence of a shear stress. A shear stress arises between the layers of a moving medium due to a mechanical load. The motion can be flowing, mixing or vibration.

- Thixotropic index

Measure of thixotropy of fluid in general, which is the viscosity ratio of fluid at different rpm :

$$\frac{\eta@X\ (\text{rpm})}{\eta@10\ X\ (\text{rpm})}$$



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Technical Tool – Material view (Patent search)

It is recommended to add fine particles and dispersant agents in order to Increase thixotrophy

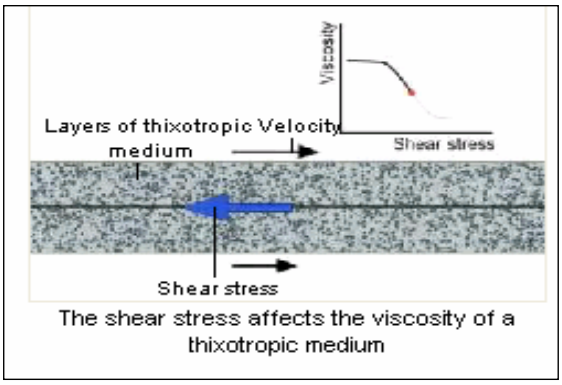
<< Thixotrophy-Related Patent Search >>

Patent No.	Key words
US3982334	Cab-O-Sil, ethylene glycol
US20070072981	thixotropic agent
US20070074900	filler
US20030089251	Beads
US4895598	polymer particle
EP0878839	large quantity of filler
US7154657	fumed silika
US6414077	fumed silika, propylene glycol
US20060262374	filler
wo2006070674	microfine inorganic powder with hudroxyl group
us20050154110	surface area, small particle
us20050131131	thixotropic agent
ep1526144	thickening agent
us20040131688	fumed silika, ultra disperse agent, surface area
us20020046851	inorganic particle
us5510436	clay particle
us5013383	Cabot Corporation (Tuscola, Ill.) as CAB-O-SIL
ep1760123	thixotropic agent
ep1571684	silica, fused silica or core shell rubber in the form of fine particles of particle size no more than 1 μm
us20040071925	SiO2 fine particles

Technical Tool – Material view (IMC Scientific effect)

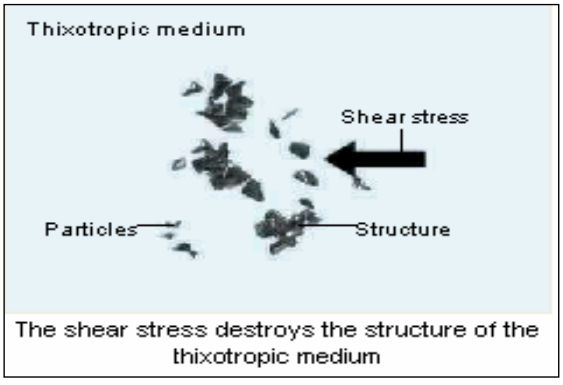
A viscosity decreases as shear stress increases, where the viscosity is the function of thixotrophy. And, a thixotropic medium requires high shear stresses to destroy its particles. In other words, if the same amount of shear stress is applied to mediums with different particle sizes, the medium with smaller particles tends to get higher effects of the shear stress on its viscosity or thixotrophy. Therefore, the medium with smaller particles is likely to have better thixotrophy than that with larger ones.

<< Relationship between viscosity & shear stress >>



The shear stress affects the viscosity of a thixotropic medium

<< Relationship between particle size & shear stress >>



The shear stress destroys the structure of the thixotropic medium

Evaluation Stage

Throughout the above studies, it is concluded that “Separation Speed”, “Add filler” and “Surface treatment of filler” are the main factors critical to improve the defects

<< Evaluation stage of effective factors for the defects >>

			Remark
Process	Squeegee pressure	Optimize parameters	Must be an equal or faster than customer spec. due to processibility : Modification is constrained by customers
	Squeegee speed	Optimize parameters	Must be an equal or lower than customer spec. due to mask abrasion : Modification is constrained by customers
	Separation speed	Optimize parameters	Must be an equal or lower than customer spec. due to processibility : Modification is not limited by customers
Material	Thixotrophy	Add filler	Very resonable to apply to increase thixotrophy
		Surface treatment of filler	Very Reasonable to apply to prevent the filler from being agglomerated
	Surface tension	Coat mask surface	Not reasonable to apply – Costs a customer extra money
		Change material	Not reasonable to apply – May change paste properties
		Change PCB	Not reasonable to apply – Fixed by customer

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Conclusion

–There are several factors that may cause the defects that could be revealed and analyzed, and some solutions are suggested by tools like Root & Cause, Structural Analysis, Knowledge Search, IMC Scientific Effect, Patent Search, etc.
–It was found that it is most reasonable and efficient way to improve the problems by increasing thixotrophy of adhesive adding nano-sized filler :

Experiment		1	2	3	4
Processibility	Clogging (%)	12.0	13.1	11.7	26.8
	Bleed-out	None	None	None	Yes
	Bubble	None	None	None	Yes
Reliability	Without modification of surface treatment	Acceptable but not perfect	Acceptable but not perfect	Acceptable but not perfect	Fail
	With modification of surface treatment	Acceptable but not perfect	Pass	Pass	–

Effect of filler

Effect of filler & surface treatment

–Modification of thixotrophy improved the processibility and reliability. However, in order to have a better reliability, filler agglomerations should be reduced by applying an appropriate surface treatment agent.
–It was possible to have a good quality of adhesive through TRIZ, resulting in passing the qualifications by “H” company in Korea and “F” company in Taiwan.

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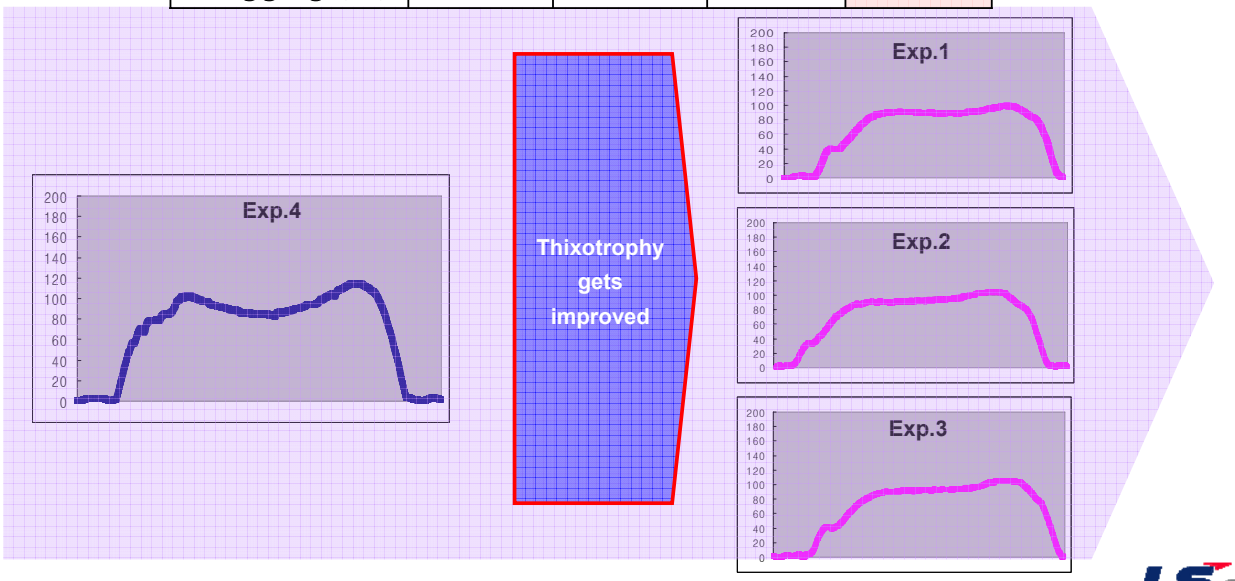
Appendix I

Clogging has been reduced as shown in Exp.1 ~ 3

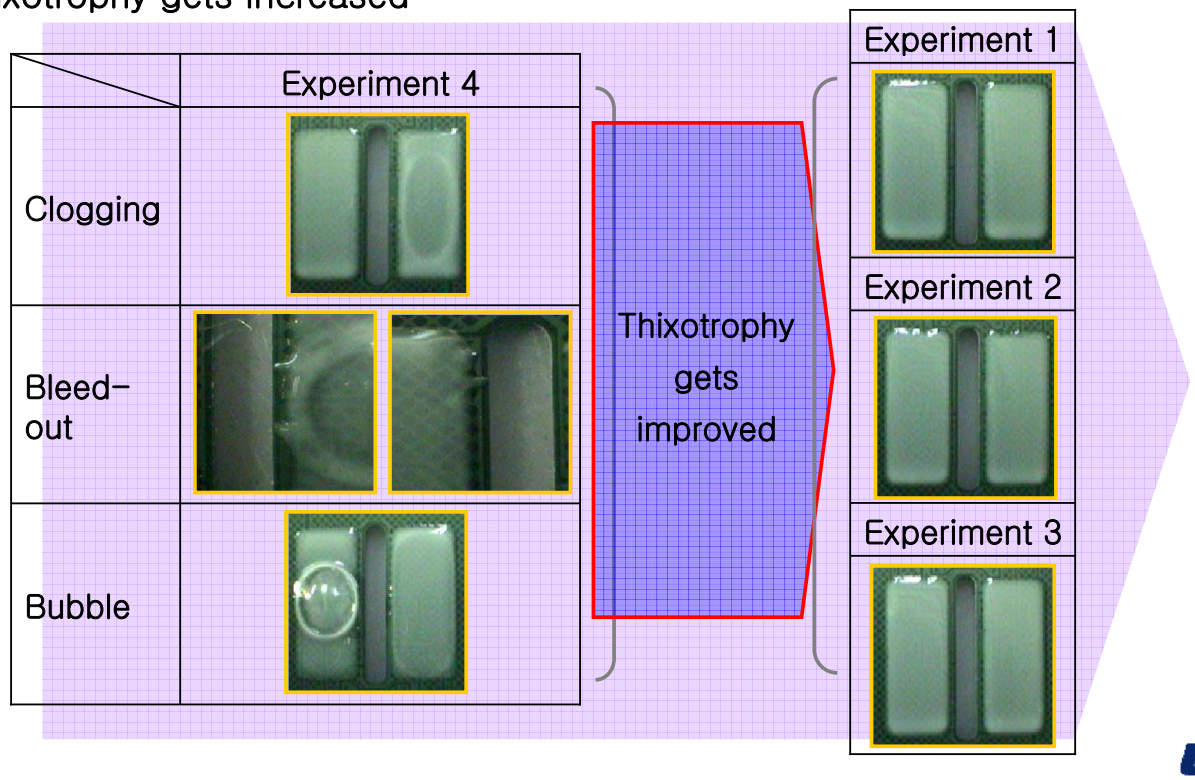
<< Improved Clogging defect when thixotrophy gets increased >>

Experiment	1	2	3	4
Clogging (%)	12.0	13.1	11.7	26.8



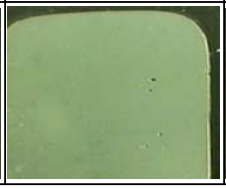
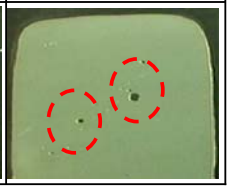
Appendix II

The overall defects has been improved as shown in Exp.1 ~ 3 when the thixotrophy gets increased



Appendix III

New surface treatment materials were applied for Exp.1,2 and 3 in order to reduce filler agglomerations

			Experiment 1	Experiment 2	Experiment 3
Material Property	Primary Particle size (nm)		7	12	17
	Thixotropic index		5.9	5	3.5
	Viscosity (cP, @ 1 rpm)		39,000 ± 10	45,000 ± 10	47,000 ± 10
	BET surface area m2/g		150	100	80
Reliability	Surface treatment*	A	△	o	o
		B	x	o	△
		C	x	△	△
	Adhesive image with surface treatment agent, A				

(* △ : Acceptable but not perfect, O : Pass, X : Fail)