An Innovative High CTI RCC Material

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Abstract

Consumption electronic devices are becoming much smaller, lighter and multifunctional, and high CTI application has already been not satisfied with double sided design and requested thinner & multilayer compatible. We developed a new halogen free and high CTI RCC to meet these new requirements. Compared to traditional FR-4, it provides flexible selection by combination with different material to meet fine line, lead free & halogen free application.

Key word

High comparative tracking index (high CTI), Resin coated copper foil (RCC or RCF)

Introduction

Per the definition in UL, comparative tracking index is expressed as that voltage which causes tracking after 50 drops of 0.1 percent ammonium chloride solution have fallen on the material. The results of testing the nominal 3mm thickness are considered representative of the material's performance in any thickness.

Tracking is an electrical breakdown on the surface of an insulating material, which is created by a voltage difference by forming a carbonized track across the material surface. UL has listed the Performance Level Categories (PLC) as table 1.

Table 1- CTI PLC range in UL

CTI range	PLC
Tracking index(in volts)	Assigned
600 and Greater	0
400 through 599	1
250 through 399	2
175 through 249	3
100 through 174	4
< 100	5

Generally, a material with CTI>400 (>PLC1) is considered able to provide enough safety performance.

As high CTI material provides better surface dielectric reliability and safety, helping PCB to resist poor surroundings such as high temperature, high humidity and dirtiness, nowadays it’s been widely used on consumption electronic and home used products. However, owing to lead free application and high multifunction of end products, there are more and more new demands requiring better heat resistance and multilayer application with high CTI performance. The traditional FR-4 is made of glass fabric as reinforcement, which’s unable to satisfy the trends of much lighter and thinner requirement due to limitation on reinforcement design. To work it out, a new type of high CTI RCC was developed. By careful selection on inorganic fillers and modified epoxy resin, the RCC formula gets sufficient thermal reliability and is

able to satisfy different requirements by combination with traditional glass fabric reinforced material.

Strategy of high CTI RCC

a. Selection on main type of resin

Traditional FR-4 is usually adopted a kind of brominated bisphenol A (BBA) epoxy resin as a main part of resin formula. The molecule structure of BBA includes easy-carbonized aromatic groups like benzene, and the C-Br bonding in structure is weak and easily to generate HBr when suffered from high temperature, which would correspondingly accelerate the process of resin carbonization. Therefore, this kind of resin can't approach to good CTI value. However, some special kinds of epoxy resin, such as cycloaliphatic epoxy resin, glycidyl ester epoxy resin and hydrogenated bisphenol A epoxy resin, include uneasy-carbonized groups like $-CH_3$, $-CH_2$, -CH in molecule structures which can comparatively get higher CTI value, thus they're the target selection. The formula design shall try to reduce the proportion of BBA epoxy resin under the premise of ensuring flammability.

b. Selection on inorganic filler

The application of rich-oxygen inorganic compounds can increase CTI value obviously. The reason is considered that they would react with carbon residues under high temperature and generate volatile gas. The reaction would reduce the forming of carbon and balance the process of carbon forming and volatility. The common used filler is aluminum hydroxide with a mechanism as below.

Step 1: Aluminum hydroxide decomposes under high temperature during discharge process.

$$2Al(OH)_3 \longrightarrow Al_2O_3 + 3H_2O\uparrow$$

This is an endothermic reaction and able to lower material's surface temperature. At the same time, water can generate vapor flow by high temperature and correspondingly get rid of deposited carbon on sample's surface, which would weaken the forming of tracking.

Step 2: Aluminum hydroxide can react with dissociated carbon and transform to volatile gas.

$$Al_2O_3.3H_2O + 3C \longrightarrow 3CO\uparrow + Al_2O_3 + 3H_2\uparrow$$

Step 3: The reaction outcome Al_2O_3 has a good performance of thermal conductivity, which can reduce the heat accumulation and decrease material decomposition and carbon forming.

In theory, the use of aluminum hydroxide would show a positive effect on CTI values, the more the better. However, as the weight increased, the resin formula would gradually become instable, easy-deposited and phase separated, all of which would affect subsequent processing and CCL performance. Therefore, it's essential to find out a proper weight proportion to ensure CCL properties and also reach high CTI purpose.

Performance of High CTI RCC

Traditional high CTI material is generally adopted reinforcement pre-dipped technology. In order to reach high CTI purpose, the selection of glass fabric and resin content is important but the range is quite narrow, so it's limited especially on thinner and multilayer application. High CTI RCC is coated with a thin resin layer around 50-80um without limitation of reinforcement, thus it can satisfy varieties of multilayer dielectric design and thinner PWB requirements. Moreover, by combination with different specified materials, such as lead free and halogen free material, it can also meet individual application.

Tg value is generally used to show material's basic property as below figure 1.

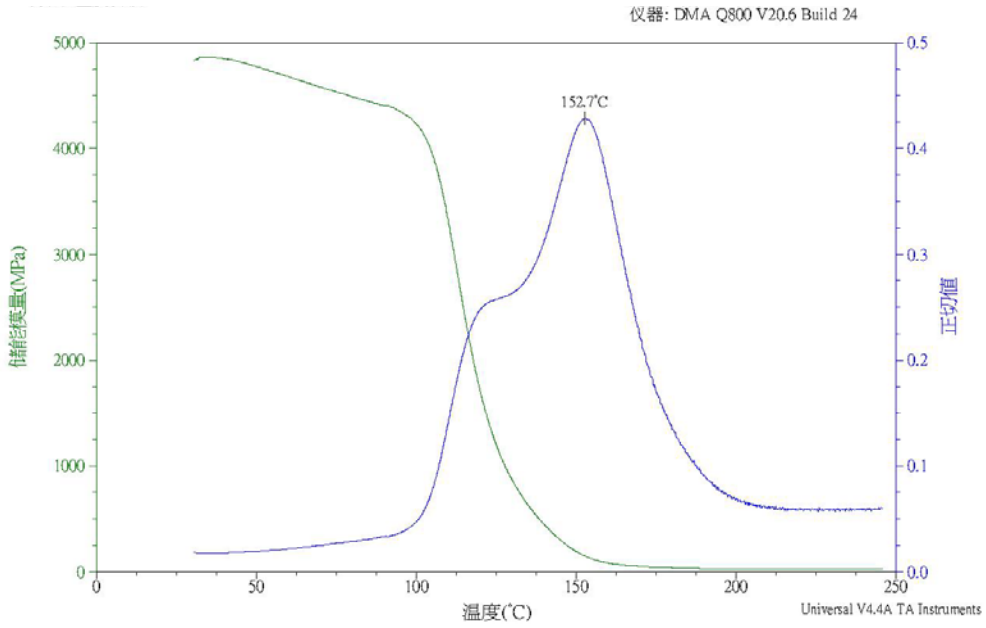


Figure 1- Tg testing by DMA

In order to indicate general performance of Hi-CTI RCC, two type of standard double sided CCLs with a construction of RCC+PREPREG+RCC had been made for evaluation. Standard and halogen free material were selected for comparison, showed as table 2.

Table 2- High CTI RCC general properties

Test item	Test Method	Unit	RCC+Std PP+RCC	RCC+ H/F PP+RCC
CTI	IEC 60112	V	500	500
Td	IPC-TM-650 2.4.24.6	℃	315	363
T260	IPC-TM-650 2.4.24.1	min	10	60
Tg(DSC)	IPC-TM-650 2.4.25c	℃	135.87/136.10	146.31/148.60
Peel strength	IPC-TM-650 2.4.8	N/mm	1.55	1.51
Solder limit (inc.Cu)	IPC-TM-650 2.4.13.1	min	>3	>3
PCT	IPC-TM-650 2.6.16	-	PASS	PASS
Thermal Stress	IPC-TM-650 2.4.13.1	cycle	>10	>10
Flamability	UL94	s	V-0	V-0

Based on general properties of high CTI RCC, all test items above are acceptable, which indicates it's able to match with different base material for individual feature.

Application of High CTI RCC

a. To improve PWB surface pattern density

As electronic devices are becoming much smaller, lighter and multifunctional, PCB pattern design trends to be much closer than before. Nowadays, 3mil line width/space is more and more common in PWB industry, and 2mil or less is expected to reach in the near future. Therefore, a new material with better surface dielectric reliability is demanded.

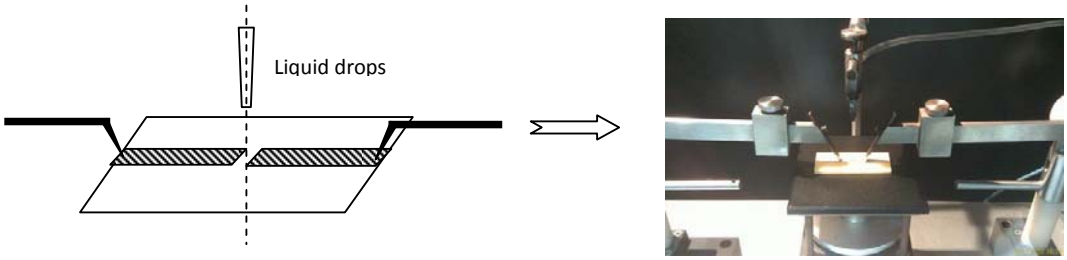
According to IEC 60335-1:2001 specification, if reached to a same level of dielectric reliability, the minimum creepage

space for high CTI material is only half compared to that of standard material. In other words, high CTI materials can double surface dielectric reliability under a same space, showed as table 3.

Table 3- Voltage vs CTI grade

CTI Voltage (DC)	I CTI≥600	II 400≤CTI<600	III a 175≤CTI<400
50V	0.6mm	0.9mm	1.2mm
100V	0.8mm	1.1mm	1.5mm
200V	1.3mm	1.8mm	2.5mm
400V	2.5mm	3.6mm	5.0mm
600V	3.2mm	4.5mm	6.2mm
1000V	4.0mm	5.6mm	8.0mm

To indicate the actual behavior of different CTI values, we selected two kinds of test method for evaluation, including conductor model test method (showed as figure 2) and IEC standard test method. Evaluation result please refers to table 4 and figure 3.



Remark: Copper conductor space is 4.0mm, all other test conditions refer to IEC standard method, except of test pattern and electrode contact way.

Figure 2- Conductor model sketch

Table 4- CTI test result

Test method	Test item	Condition	Unit	Std material	CTI600 material	Hi CTI RCC
Std. Pt electrode	CTI	IEC 60112	V	175	600	500
Cu conductor electrode				75	175	150

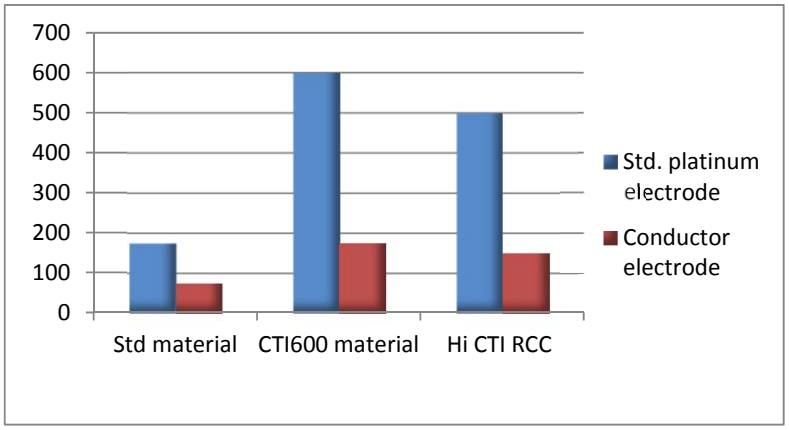


Figure 3- copper conductor Vs standard electrode

It's showed that the CTI values tested by copper conductor electrode are much lower, which is probably related to minor

dissolution of copper conductor and point discharge due to copper matte side, thus the test results couldn't reflect exactly the actual situation and be for reference only. Even so, it's significant to get that high CTI material is able to increase obviously the dielectric reliability under a same pattern space.

b. To match with different material for typical requirement

At present, PWB industry requires more and more lead free and halogen free material, the demand on heat resistant and reliability has been paid more attention to. High CTI RCC is able to provide optional solution by matching with different lead free and halogen free material for various requirements of electric product. In the following evaluation, there are two types of double sided CCLs made of high CTI RCC and related material for properties verification, showed as table 5. IR reflow cycling test with peak temperature 259℃ was selected, showed as table 6. Evaluation result indicated that both materials could satisfy lead free reflow more than 5 cycles.

Table 5- Thermal properties of testing laminate

Test item	Test method	Unit	RCC+L/F PP+RCC	RCC+H/F PP+RCC
Td	IPC-TM-650 2.4.24.6	℃	332	365
T260	IPC-TM-650 2.4.24.1	Min	60	60

Table 6- Lead free IR reflow conditions

1	2	3	4	5	6	7	8	9	10
140	150	165	170	180	190	230	275	280	220

Peak temp.	>217℃	>230℃	165℃－217℃	Speed (cm/min)
259℃	101s	83s	93s	70

c. Multilayer application

As description above, standard high CTI material is limited to multilayer board application, especially for thinner dielectric design. High CTI RCC is able to work it out effectively for its coated resin layer is only 50-80 micron. Compared to standard 7628 prepreg, i.e. 200 micron, it provides flexible selection for dielectric design even by combination with standard type of prepreg. Typical multilayer construction shows as figure 4.

Figure 4 – 4L multilayer construction coated with RCC resin

d. To improve structure-caused measling

At present, a kind of common measling is bothering PWB maker, with a phenomenon of locating beside copper grounds showed as figure 5. The heavier of copper foil and the narrower of space, the easier measling occurs. The mechanism is considered to be caused by huge thermal stress created by different CTE between base material and copper foil during high temperature process, such as thermal stress or hot air leveling, which would result in micro crack at the interlaced glass fabric.

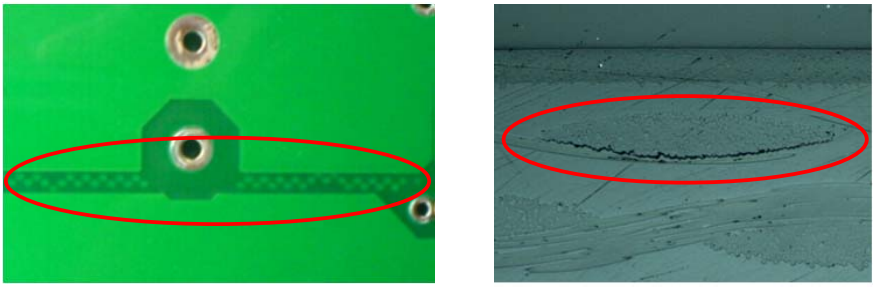


Figure 5- Measling beside copper ground (left) and cross section (right)

High CTI RCC-made base material, as covered with a layer of functional resin, is able to buffer well the thermal stress caused by different CTE between copper foil and base material, thus it's proved to be helpful for this kind of structural measling.

Conclusion

By careful selection on inorganic fillers and modified epoxy resin, it's proved that the strategy of halogen free and high CTI RCC is feasible and practice, and is able to improve material's surface dielectric reliability. By combination with different kind of FR-4 materials, it can meet typical demands, such as fine line, lead free, halogen free and thin multilayer board application and so on.

Reference

1. IEC 60335-1:2001 household and similar electrical appliances - safety - part 1: general requirements;
2. http://www.ul.com/global/eng/pages/offerings/industries/chemicals/plastics/testing/746a/cti/;
3. Gu Xinshi, Copper clad laminate used for printed circuits, Beijing, Chemical industry publisher, 2002, Chapter 8 & 10.
4. Ru Jinghong, Development on high CTI epoxy and glass fabric base copper clad laminate, the eighth national dielectric material and technology forum thesis compilation, 2002.

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Agenda

- 1. Development
  - Introduction
  - Strategy of high CTI RCC
- 2. Performance
  - combination with standard material
- 3. Application
  - -Improve PWB surface pattern density
  - -Match to different material for typical requirement
  - -Multilayer application
  - -Improve structural measling
- 4. Conclusion

Introduction

High CTI provides better surface dielectric reliability and safety

Consumption electronic and home used products

Introduction

- CTI = Comparative tracking index.
- Created by a voltage difference by forming a carbonized track across the material surface.
- UL has listed the Performance Level Categories (PLC) as below table.

CTI range	PLC
Tracking index(in volts)	Assigned
600 and Greater	0
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250 through 399	2
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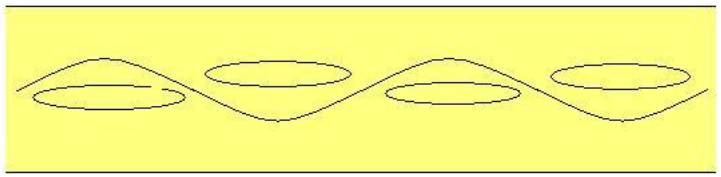
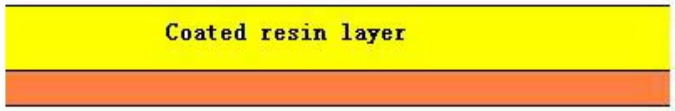
Introduction

- Traditional high CTI material is generally adopted reinforcement pre-dipped technology



Sketch for prepreg structure

- Limited on glass fabric type and resin content, especially for thinner and multilayer application



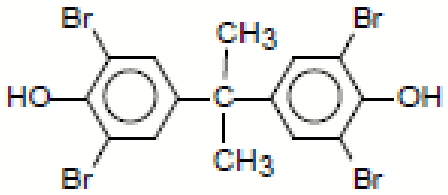
Sketch for RCC structure

- Resin layer around 50-80um
- Flexible for dielectric design and thinner PWB requirements.

Strategy of high CTI RCC

a. Selection on main type of resin

- **brominated bisphenol A (BBA) epoxy resin**



→ easy-carbonized aromatic group

C–Br → The bonding is weak and easily to create HBr volatile gas

- Not the target selection!

Strategy of high CTI RCC

a. Selection on main type of resin

- cycloaliphatic epoxy resin
- glycidyl ester epoxy resin
- hydrogenated bisphenol A epoxy resin

$-CH_3$, $-CH_2$, $-CH$ → uneasy-carbonized groups

- Target selection!

Strategy of high CTI RCC

b. Selection on inorganic filler

- The application of rich-oxygen inorganic compounds can increase CTI value obviously.
- Aluminum hydroxide is common used.

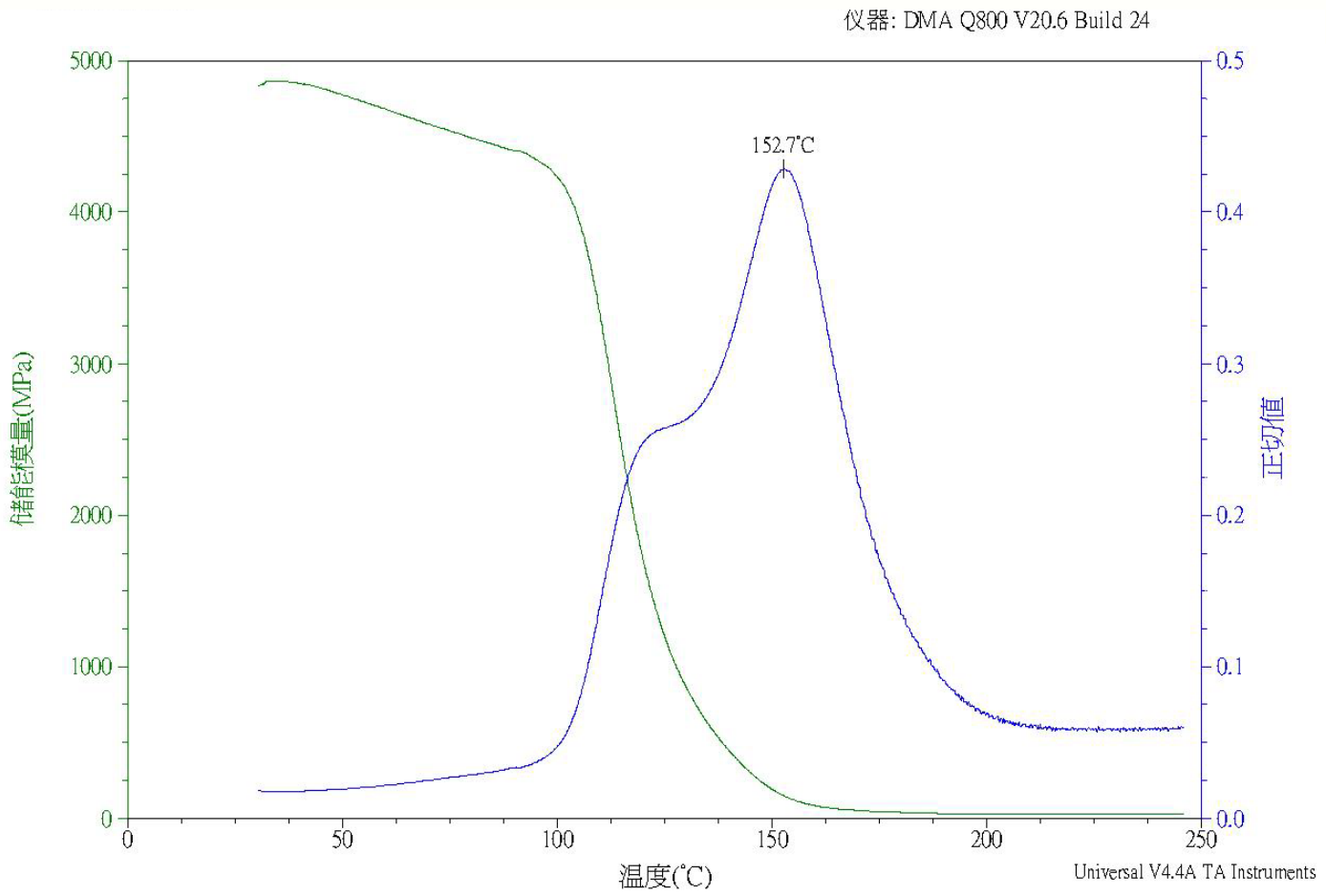
①: $2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O \uparrow$

②: $Al_2O_3 .3H_2O + 3C \rightarrow 3CO \uparrow + Al_2O_3 + 3H2 \uparrow$

③: Al_2O_3 is able to reduce the heat accumulation, decrease material decomposition and carbon forming.

Performance

- Tg



Performance

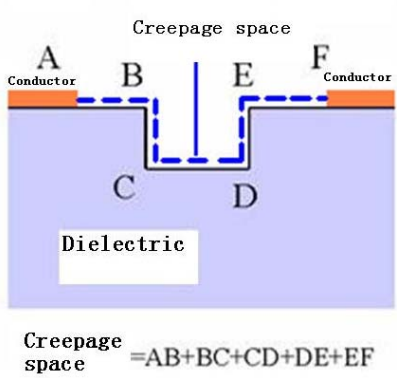
Generally properties

Test item	Test Method	Unit	RCC+Std PP+RCC	RCC+ H/F PP+RCC
CTI	IEC 60112	V	500	500
Td	IPC-TM-650 2.4.24.6	℃	315	363
T260	IPC-TM-650 2.4.24.1	min	10	60
Tg(DSC)	IPC-TM-650 2.4.25c	℃	135.87/136.10	146.31/148.60
Peel strength	IPC-TM-650 2.4.8	N/mm	1.55	1.51
Solder limit (inc.Cu)	IPC-TM-650 2.4.13.1	min	>3	>3
PCT	IPC-TM-650 2.6.16	-	PASS	PASS
Thermal Stress	IPC-TM-650 2.4.13.1	cycle	>10	>10
Flamability	UL94	s	V-0	V-0

Application

a. Improve PWB surface pattern density

- Per IEC 60335-1 specification, the minimum creepage space for high CTI material is only half compared to that of standard material.



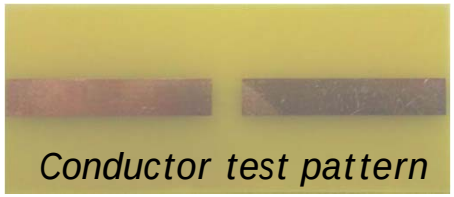
CTI Voltage (DC)	I CTI≥600	II 400≤CTI<600	III a 175≤CTI<400
50V	0.6mm	0.9mm	1.2mm
100V	0.8mm	1.1mm	1.5mm
200V	1.3mm	1.8mm	2.5mm
400V	2.5mm	3.6mm	5.0mm
600V	3.2mm	4.5mm	6.2mm
1000V	4.0mm	5.6mm	8.0mm

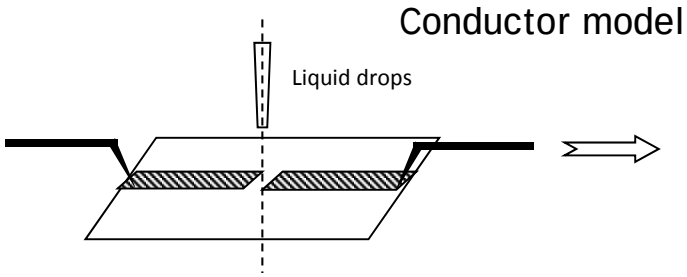
Application

a. Improve PWB surface pattern density

Two kinds of test methods are selected for evaluation.

- Conductor model test method
- IEC standard test method

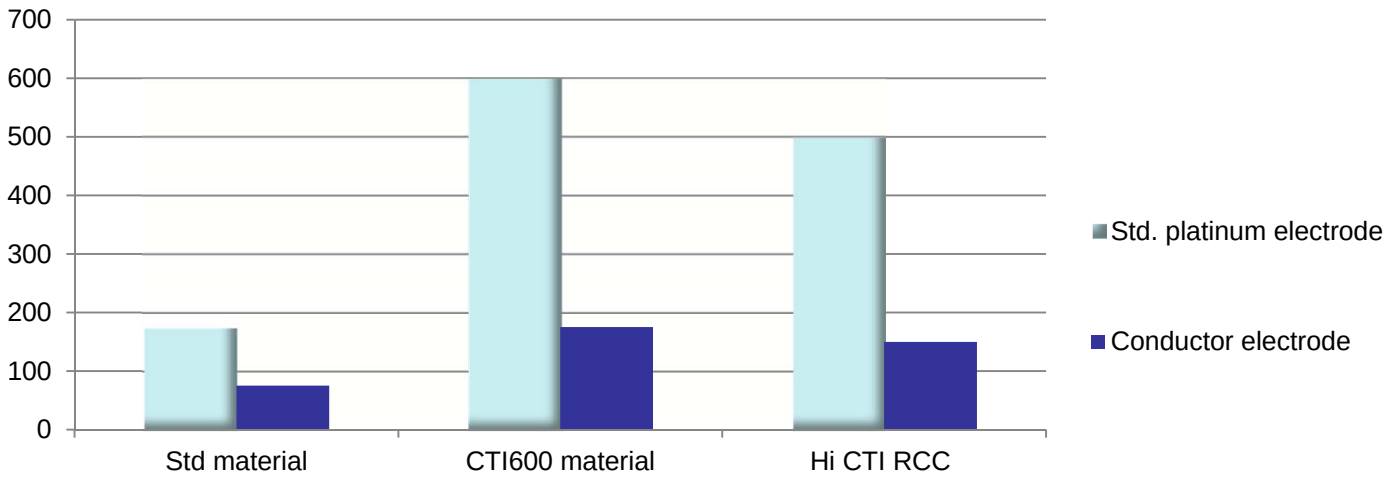




Test method	Test item	Condition	Unit	Std material	CTI600 material	Hi CTI RCC
Std. Pt electrode	CTI	IEC 60112	V	175	600	500
Cu conductor electrode				75	175	150

Application

a. Improve PWB surface pattern density

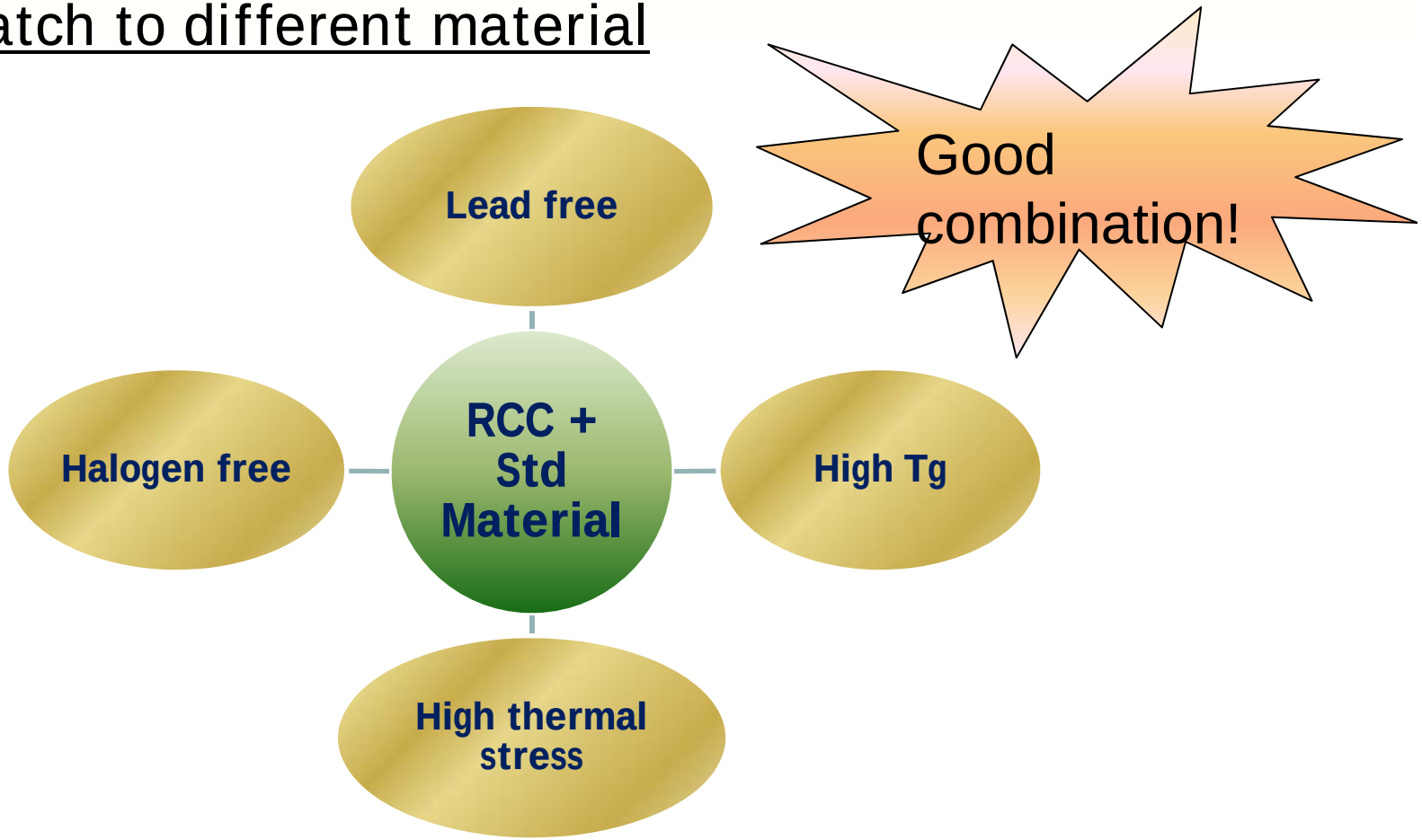


Remark: Test results couldn't exactly reflect actual situation due to minor dissolution of copper conductor and point discharge, for reference only.

It's significant to get that high CTI material is able to increase dielectric reliability under a same pattern space.

Application

b. Match to different material



Application

b. Match to different material

- Two types of double sided CCLs made of high CTI RCC for properties verification

Table for typical properties

Test item	Test method	Unit	RCC+L/F PP+RCC	RCC+H/F PP+RCC
Td	IPC-TM-650 2.4.24.6	℃	332	365
T260	IPC-TM-650 2.4.24.1	Min	60	60

Application

b. Match to different material

- IR reflow cycling test with peak temperature 259℃ was selected.

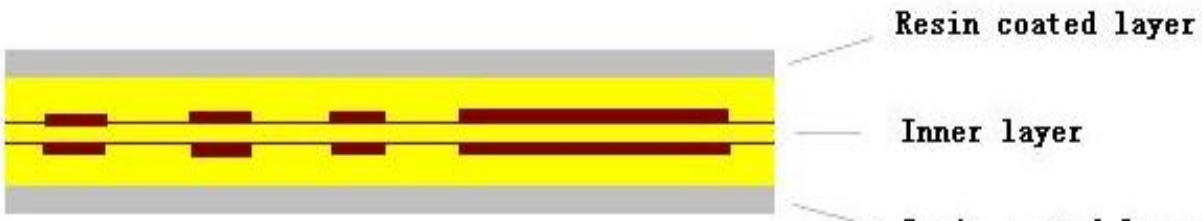
1	2	3	4	5	6	7	8	9	10
140	150	165	170	180	190	230	275	280	220

Peak temp.	>217℃	>230℃	165℃—217℃	Speed (cm/min)
259℃	101s	83s	93s	70

- Satisfy lead free reflow >/=5 cycles
- Good combination with different materials

Application

c. Multilayer application

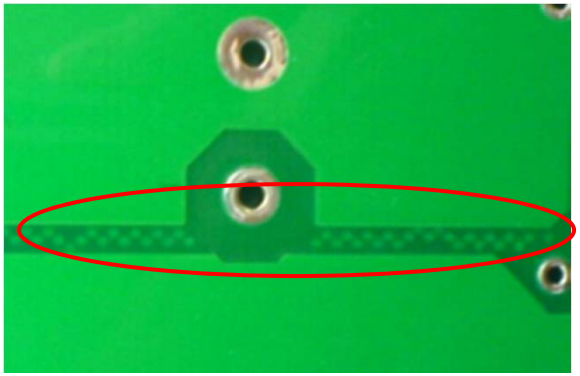


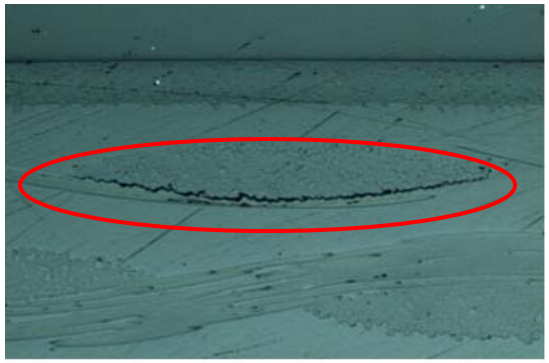
MLB construction covered by RCC

- Coated resin layer = 50-80 micron;
- No limitation of glass fabric;
- provides flexible selection for dielectric design even by combination with standard type of prepreg.

Application

d. Improve structure-caused measling





- covered with a layer of functional resin
- buffer well the thermal stress caused by different CTE
- proved to be helpful for this kind of structural measling

Conclusion

- Halogen free and high CTI RCC is feasible and practical.
- By combination with different kinds of FR-4, high CTI RCC can meet typical demands, such as fine line, lead free/halogen free and thin multilayer board application and so on.

A good solution for future CTI material's demands.

Thanks for your attention!

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Shengyi Technology Co. Ltd