The Evaluation of CAF property for narrow TH pitch PCB

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Abstract

To better evaluate CAF (Conductive Anodic Filament) growth we have developed a Test Printed circuit board (PCB) with narrow pitch through holes. (THs) This test PCB can evaluate anti-CAF properties by using very narrow pitch TH (wall to wall 0.05-0.10mm) We tested several laminates using this Test Vehicle and found one of the High Tg Halogen-free FR-4 has excellent anti-CAF restraining properties.

Introduction

The current trends in electronics require higher performance and miniaturization accelerating the need for thinner and higher-density PCBs. As the result, the though hole pitch becomes narrower from year to year and it becomes very important to maintain reliability between through holes. The main materials for high density printed circuit board are FR-4 due to performance of process ability and price. But recently halogen-free FR-4 is also increasing in use for environmental reasons. In the case of FR-4 CAF is becoming a serious problem. CAF (Conductive Anodic Filament) is the result of Cu migration occuring through the glass fabric for high density PCBs. The mechanism of CAF is shown in Fig 1. At first Cu dissolves at the anode side and becomes Cu ion. Then Cu ions move through the glass fabric, And finally Cu ions reach the cathode side and deposit to form a dendrite. The CAF phenomena is influenced by base material properties and processing of the PCBs. Recently the Industry has come to recognize several properties of laminates, for example the water absorption property and impurity ions etc, that are the largest contributions to CAF occurance. On other hand, the manufacturing process of PCBs, the drilling process and the plated copper process etc, also influence the occurrence of CAF. However the current CAF test vehicles are not capable of evaluating patterns having less than 0.1mm TH wall to wall spacings. Our study proposes an evaluation pattern for designs less than 0.1mm and presents the results we achieved in evaluating several laminates with this Test Vehicle.

Experimental

(1) The design of CAF evaluation PCB

The TH vias of PCBs generally have lands. But the land of via sometimes becomes an obstacle in narrow pitch TH. So we proposed a new test PCB vehicle with landless through holes on the surface and set up the joint area in inner layer.(4 layer board) This new structure worked well making narrow pitch circuits with wall to wall clearance of 50μm independent of land pitch. At first we tried to optimize drilling condition because we would

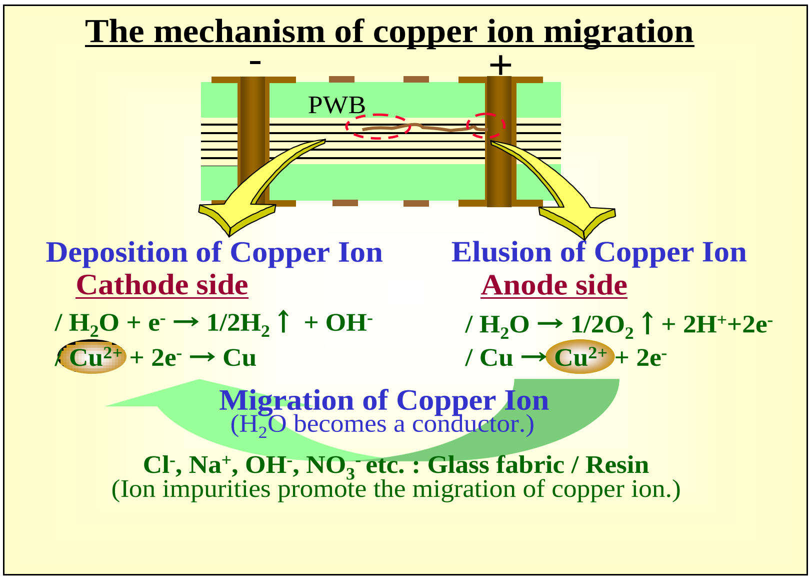


Figure 1- CAF phenomena

like to minimize the influence of drilling process. We parameterized the experiment to reduce cracking by using one length of drill and the deviation of accuracy of position. Fig 2 indicates our study. We put a lot of effort into decreasing the influence of drilling process. In this way we found out the best condition for drilling of the narrow pitch TH test coupon. In this manner we could build the new CAF evaluation vehicle, as shown in Fig 3, with a joint located in the inside layer and were thus able to test the insulation properties for 50µm, 70µm,90µm and 110µm length from wall to wall.

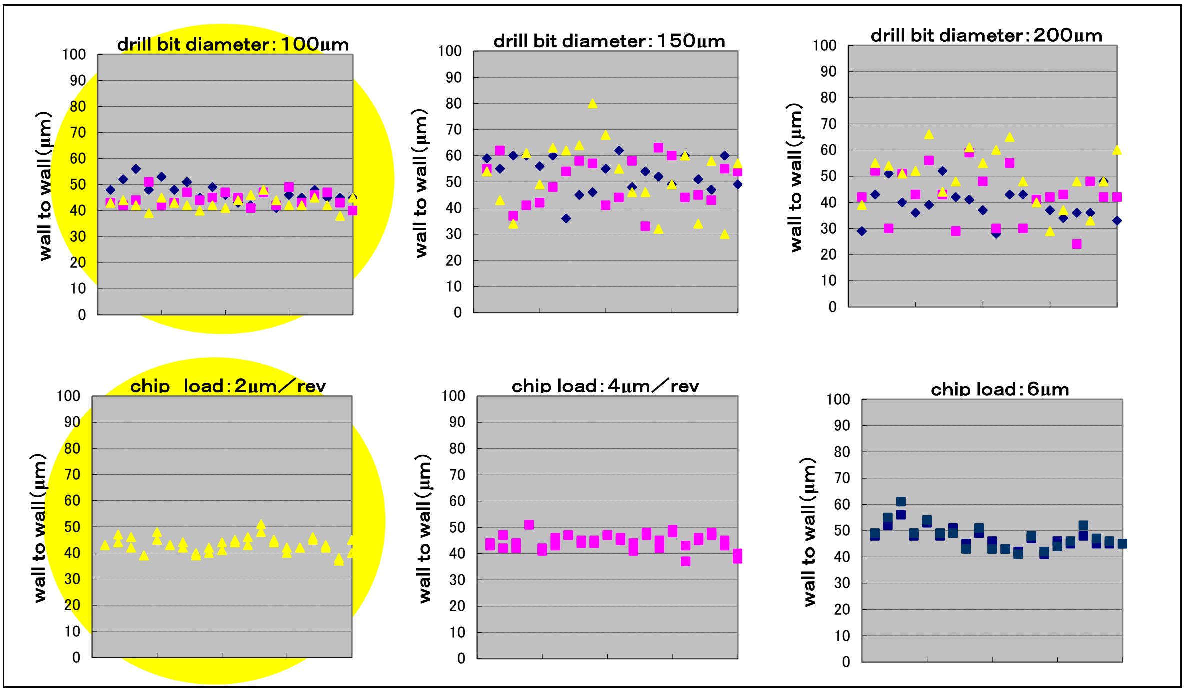
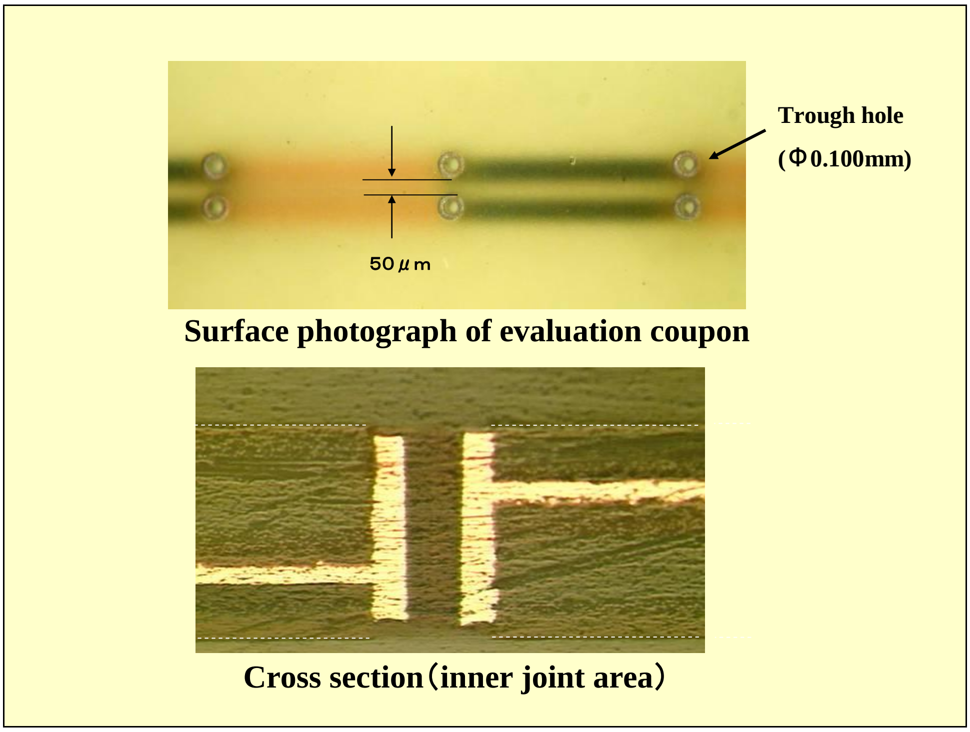


Figure 2-The study of drilling condition about 50µm between TH walls



Surface photograph of evaluation coupon

Cross section（inner joint area）

Figure 3-The new CAF test vehicle photographs

(2) Evaluation of laminate materials

Using this test vehicle, we evaluated several laminate materials which are indicated in table 1.Regarding the base materials, we selected different Br contents and Tg epoxy-based materials with and without filler and halogen-free and non-epoxy-based materials. For the glass fabric we chose #1080 (50µm) glass cloth because in our preliminary study we found it was least influenced by the drilling process. We built up the 4 layer boards for CAF evaluation using each of the laminates. Before testing, we pre-treated all the samples to JEDEC Level 3 + reflow 3 times at 260 deg. max. temperature. Next we placed those samples into the test oven where we started the HAST test conditioning @ 110 deg.C , 85%RH, DC6V. We checked each for insulation resistance every 24 hours until 254 hours and after that we were continuous checking every 3 days until 1200 hours. The result of the test are indicated Fig 4.

Table 1-The laminate materials of PCBs for CAF evaluation

Material	Glass fabric	Rsin system	Br contents(%)	Filler	Tg(TMA)
A	1080	Epoxy	15	Non	180
B			15	Included	170
C			17	Included	170
D			18	Non	130
E			0	Included	180
F		Non-epoxy	15	Non	180

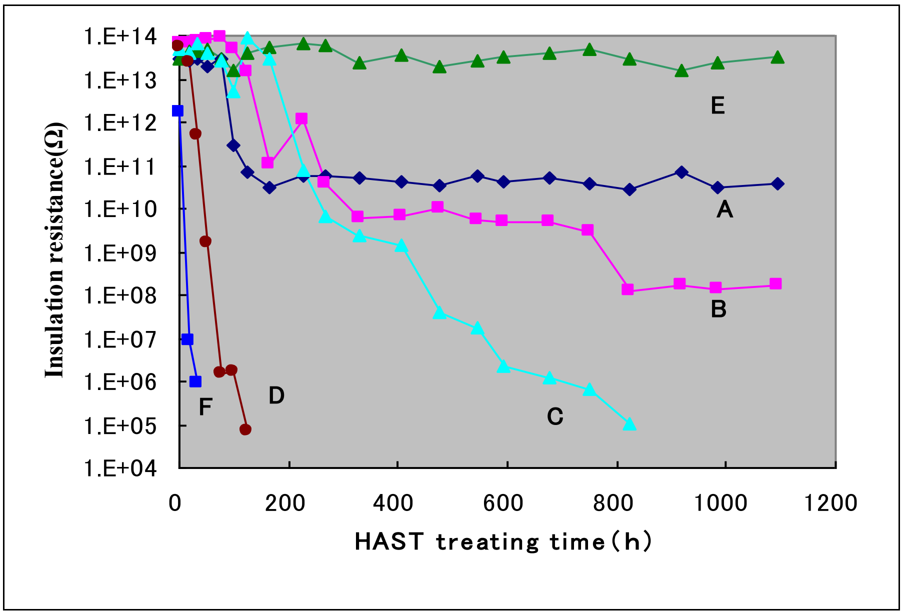


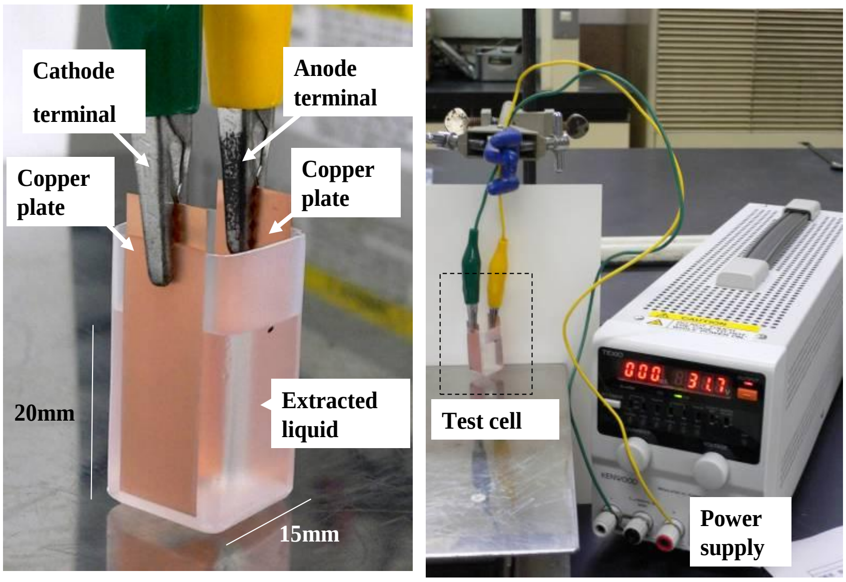
Figure 4-The evaluation test results for CAF restraining property

Upon examining the results, the sample E, a halogen-free material, was shown to have excellent CAF restraining properties while samples D and F showed CAF in very early stages. After testing, we examined the samples and analyzed for the failure mode. In the sample F, we found a crack occurred from the TH and was longer than others, meaning the sample F was damaged by drilling process and the actual insulation length between THs became shorter than others.

To investigate the reason why the sample E was the best, we performed ion extraction from each material. The ion extraction was done using three test vehicles (40 x 30mm) placed in pure water at 110 deg. C (pressure oven). We decided the extracting time should be 200 hours because we thought that CAF phenomenon occurred by 200 hours. After the extraction we removed the test vehicles and analyzed electric conductivity, PH and Br ion peak of each extracted liquid. The test result is indicated in table 2. The sample D, was the worst one, indicated higher electric conductivity and higher Br ion peak compared with others. Then, using the extracted liquids of sample E and D, we did copper migration testing. The test equipment is shown in Fig 5.

Table2- Analysis result of extracted liquids

Material	Extracted liquid		
	Electric conductivity(μs/cm)	PH	Br ion peak(μs)
A	6.9	5.7	0.015
B	6.1	6.3	0.009
C	7.6	5.8	0.009
D	35	6.7	0.122
E	20	8.1	0
F	14.3	5	0.118



Test cell **Test equipment**

Figure 5-Copper migration test equipment

We observed the change of the cells and took a photograph every 10 minutes. The test results are indicated in Fig 6. The photographs showed the different tendency between E and D. In case of sample E, the precipitation occurred with anode side and a color of precipitation was light blue. On other side sample D's precipitation occurred with cathode side and a color of them was black. It is probable that in the case of sample E Cu $(OH)_2$ is deposited near the anode side and in the case of sample D CuO I s deposited near the cathode side. We believe that the electric conductivity and Br ions isolated from laminate materials influence this phenomenon. As we mentioned, the CAF phenomenon happens from anode side with first dissolving copper, so in the case of E a Cu ion receives an electron and the precipitation then occurs on the anode side.

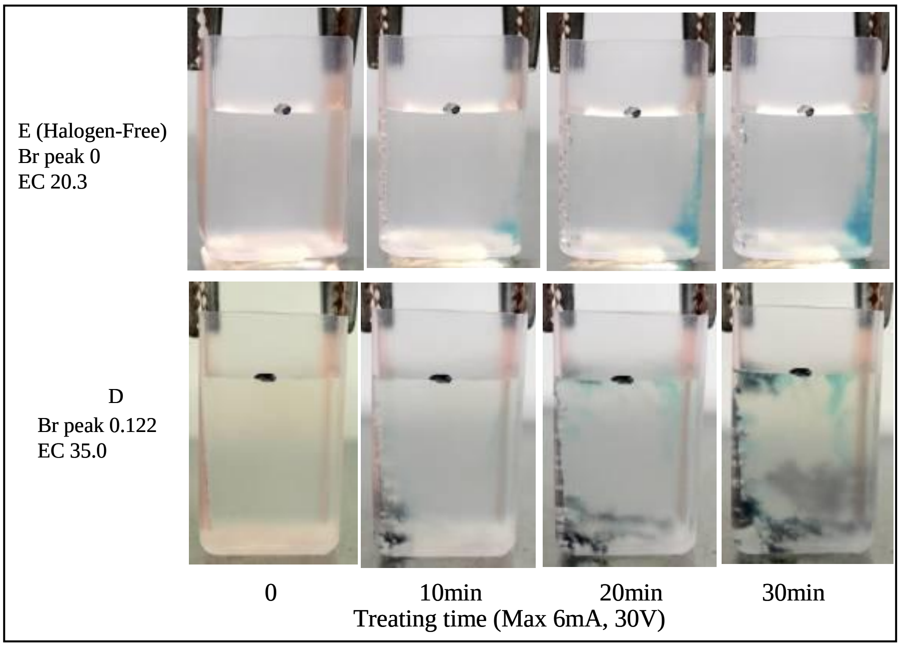


Figure 6-Copper Migration test result

In case of sample D, Cu becomes Cu ion and moves to the cathode side. There, it is after getting an electron that the precipitation of CuO occurred on the cathode side. Before our study it was our understanding that halogen ions, such a chloride or bromide, promote copper dissolution thus halogen-free laminate materials should have good CAF properties because there are no included halogen ions in the base polymer. We also believe PH is a key to reducing CAF but we don't know how to control this value. We intend to continue to study what properties constrain CAF.

Conclusion

To keep up with narrowing of the pitch of through holes in higher density printed circuit board we have a new method of evaluation used it to evaluate which materials are the best for prevention of the CAF phenomenon. After repeated trial and error, we report the following:

1. We have developed a new CAF evaluation vehicle for having narrow through hole pitch.
2. The new CAF evaluation vehicle can be tested to as low as 50μm wall to wall spacings between through holes
3. We have evaluated the CAF restraining properties of several kinds of laminates.
4. Our evaluation indicated that one of halogen-free material had the best CAF property.
5. The migration test we developed using extracted liquids was able to identify the difference between good and bad laminates.

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The Evaluation of CAF property for narrow TH pitch PCBs

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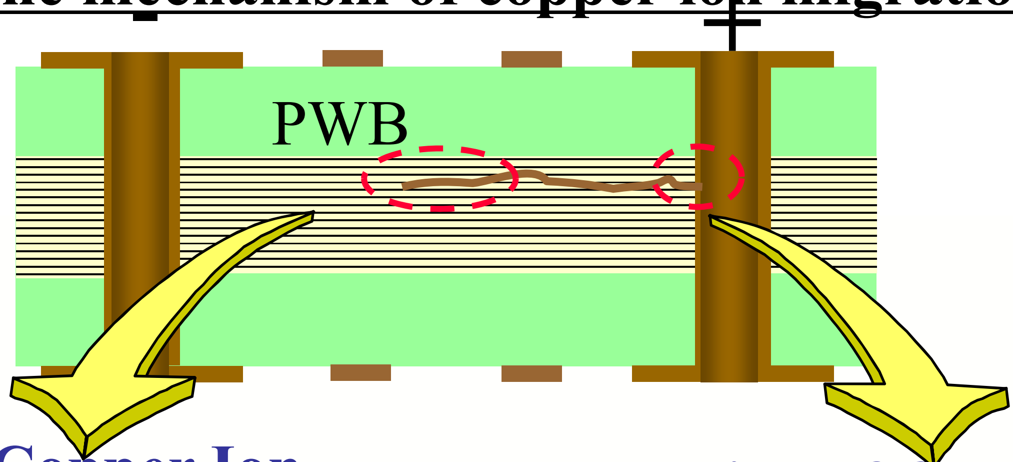
Contents

1.Introduction and history

The mechanism of copper ion migration



Deposition of Copper Ion

Cathode side

/ $H_2O + e^- \rightarrow 1/2H_2\uparrow + OH^-$

/ $Cu^{2+} + 2e^- \rightarrow Cu$

Elusion of Copper Ion

Anode side

/ $H_2O \rightarrow 1/2O_2\uparrow + 2H^+ + 2e^-$

/ $Cu \rightarrow Cu^{2+} + 2e^-$

Migration of Copper Ion

(H_2O becomes a conductor.)

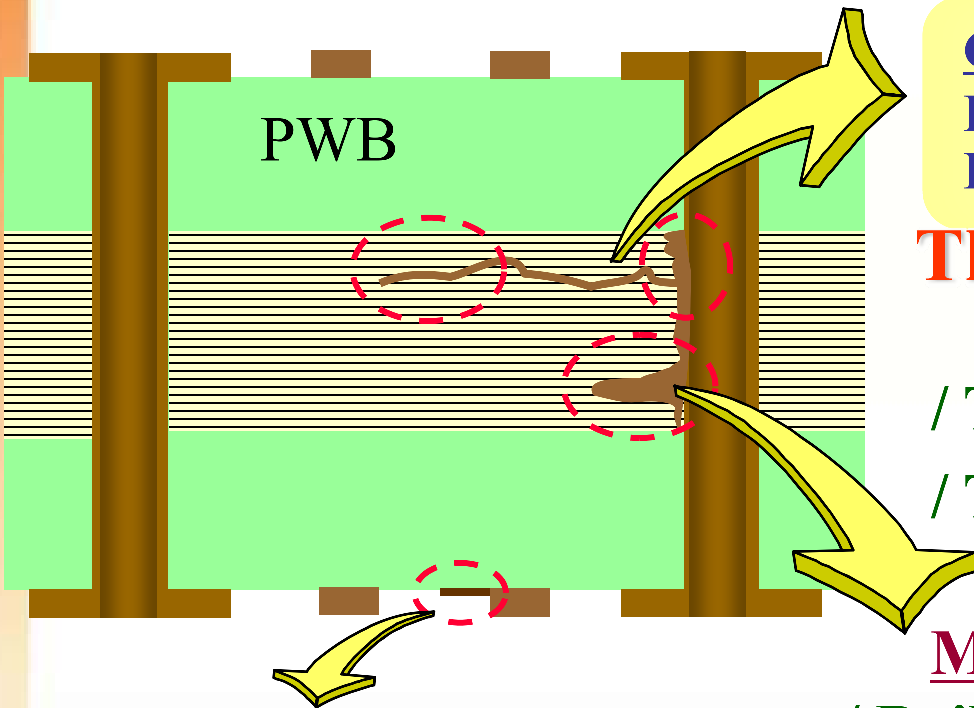
Cl^-, Na^+, OH^-, NO_3^- etc. : Glass fabric / Resin

(Ion impurities promote the migration of copper ion.)

Use high purity glass fabric (including coupling agent) and resin system

1.Introduction and history

The factors of copper ion migration



CAF : Conductive Anodic Filament
Resin / Fiber (TH/TH,Inner L/TH etc.)
Depending on the laminate properties

The factor of CAF occurrence

Chemical factor

/ The elusion of copper ion

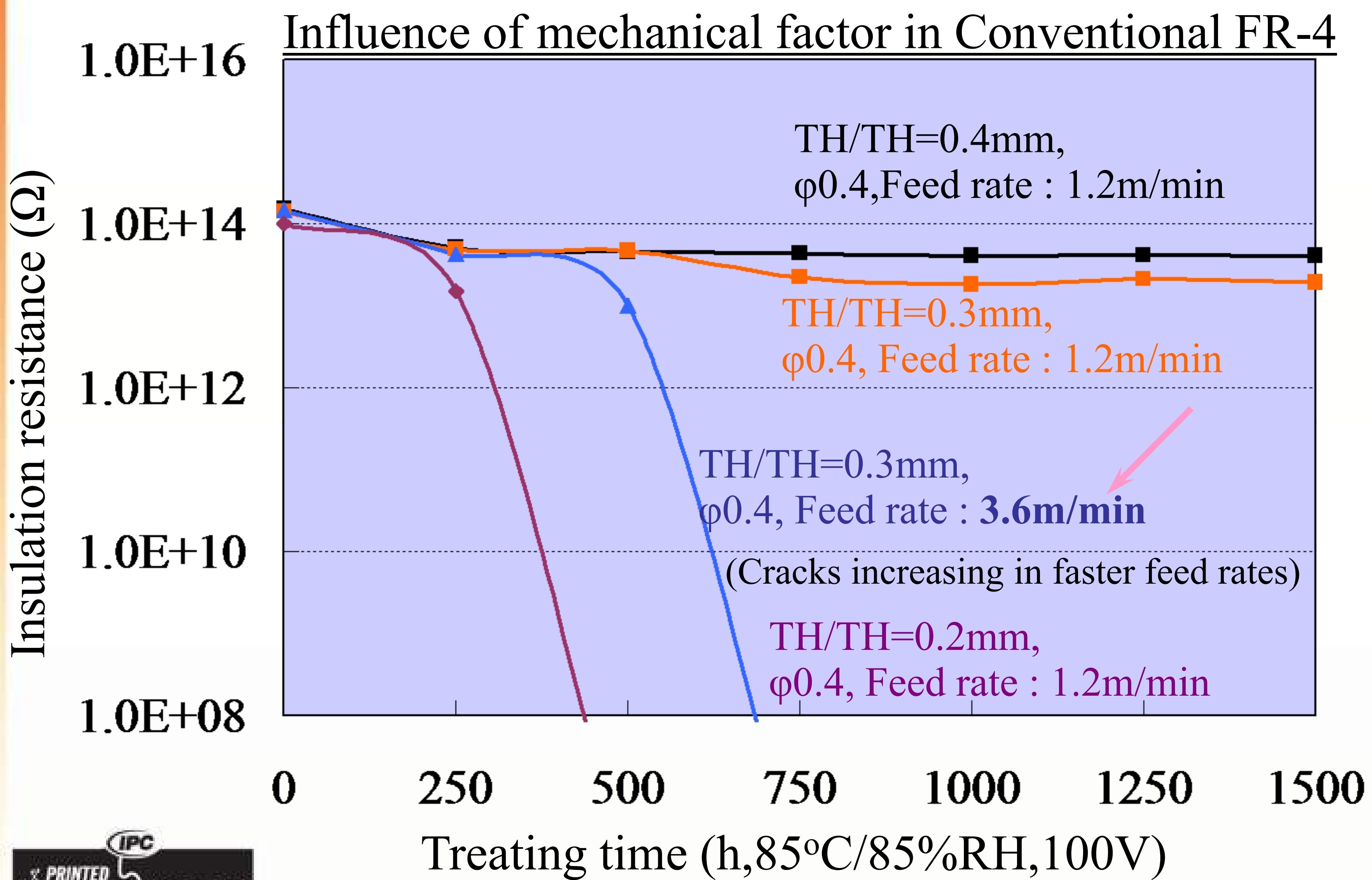
/ The migration of copper ion

Mechanical factor

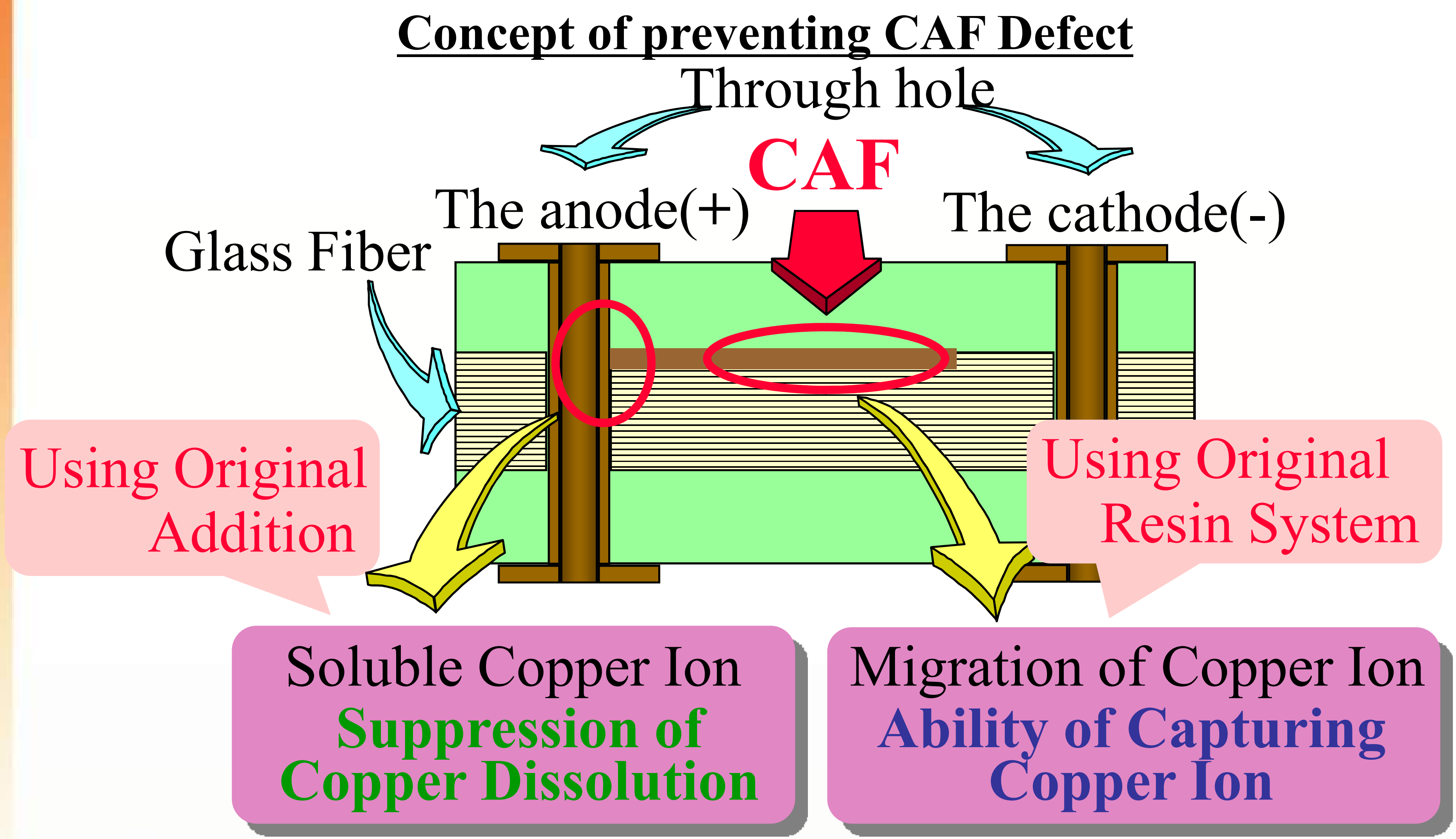
/ Drilling processability
(Shortening of the insulation distance)

Dendrite: Line / Line
Occurring during MFG. process

1.Introduction and history



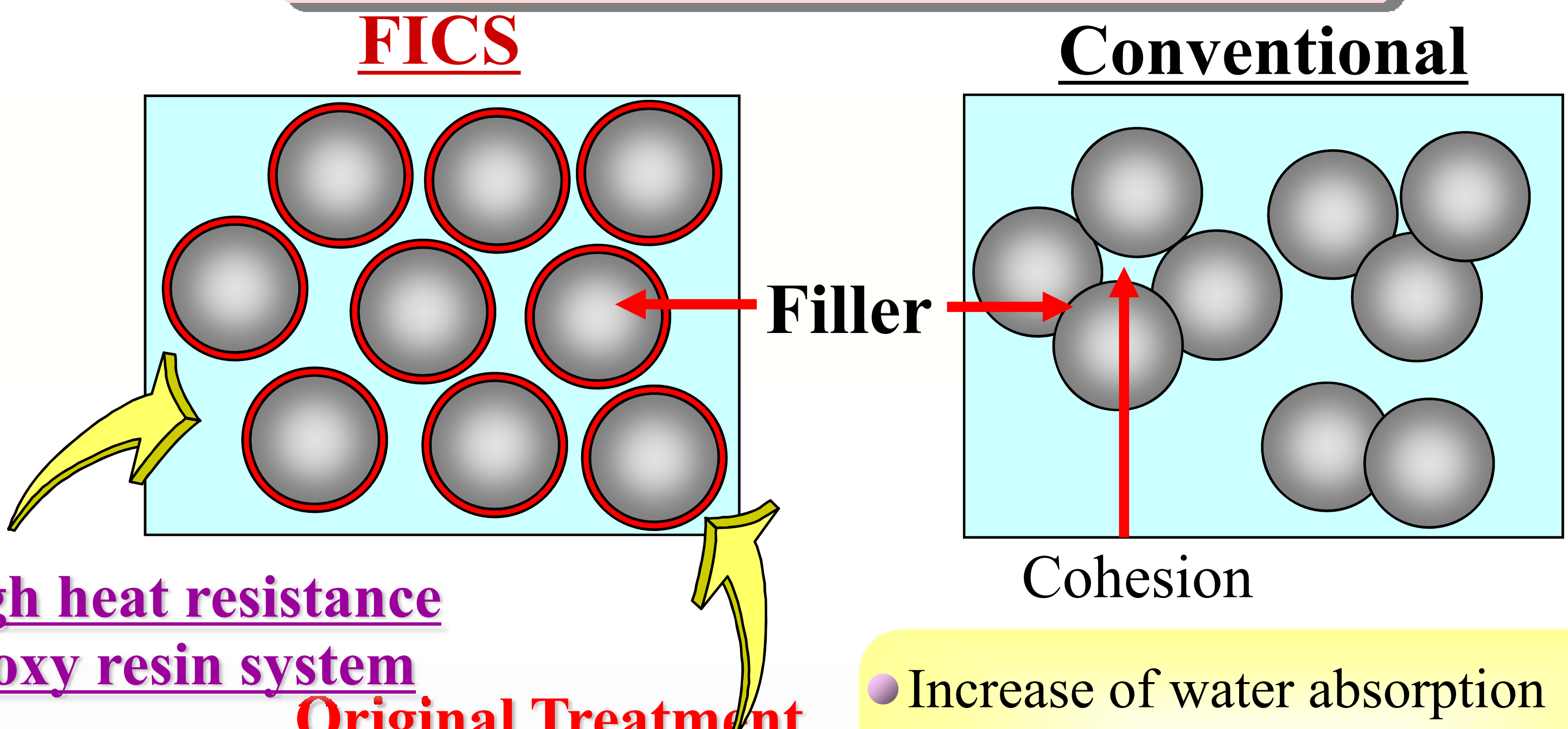
1.Introduction and history



1.Introduction and history

Technical Concept of Filler Hybrid System

Filler Interface Control System (FICS)



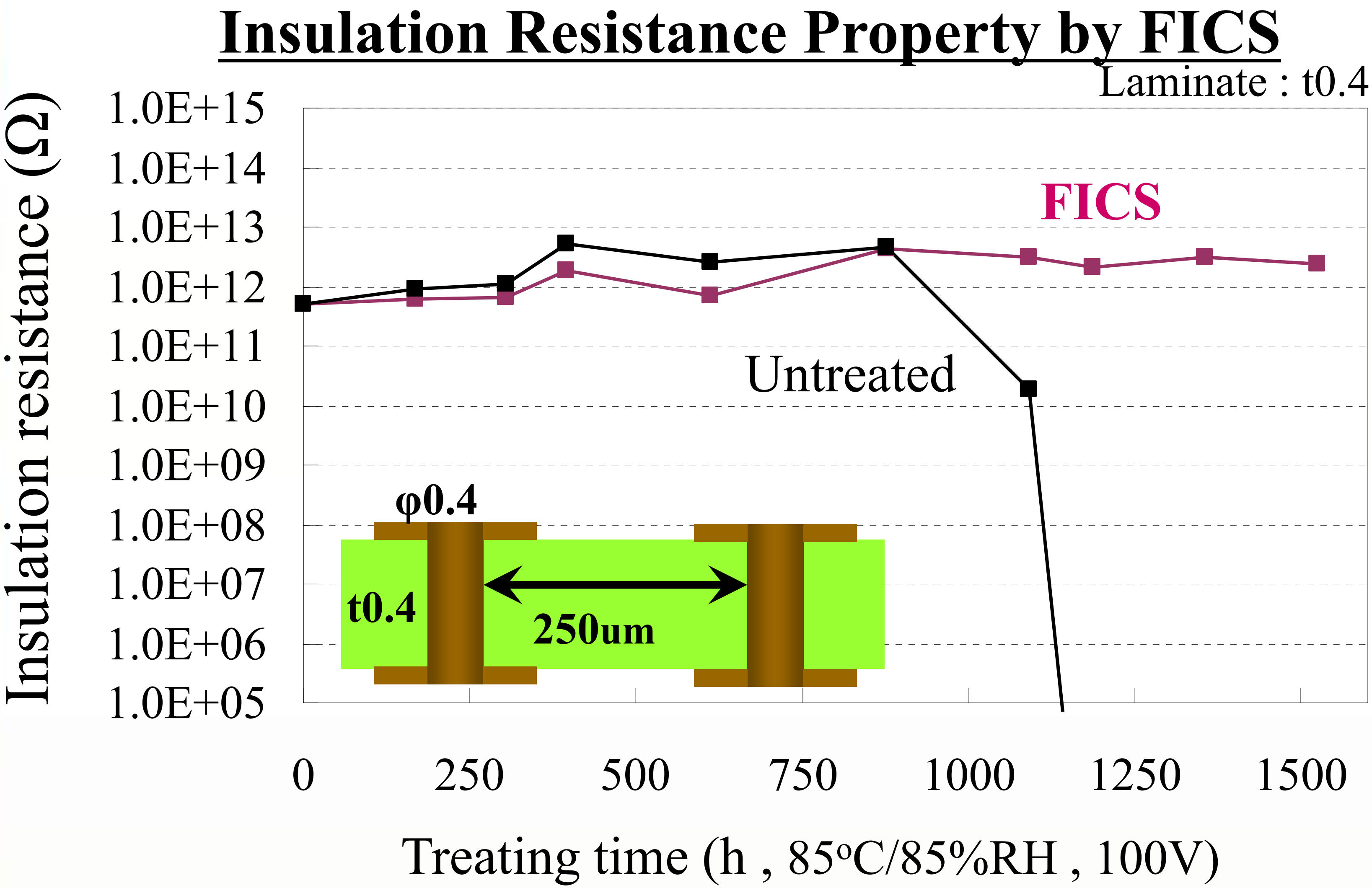
High heat resistance epoxy resin system

Original Treatment

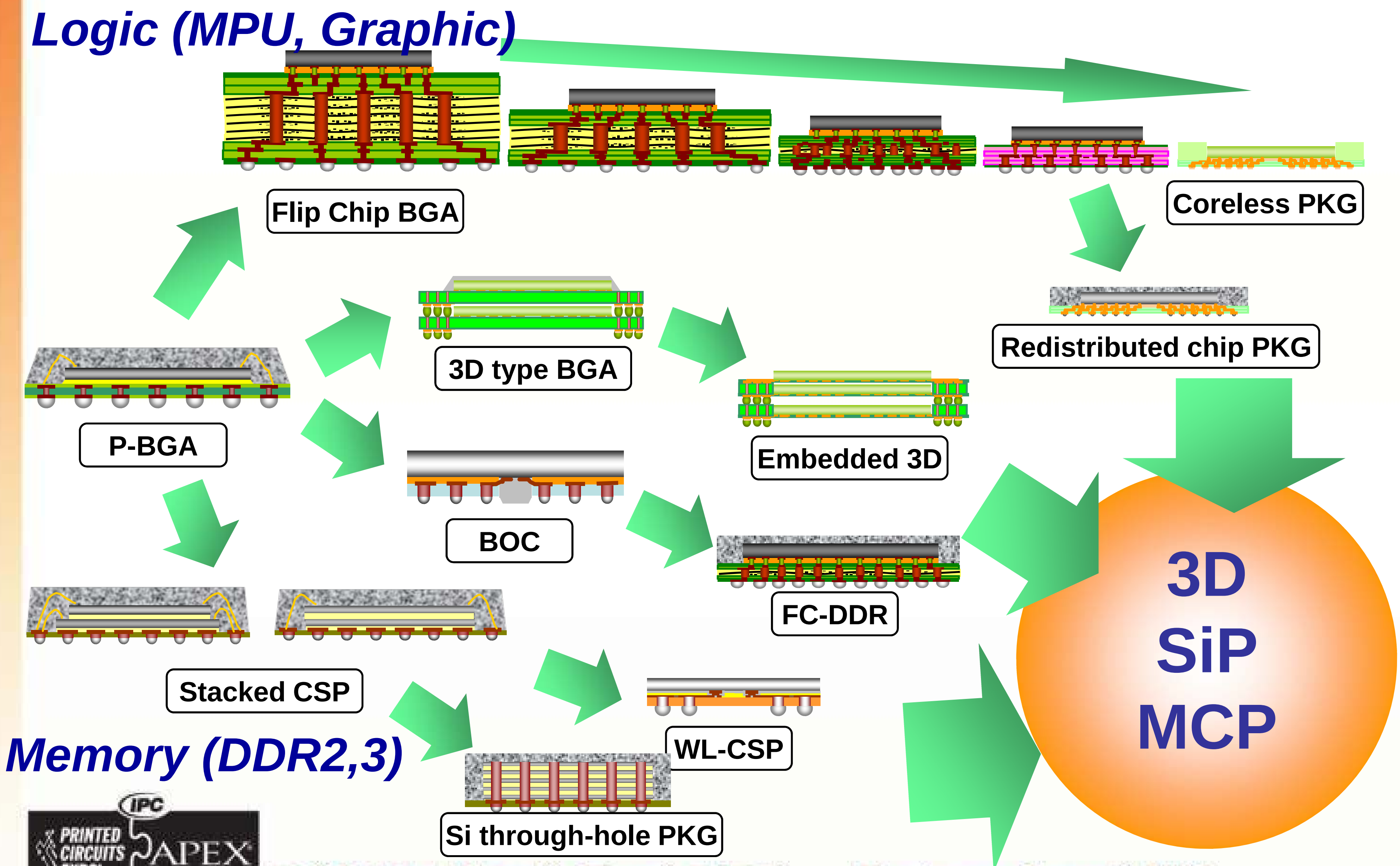
/ High Dispersion
/ Good adhesion
/ High heat resistance

- Increase of water absorption
- Decline of the electric insulation & CAF restraining property

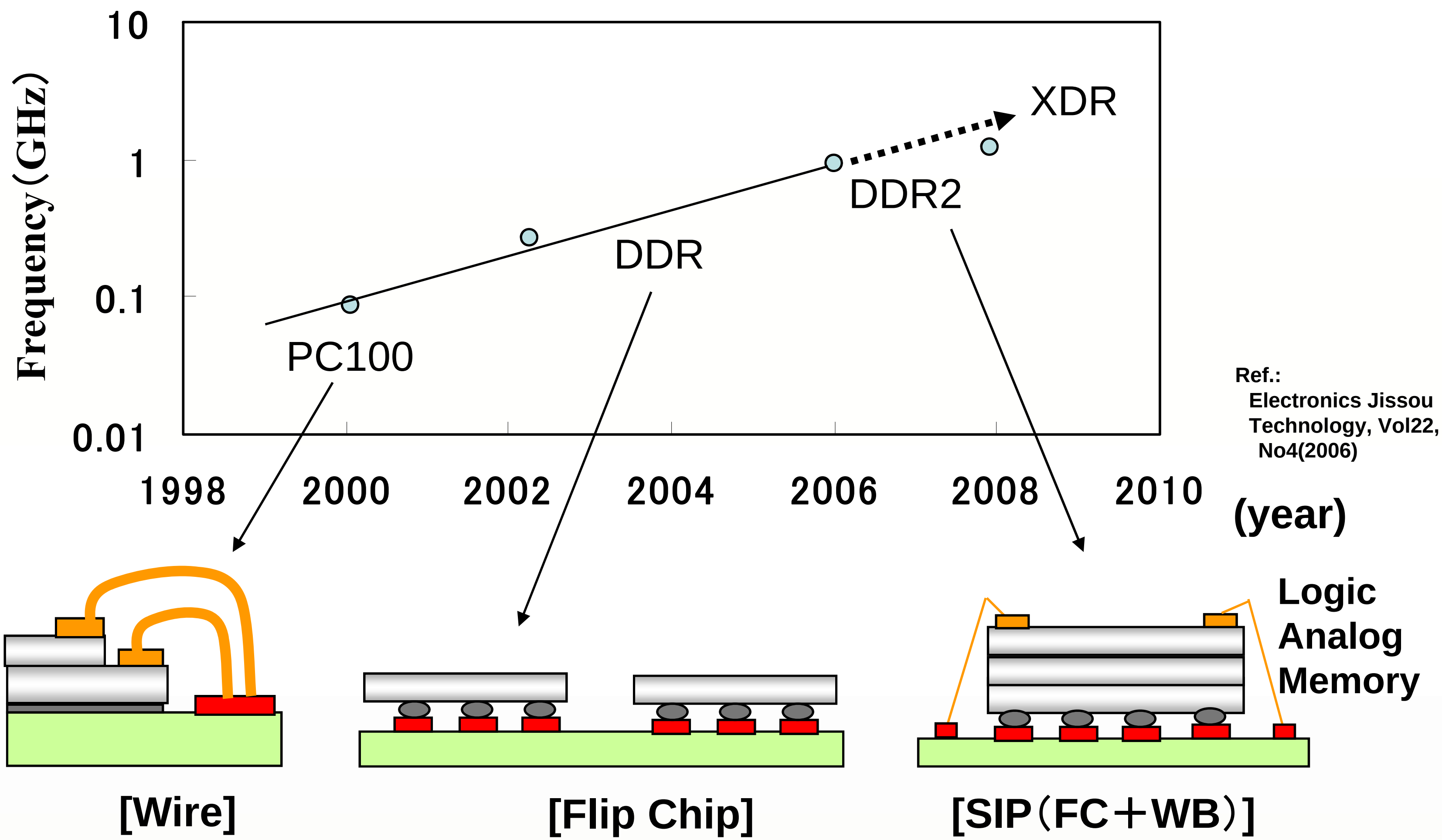
1.Introduction and history



Trend of PKG structure



Trend of packaging（Trend of interface）



Trend of packaging（Trend of interface）

Key word : High density／Thinner

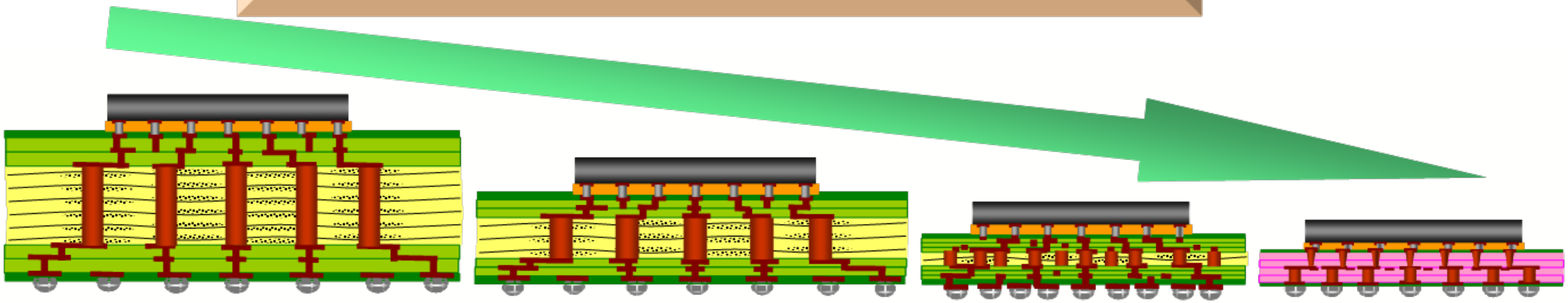


Fig. ITRS2004 BGA and FBGA/CSP Package Potential PWB"High Performance"							
Yesr of Production	2004	2005	2006	2007	2008	2009	2012
Pad size (μm)	160	120	120	80	80	80	60
Line width (μm)	48	36	36	24	24	24	18
Line spacing (μm)	48	36	36	24	24	24	18

Developing plan

- To make clear what kind of laminate should be suitable for narrow pitch TH PCBs.
- The proposal of material which has excellent reliability

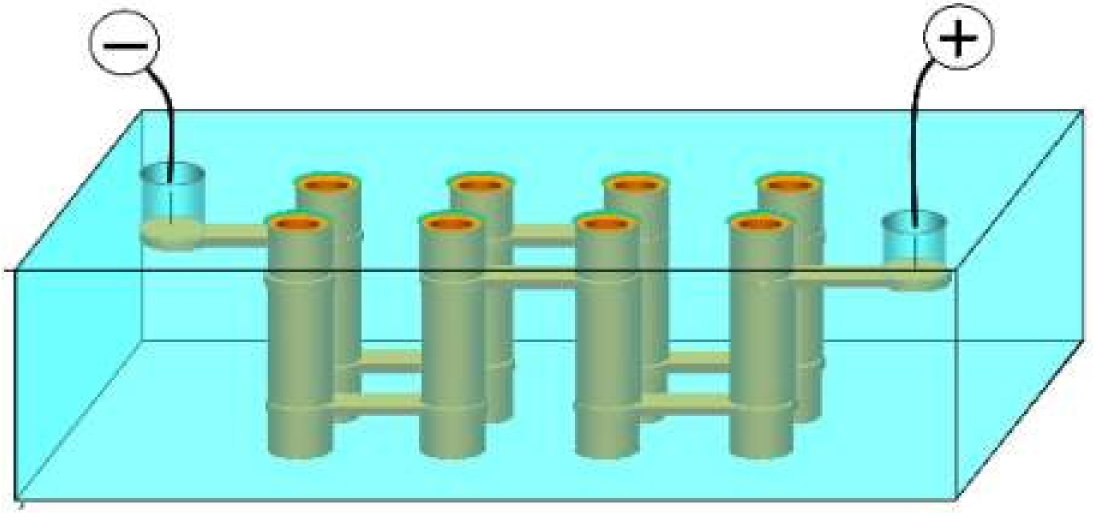
- Which material is suitable for narrow TH pitch?⇒?
- What is a subject of laminate material?⇒?
- Which level can laminates maintain?⇒?

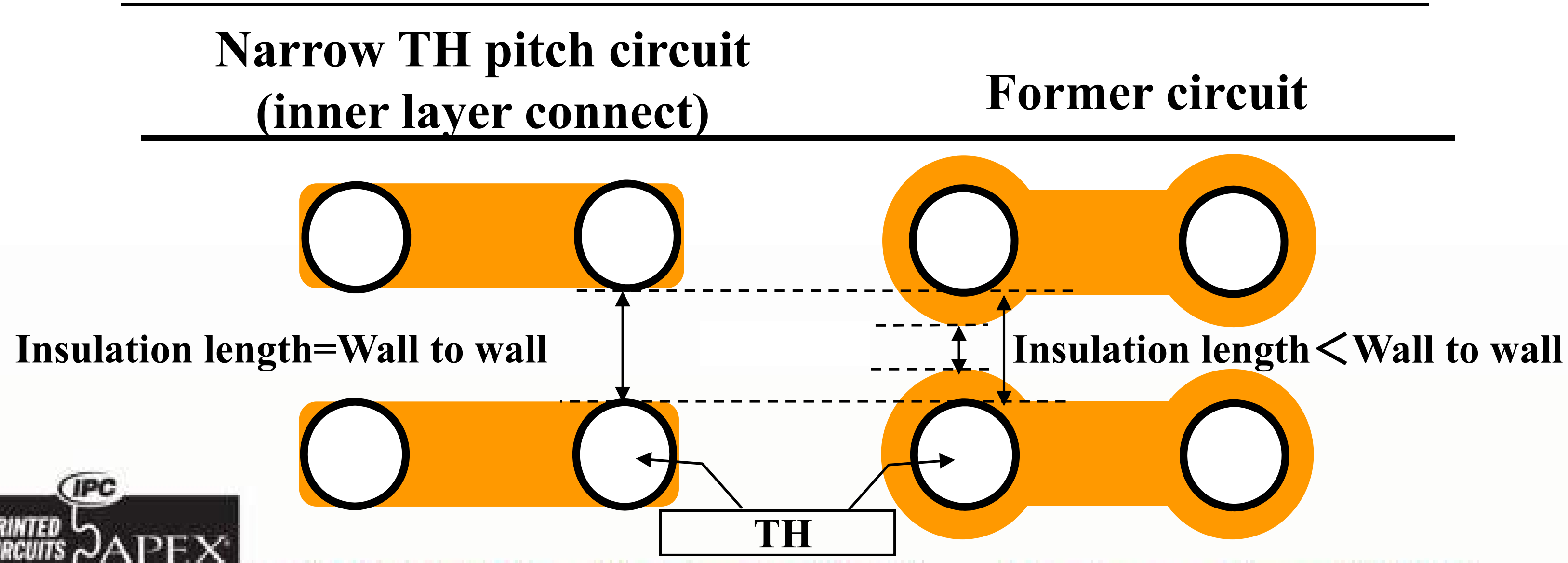
?

⇒Needs: a new test vehicle to be able to evaluate CAF property of narrow TH pitch

2.The design of CAF evaluation PCB

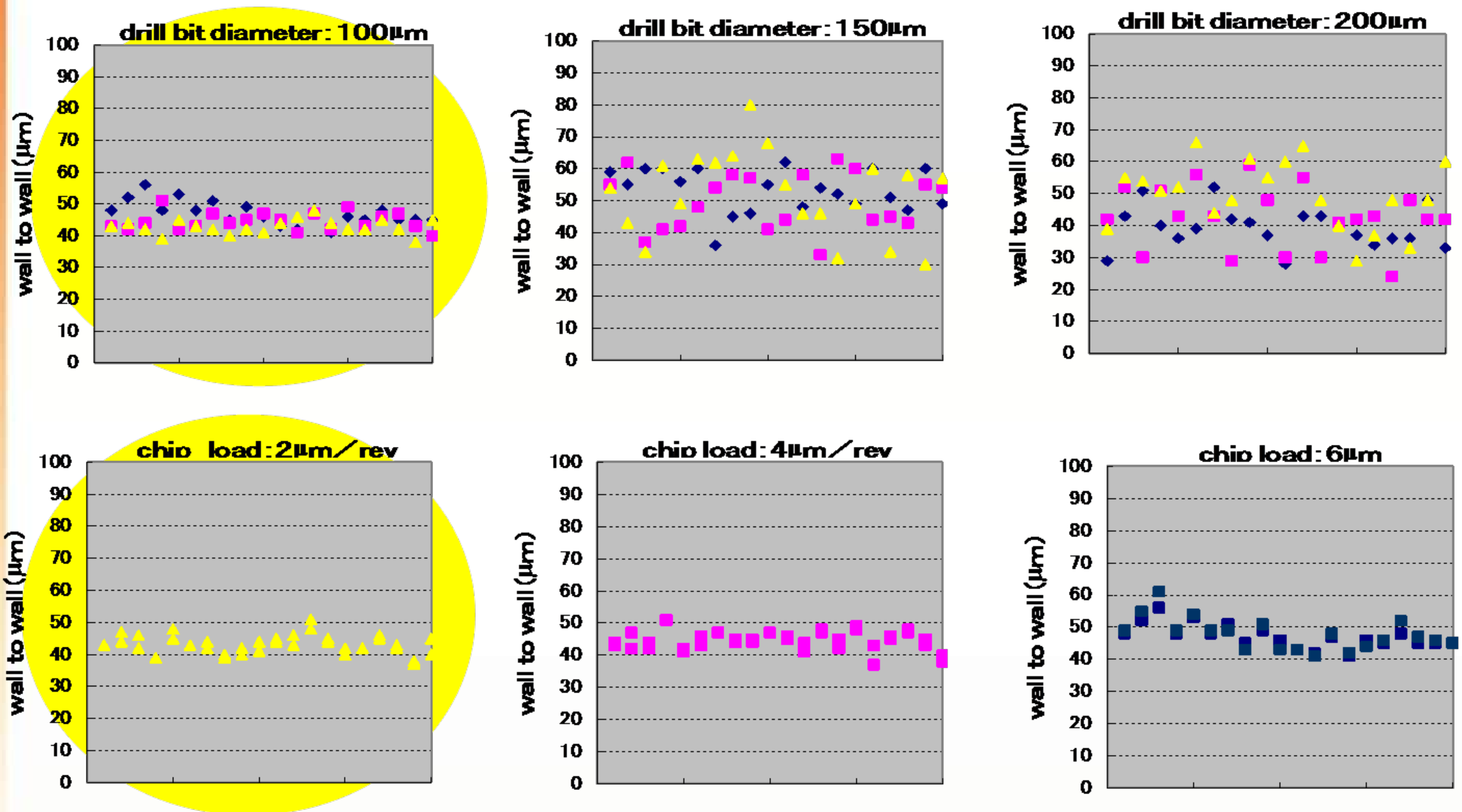
The original plan of evaluation vehicle for narrow TH pitch





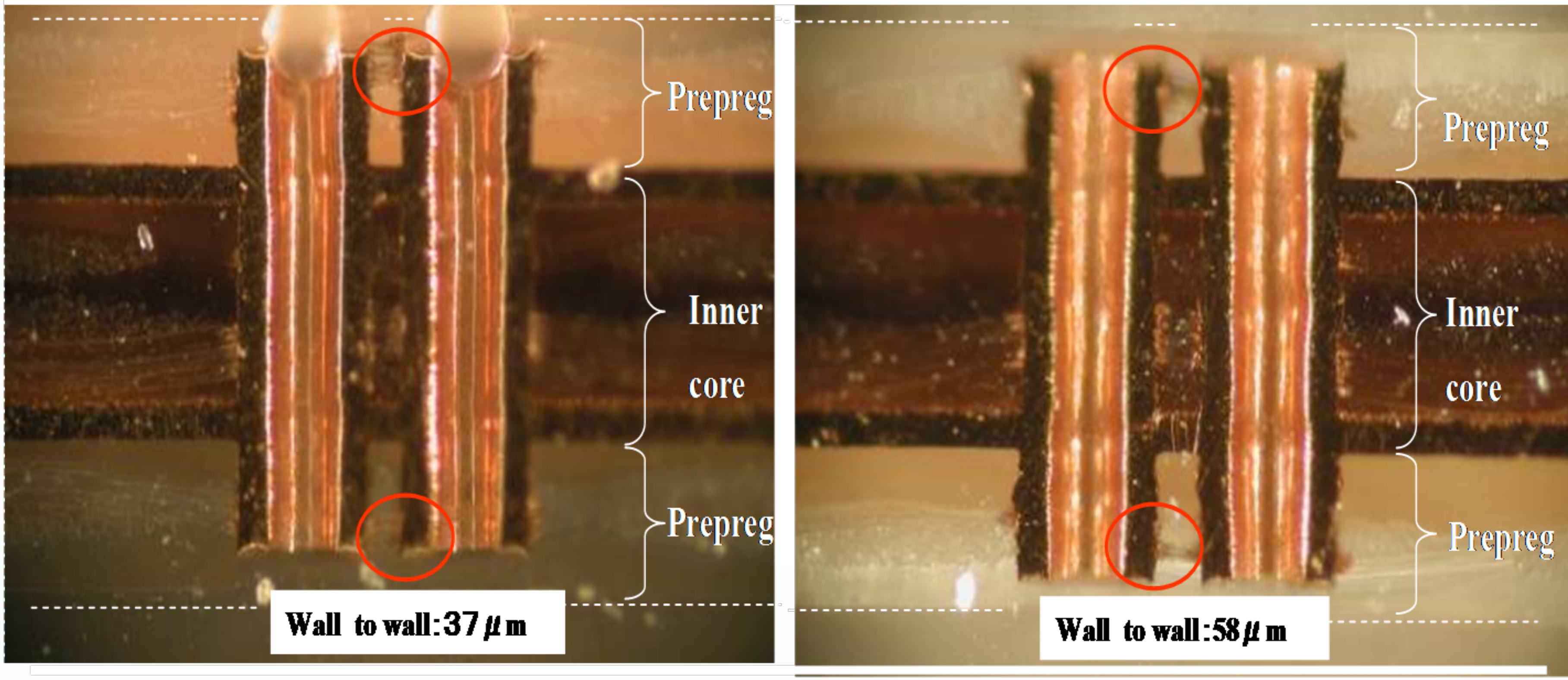
2.The design of CAF evaluation PCB

Examination of drilling condition

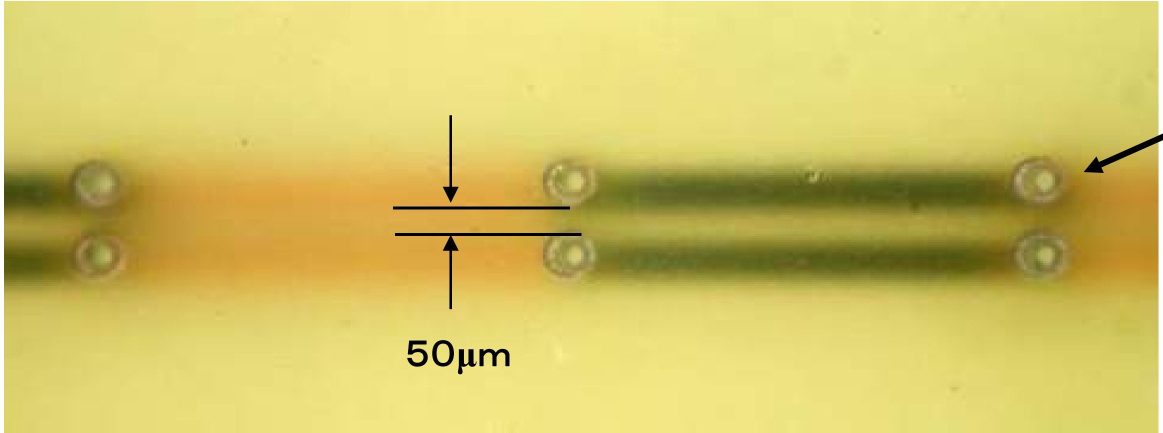


2.The design of CAF evaluation PCB

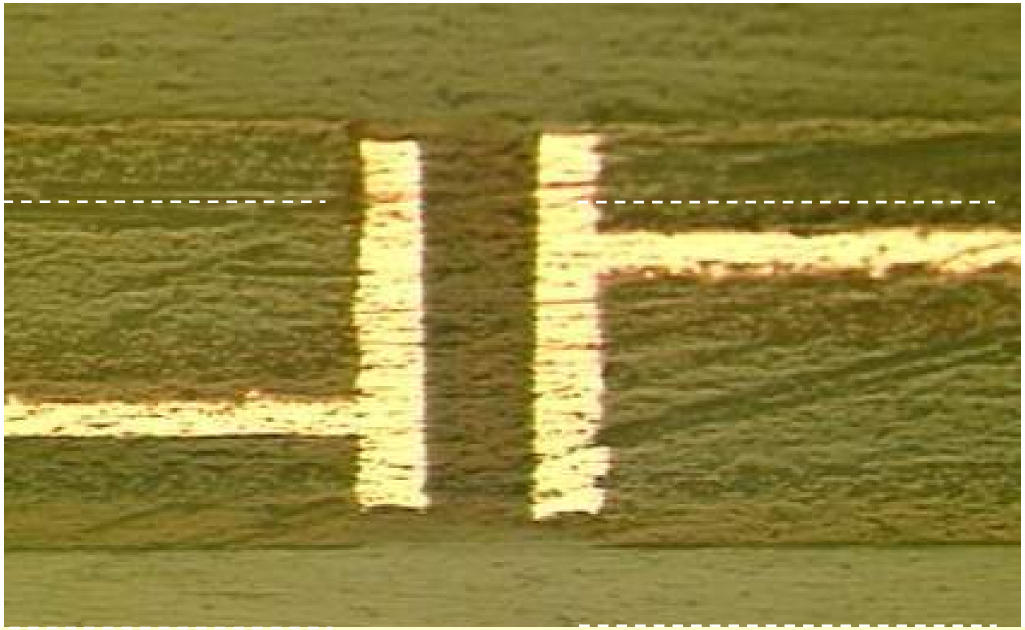
The cross section of evaluation vehicle



2.The design of CAF evaluation PCB

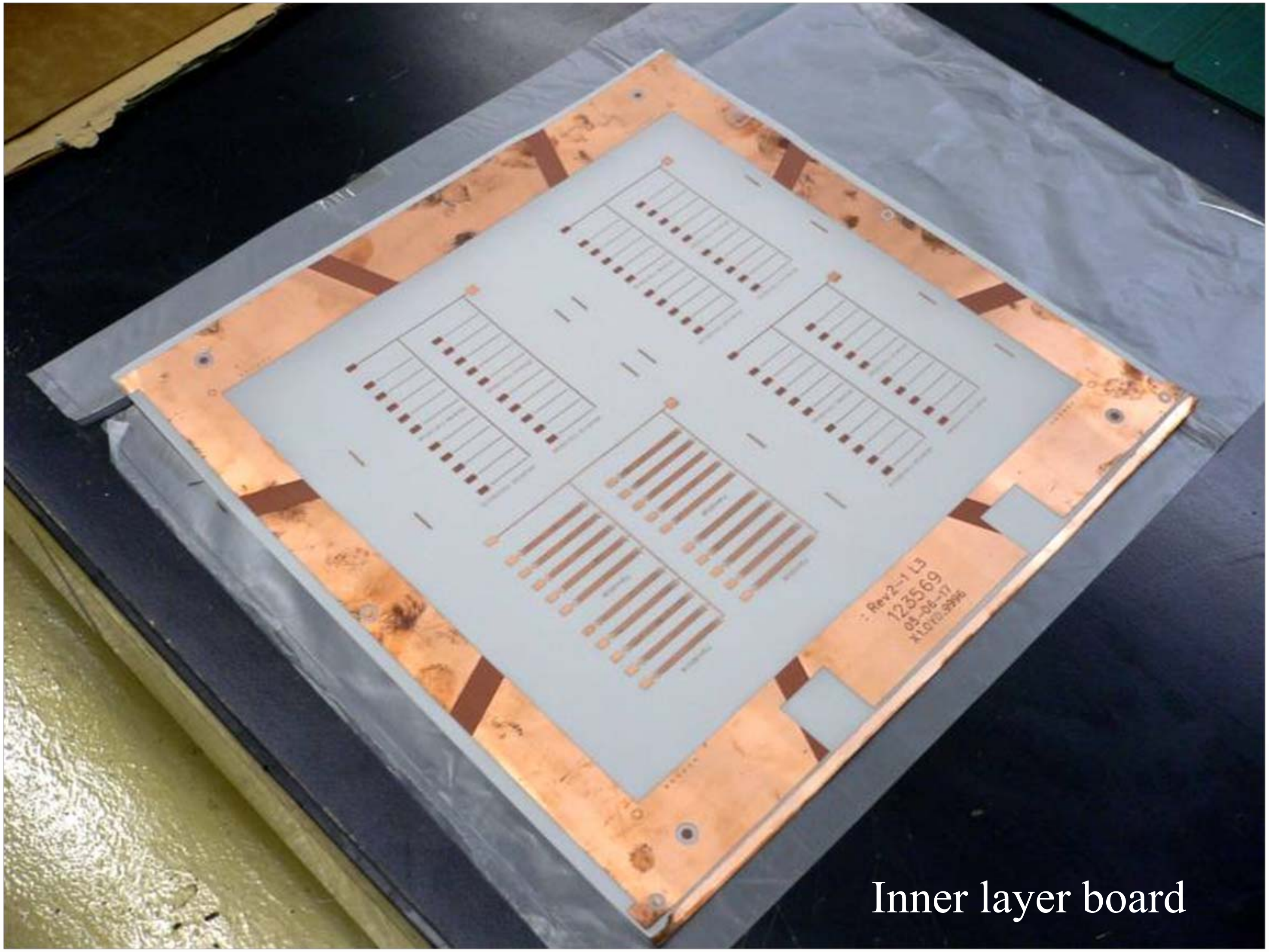


Surface photograph of evaluation vehicle



Cross section（inner joint area）

2.The design of CAF evaluation PCB

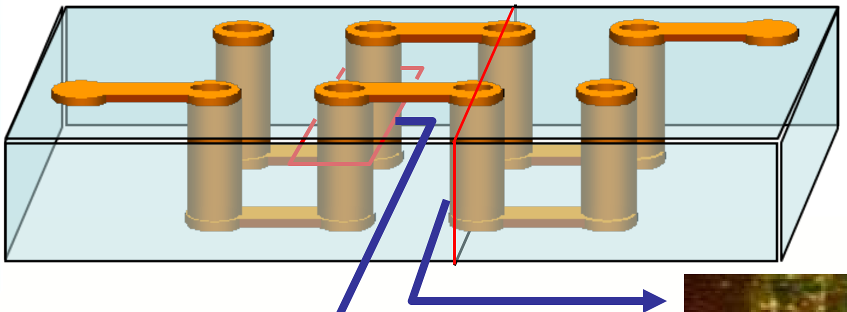


3.Evaluation of laminate materials

Table. The laminate materials of PCBs for CAF evaluation

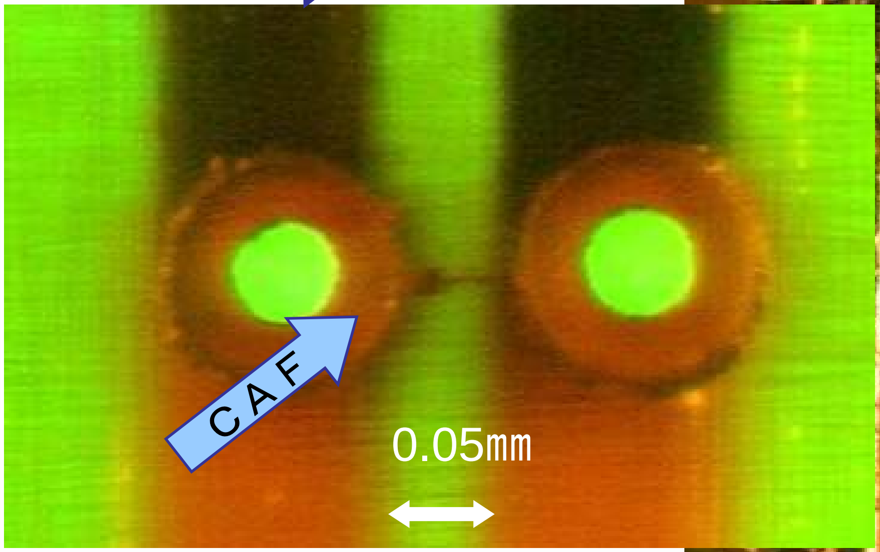
Material	Glass fabric	Resin system	Br contents(%)	Filler	Tg(TMA)
A	1080	Epoxy	15	Non	180
B			15	Included	170
C			17	Included	170
D			18	Non	130
E			0	Included	180
F		Non-epoxy	15	Non	180

3.Evaluation of laminate materials

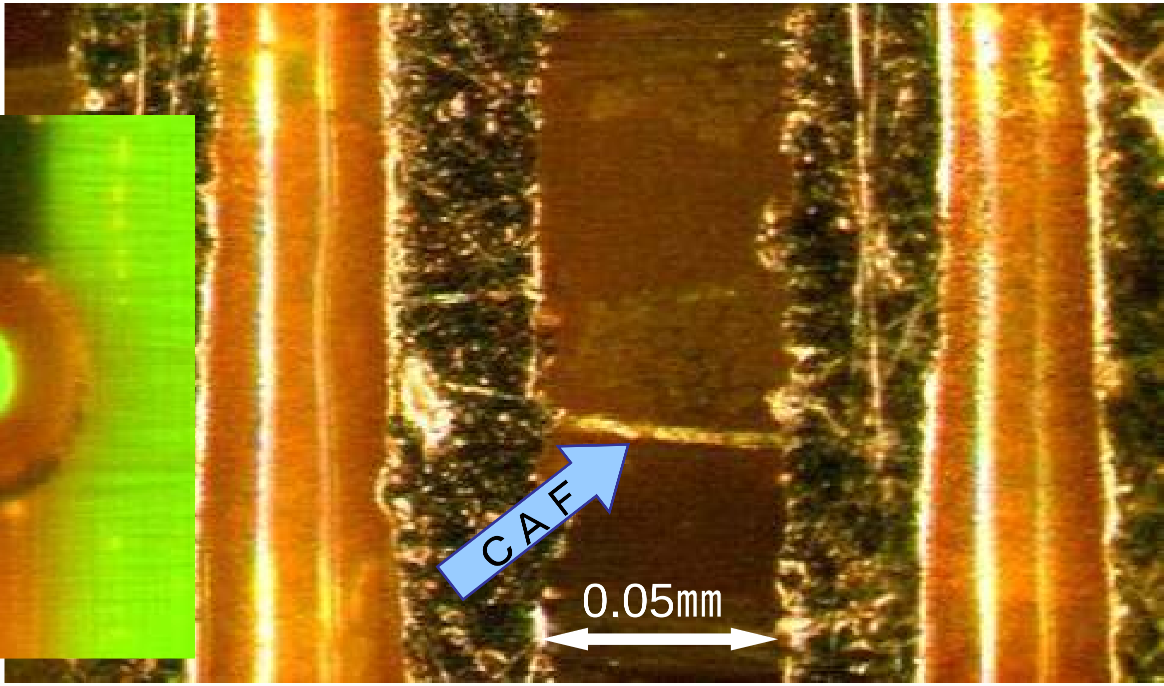


Observation circuit:

Insulation resistance less than $10^6\Omega$



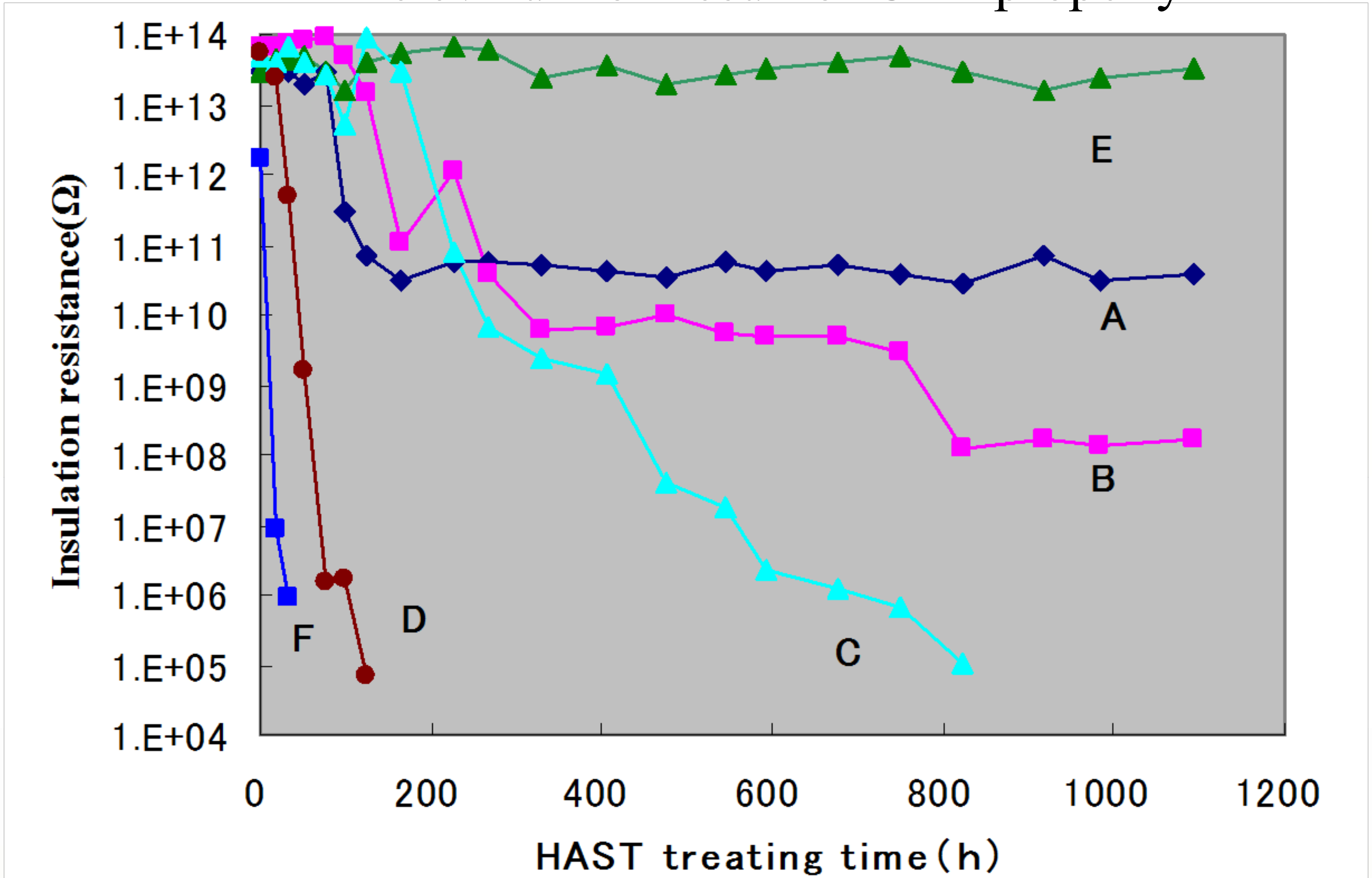
Surface photograph (CAF part)



Cross section photograph (CAF part)

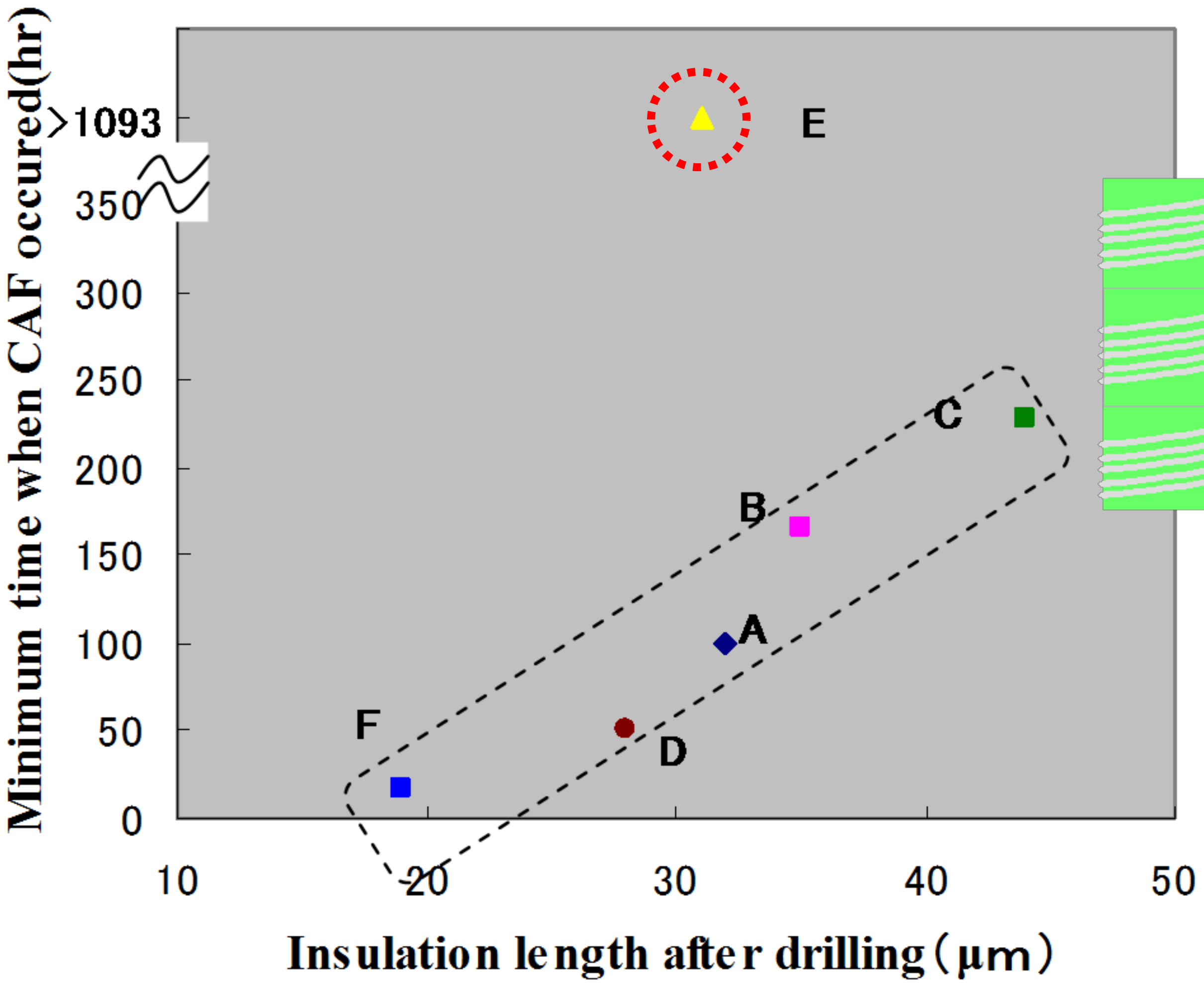
3.Evaluation of laminate materials

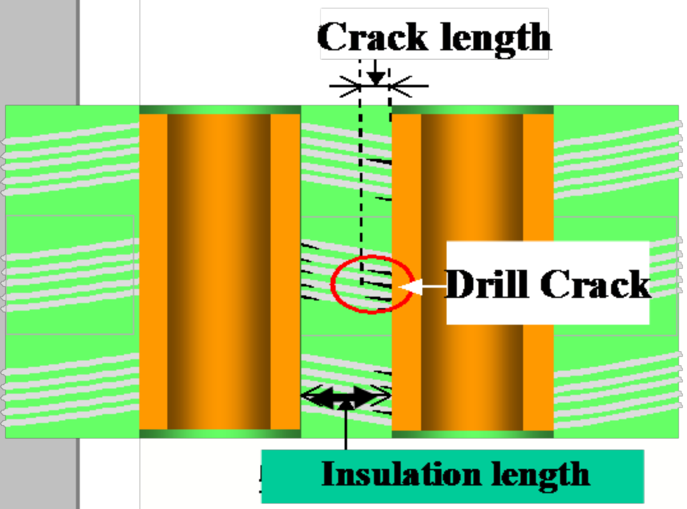
The evaluation result of CAF property



Material E indicated the best anti-CAF property

3.Evaluation of laminate materials

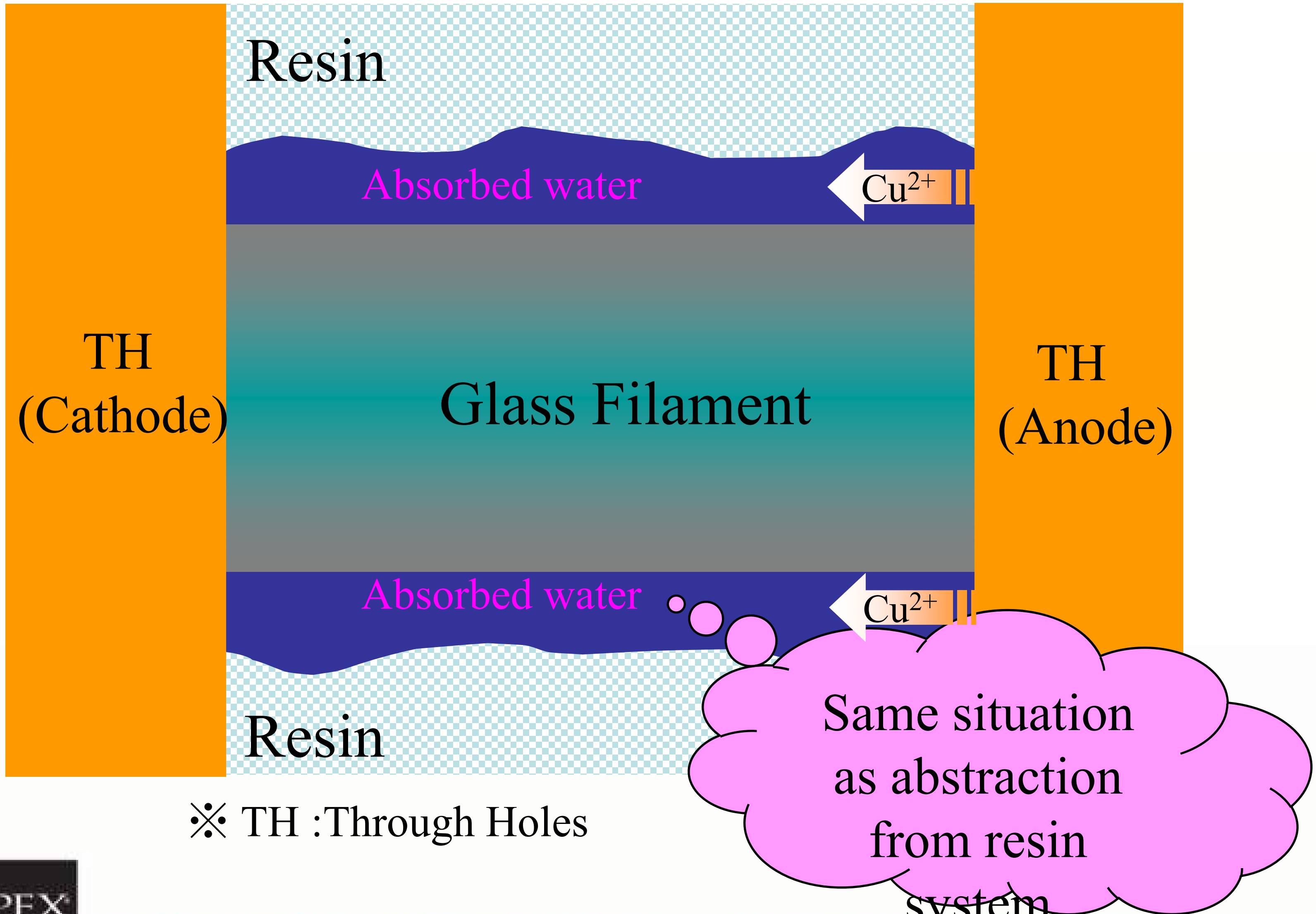




Drilling process ability influences anti-CAF performance.

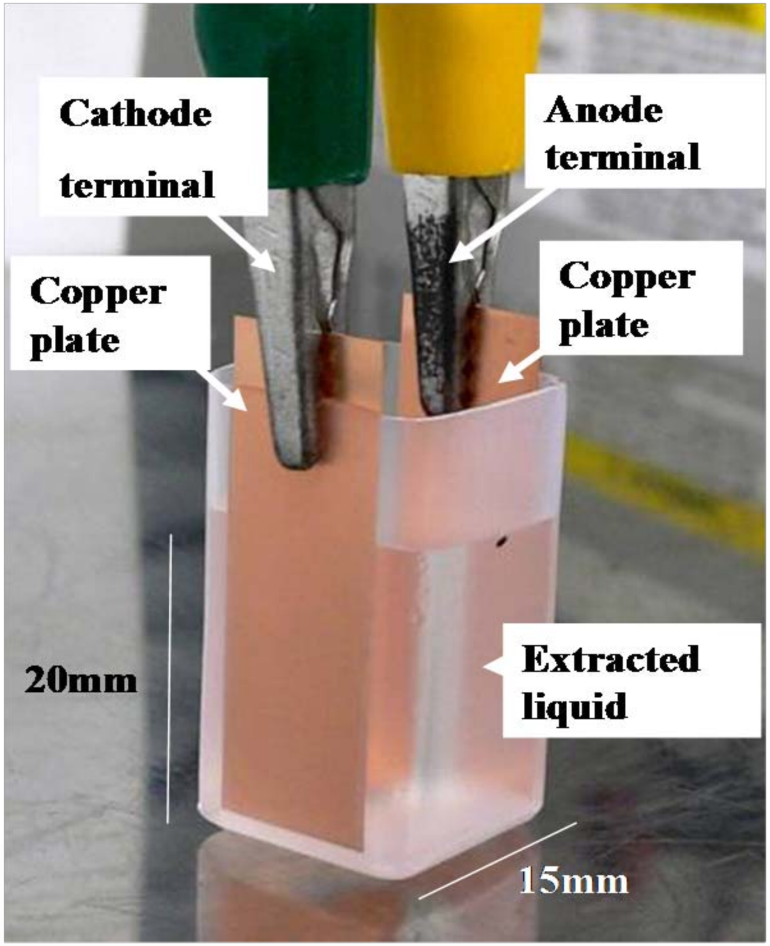
4.Result and consideration

Imaging Fig. of insulation parts after HAST

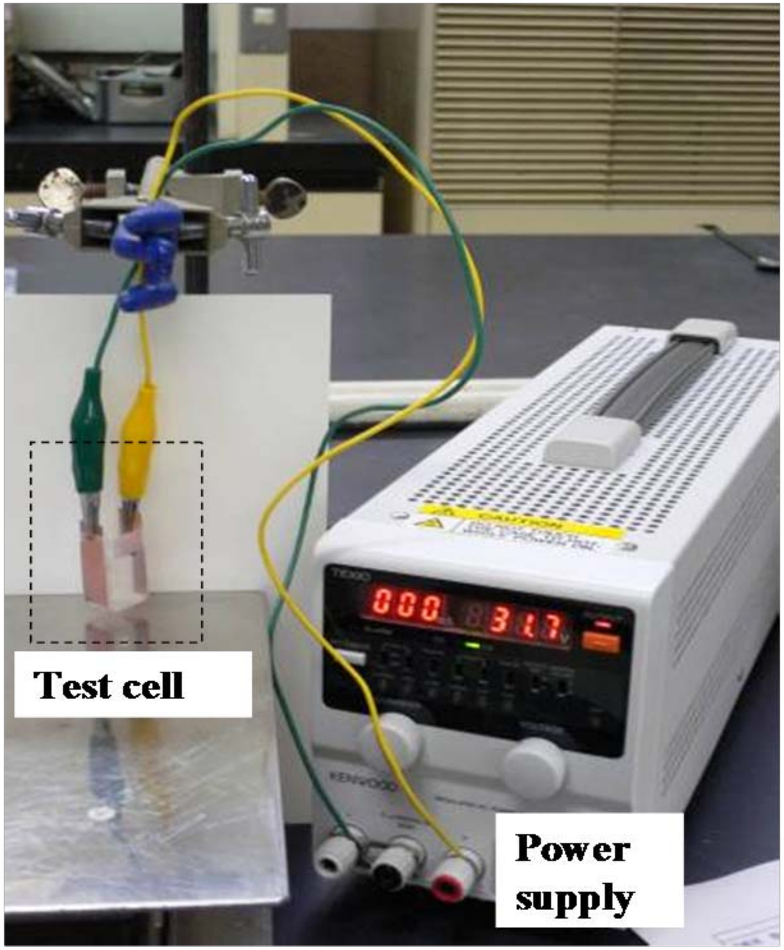


※ TH :Through Holes

Copper migration test equipment



Test cell



Test equipment

Voltage / Charge time : 30V/30min.
Max. electric current : 6mA

Table. Properties of each extracted liquid

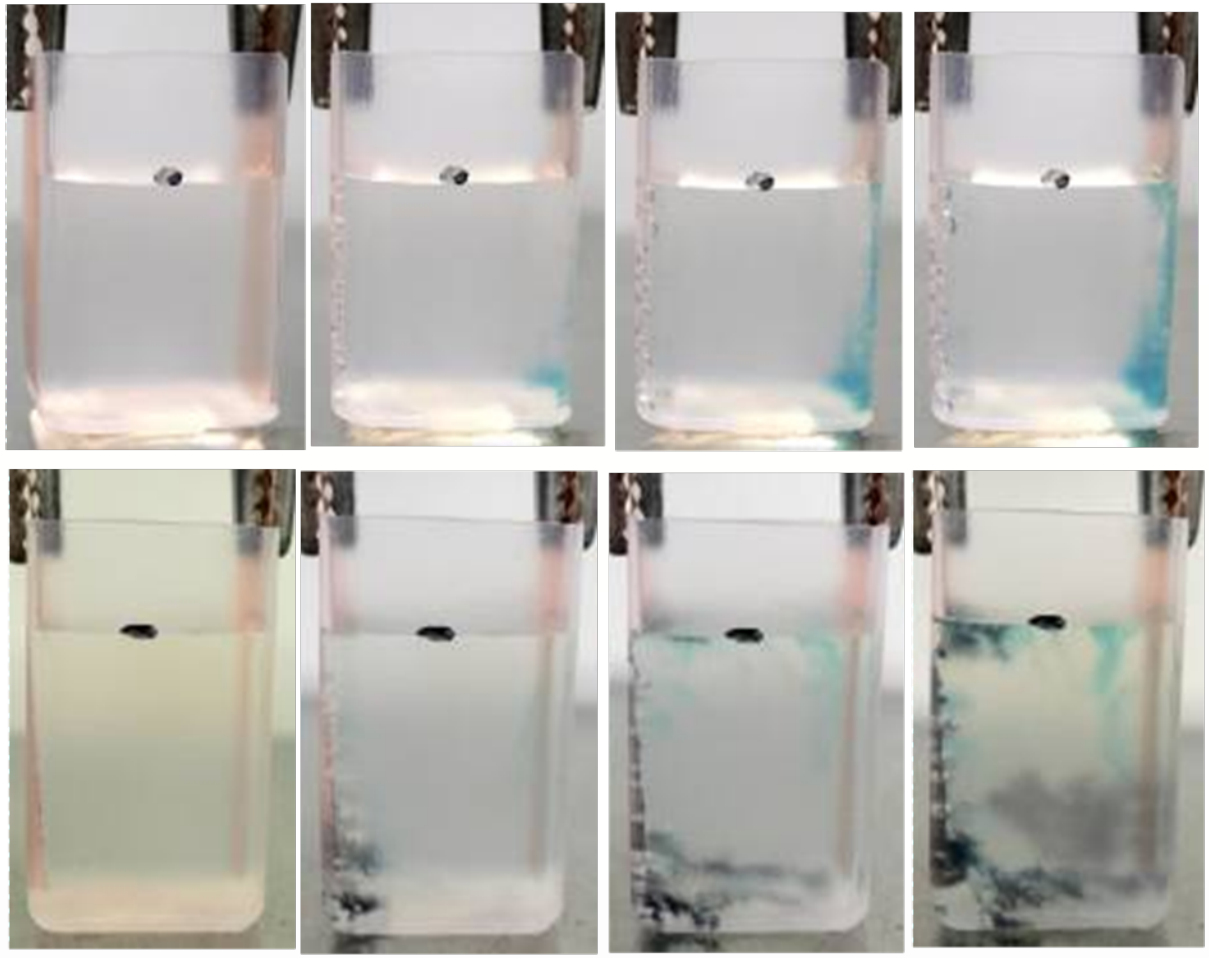
Material	Extracted liquid		
	Electric conductivity(μs/cm)	PH	Br ion peak(μs)
A	6.9	5.7	0.015
B	6.1	6.3	0.009
C	7.6	5.8	0.009
D	35	6.7	0.122
E	20	8.1	0
F	14.3	5	0.118

Extract method:
sample (40mmX 30mm: 3pcs) in pure water D-200/110

4.Result and consideration

E (Halogen-Free)
Br peak 0
EC 20.3

D
Br peak 0.122
EC 35.0



0 10min 20min 30min

Treating time (Max 6mA, 30V)

E

$$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$$

D

$$Cu^{2+} + 2e^- \rightarrow Cu$$
$$Cu + H_2O \rightarrow CuO + H_2$$

Conclusion

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1. We could propose a new CAF evaluation vehicle for having narrow through hole pitch PCBs.

2. The new CAF evaluation vehicle can be tested 50μm from the wall to wall between through holes.

3. We evaluated CAF restraining property using several types of laminates.

4. Our evaluation result indicated a new halogen-free material had the best anti-CAF property.

5. The migration test to use extract liquids indicated the different trend between good one and bad one.