Considerations on Developing Encapsulant for Green IC Packaging

조 재 욱 부장
(동진쎄미켐)

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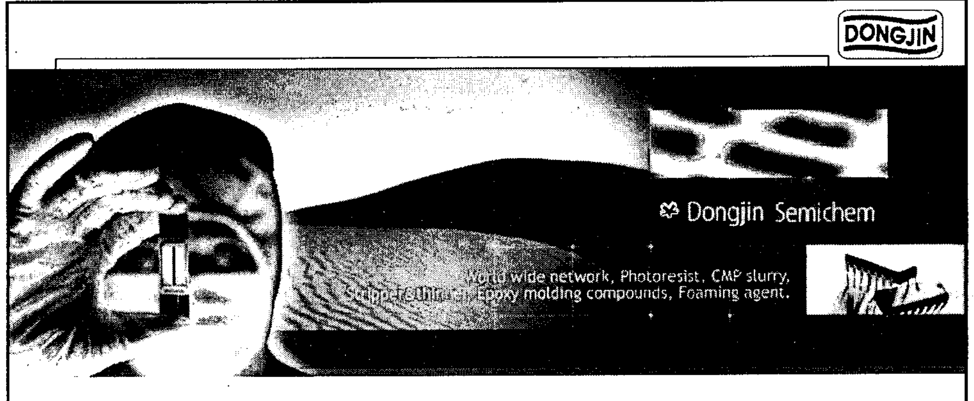

Considerations on developing encapsulant for green IC packaging

Dongjin Semichem
EMC division

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1. **Background**
2. **Investigation of Halogen-free & Antimony-free FR**
3. **Consideration on EMC for Pb-free Soldering**
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International Environmental Issue : History

1972 UN environmental declaration
1989 Montreal conference decision (protection of ozone layer)
1991 Rio declaration – Agenda 21
1995 ISO14001
1996 WTO
1997 Kyoto declaration (green house effect)
2002 **EU : WEEE, RoHS**
[Direct Restriction to Electric, Electronic Product]

WEEE : Waste Electrical and Electric Equipment
RoHS : Restriction of the use of Certain Hazardous Substances in Electrical and Electric Equipment

RoHS

Purpose :
Restriction of Harmful materials
Establishment of Laws and Regulation

Enforcement :
1st of July, 2006
Some materials are already restricted
ex) Cadmium restricted in Netherlands

Products :
All Electric/Electronic products

Material Restricted :
Heavy metal : Pb, Cd, Hg, Cr
Brominates Flame Retardants : PBB,BDE

Current Status of Pb-Free Application : Manufacture

Pb-free production by 2002

Total Value of Products : $4.1Bn

Japan	**93%**
Europe	**3.0%,**
Asia/ROW	**2.5%**
North America	**1.5%**

1998	**Matsushita** started to apply on MD products
1999	**NEC, Hitachi** (Notebook PC), **Sony** (Walkman) started to apply, **Philip** (Power system for Light) started to apply.
2000	**Fujitsu** (Server), **Toshiba** (VTR), **Nissan** (Keyless entry system), **Ford** (Car alarm system) started to apply.
2001	**JVC** (DVD), **Sharp** (Notebook PC), **Motorola** (Motorola) started to apply.
2002	**Ericsson** (80% of new products), **Fujitsu** (All products), **Hitachi** (All in company) started to apply.
2003	**Matsushita** (All in group), **NEC** (All in group) start to apply.
2004	**Hitachi** (All in group), **Sony** (All products by Mar.2006), **Toshiba** (All in group)
2005~	**Mitsubishi** (All product by Mar.2006)

Reference to the electronics industry report 2004 of Prismark & ESPEC technical report No. 26

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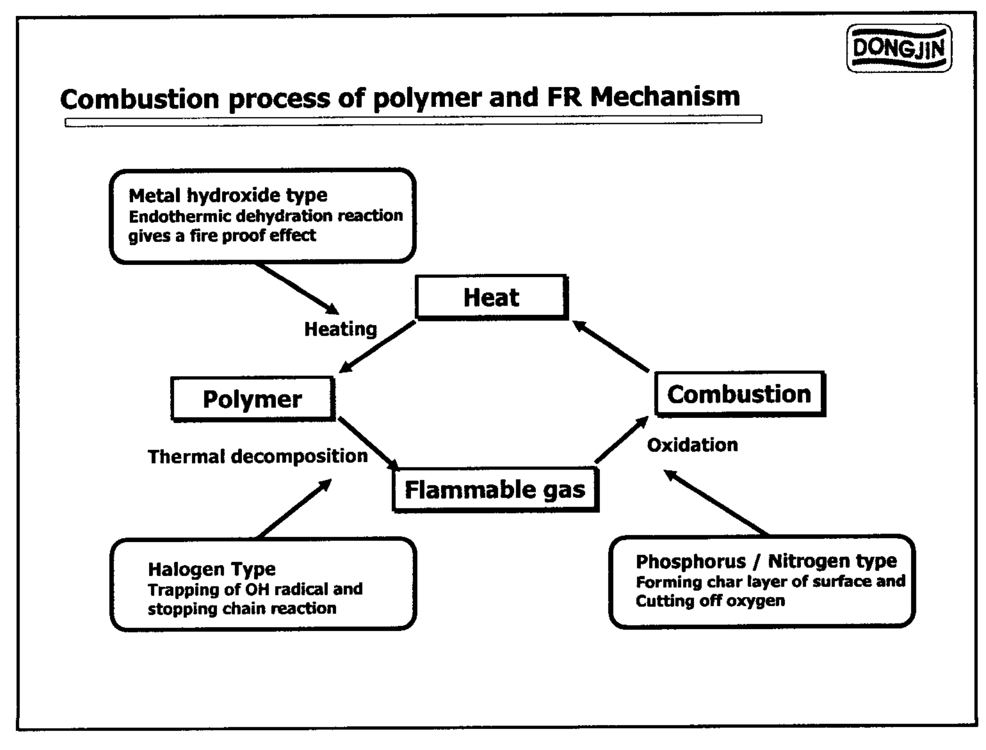
Epoxy molding compound for green IC packaging

Main focus of Green compound

- **Elimination of Harmful materials (Halogens-free & Antimony-free)**

- **High MSL performance for high temperature (Pb free / 260degC reflow)**



Flame Retardant Mechanism

Types	Process	Mechanism
Brominated Resin Sb_2O_3	$Sb_2O_3 + HBr \rightarrow SbOBr + SbBr_3$ $R \cdot + SbX \rightarrow RX + Sb$	Dilution of oxygen concentration Interruption of oxygen Termination of burning
Phosphorus	$Phosphorus \xrightarrow[O_2]{} P_2O_5$	Dilution of oxygen concentration Accelerated Carbonization Interruption of oxygen
Nitrogen	NO, NO_2 formation	Dilution of oxygen concentration
Metal Hydroxide	$Mg(OH)_2 \rightarrow Mg_2O_3 + H_2O - \Delta$	Endothermic reaction with dehydration Accelerated carbonization
No Flame Retardant	Inorganic material Foamed structure	Interruption of oxygen

Development History of Non-Halogen EMC

	Flame Retardant	Retardancy	Mold ability	Reliability	Environmental Friendship	Remark
Halogen Compound	Brominated-Epoxy Sb_2O_3	O	O	O	X	-
Inorganic-P	Red Phosphorous	O	O	X	O	-
Organic-P		△	O	?	O	Influenced from Red Phosphorous

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Development History of Non-Halogen EMC

	Flame Retardant	Retardancy	Mold ability	Reliability	Environmental Friendship	Remark
Nitrogen	(melamine structure: NH_2, triazine ring, -[N-H ... N-H]$_n$-)	△	O	?	O	Synergy Effect with phosphorus
Metal Hydroxide	$Mg(OH)_2$	O	O	O*	O	*Surface treatment
No Flame Retardant	More than 85 % Filler content, Self-Extinguish Resin	O	O	O	O	Expensive
	(epoxy resin structure)					

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Improved type of metal hydroxide

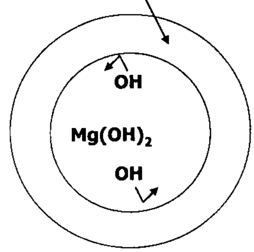
$$Mg(OH)_2 \xrightarrow{\text{Over 300degC}} Mg(OH)_2 + H_2O \quad -\Delta(=200KJ/mol)$$

Dilution　Endothermic reaction

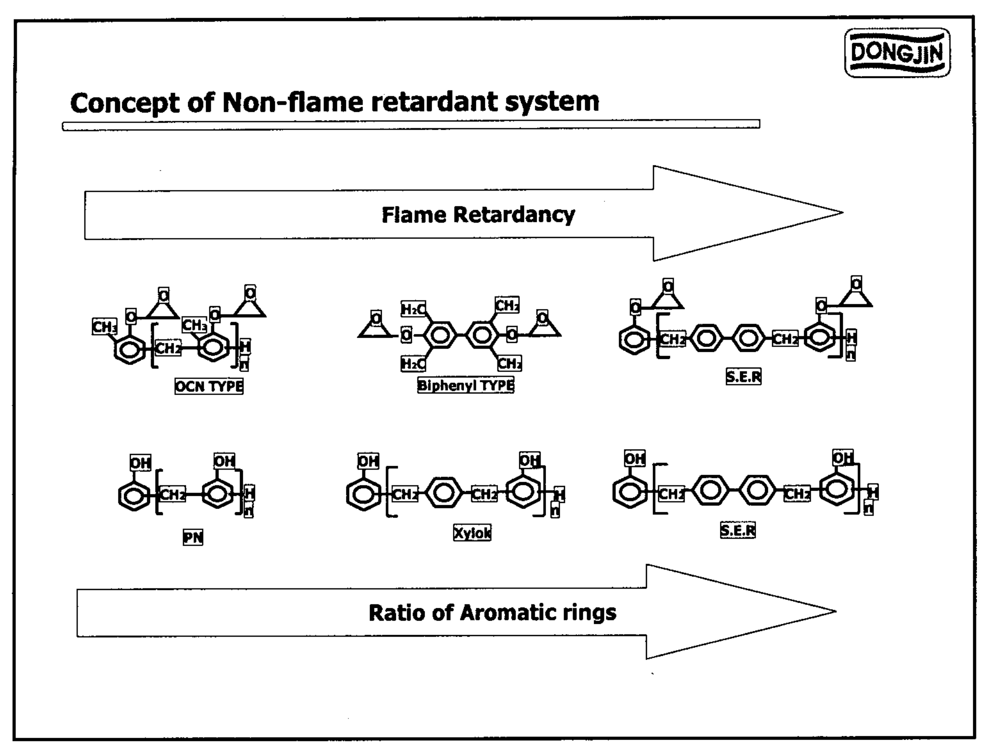
Ordinary metal hydroxide used for flame retardant purpose degraded

- hydrophobic property
- Flowability

Hydrophobic coated layer



When it's burning, Hydrophobic layer broken, metal hydroxide inside shows performance.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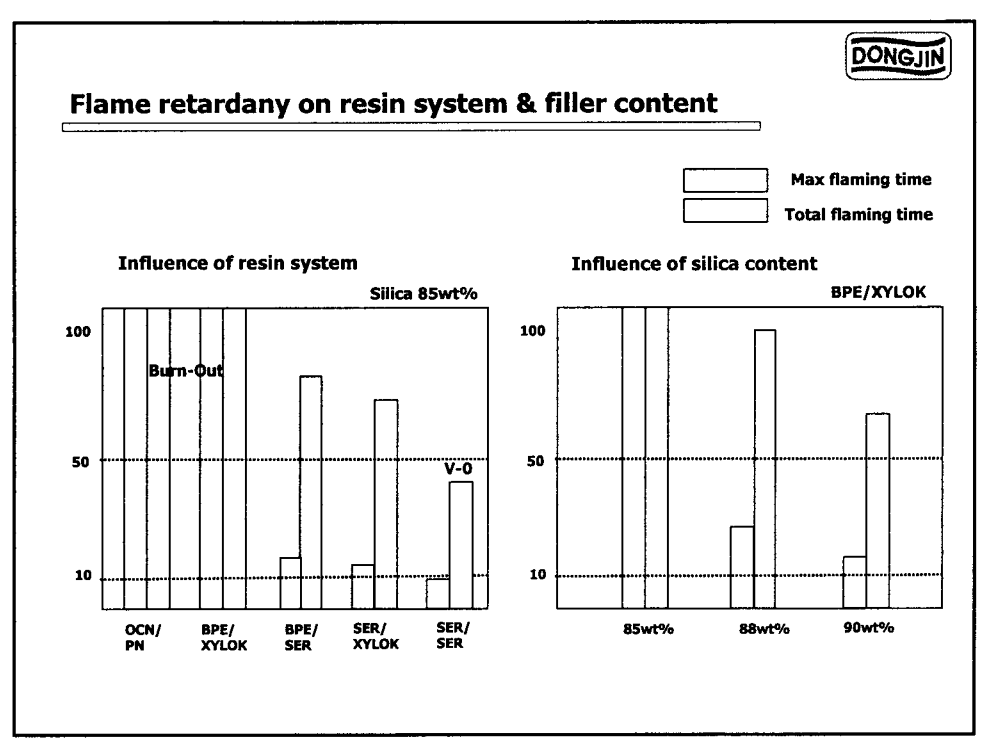
Concept of Non-flame retardant system
Flame Retardancy
OCN TYPE
Biphenyl TYPE
S.E.R
PN
Xylok
S.E.R
Ratio of Aromatic rings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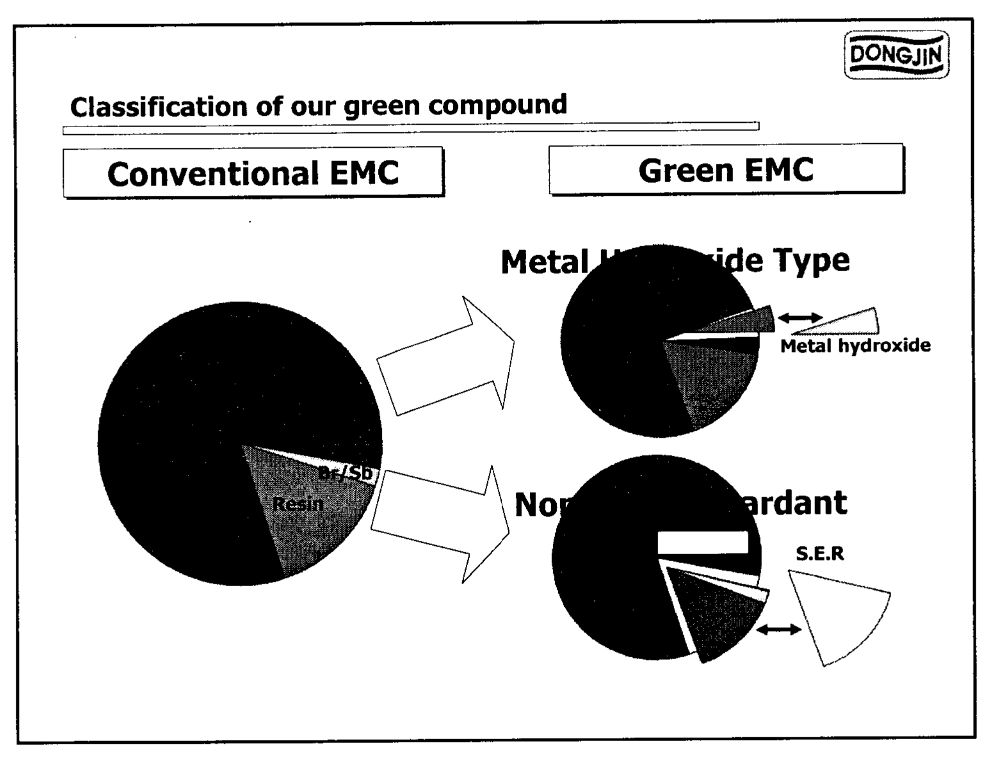
Flame retardany on resin system & filler content
Max flaming time
Total flaming time
Influence of resin system
Silica 85wt%
Burn-Out
V-0
OCN/ PN
BPE/ XYLOK
BPE/ SER
SER/ XYLOK
SER/ SER
Influence of silica content
BPE/XYLOK
85wt%
88wt%
90wt%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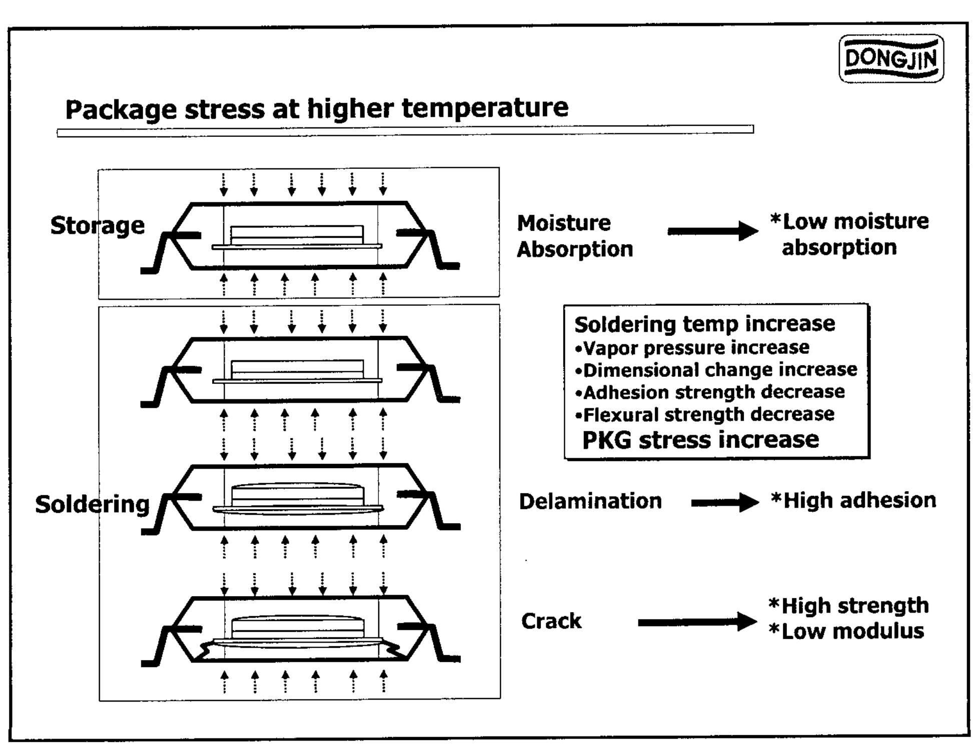
Classification of our green compound
Conventional EMC
Green EMC
Br/Sb
Resin
ide Type
Metal hydroxide
rdant
S.E.R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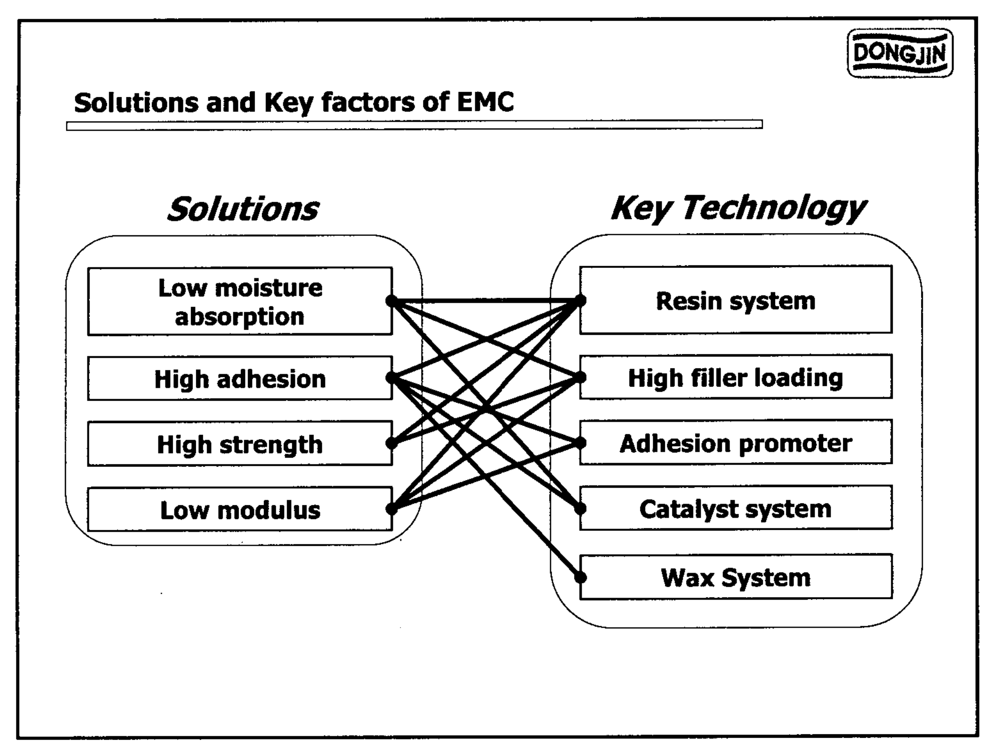
Package stress at higher temperature
Storage
Moisture Absorption
*Low moisture absorption
Soldering temp increase
•Vapor pressure increase
•Dimensional change increase
•Adhesion strength decrease
•Flexural strength decrease
PKG stress increase
Soldering
Delamination
*High adhesion
Crack
*High strength
*Low modulus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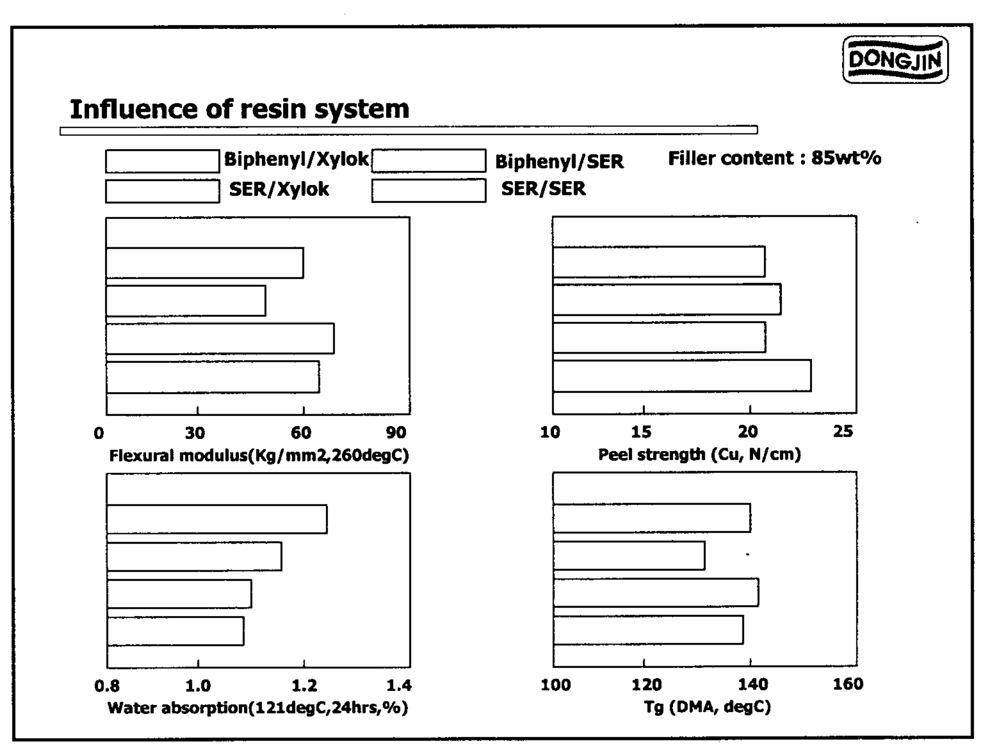
Solutions and Key factors of EMC
Solutions
Key Technology
Low moisture absorption
High adhesion
High strength
Low modulus
Resin system
High filler loading
Adhesion promoter
Catalyst system
Wax System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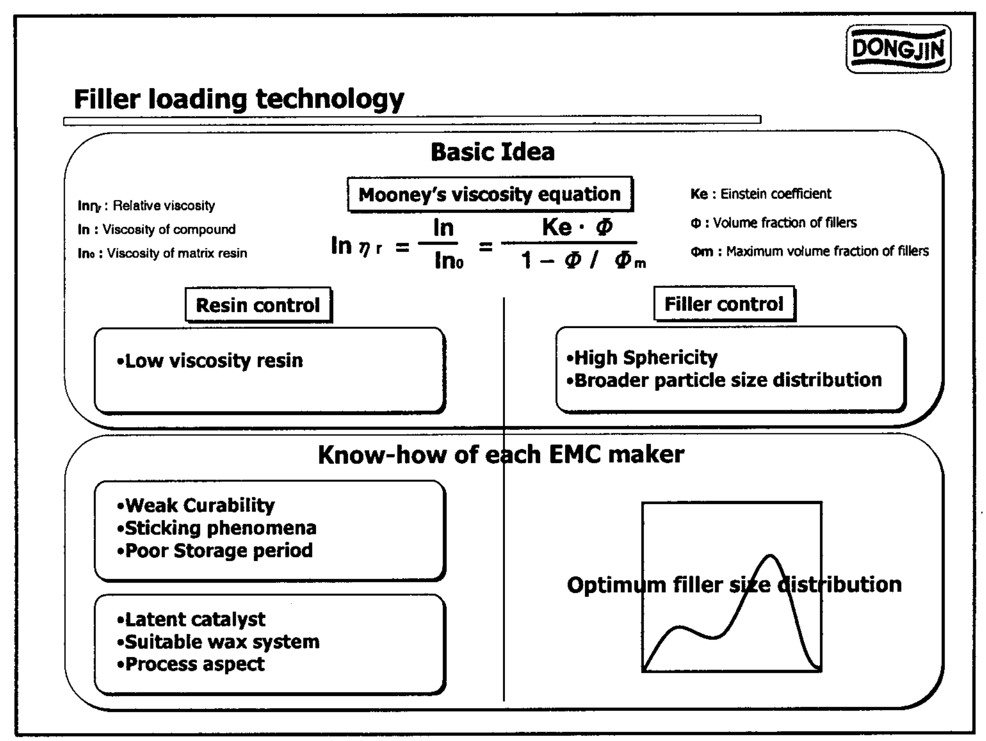
Influence of resin system
Biphenyl/Xylok
Biphenyl/SER
Filler content : 85wt%
SER/Xylok
SER/SER
0
30
60
90
Flexural modulus(Kg/mm2,260degC)
10
15
20
25
Peel strength (Cu, N/cm)
0.8
1.0
1.2
1.4
Water absorption(121degC,24hrs,%)
100
120
140
160
Tg (DMA, degC)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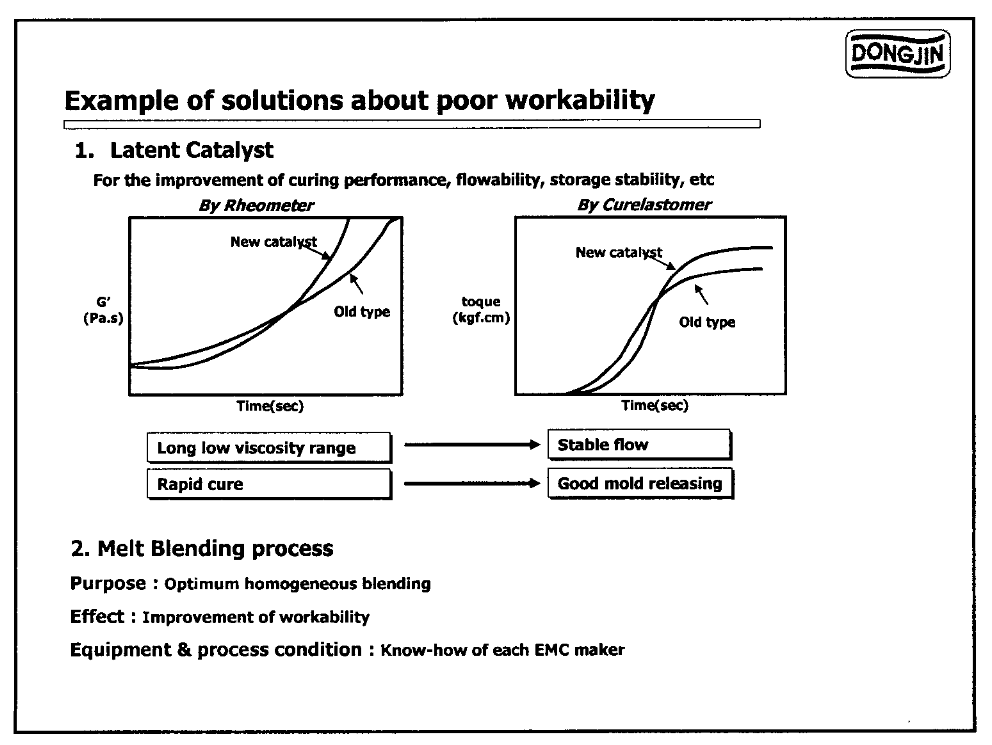
Filler loading technology
Basic Idea
Mooney's viscosity equation
$\ln\eta_r$: Relative viscosity
$\ln$: Viscosity of compound
$\ln_0$: Viscosity of matrix resin
$\ln \eta_r = \frac{\ln}{\ln_0} = \frac{Ke \cdot \Phi}{1 - \Phi / \Phi_m}$
Ke : Einstein coefficient
Φ : Volume fraction of fillers
Φm : Maximum volume fraction of fillers
Resin control
•Low viscosity resin
Filler control
•High Sphericity
•Broader particle size distribution
Know-how of each EMC maker
•Weak Curability
•Sticking phenomena
•Poor Storage period
•Latent catalyst
•Suitable wax system
•Process aspect
Optimum filler size distribution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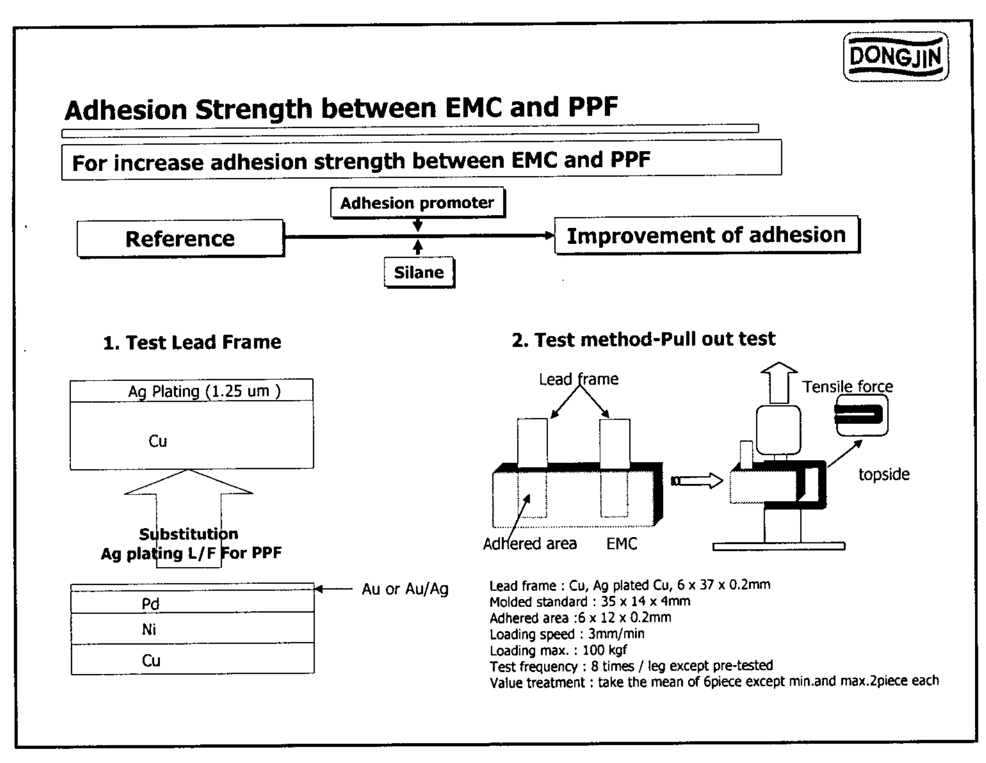
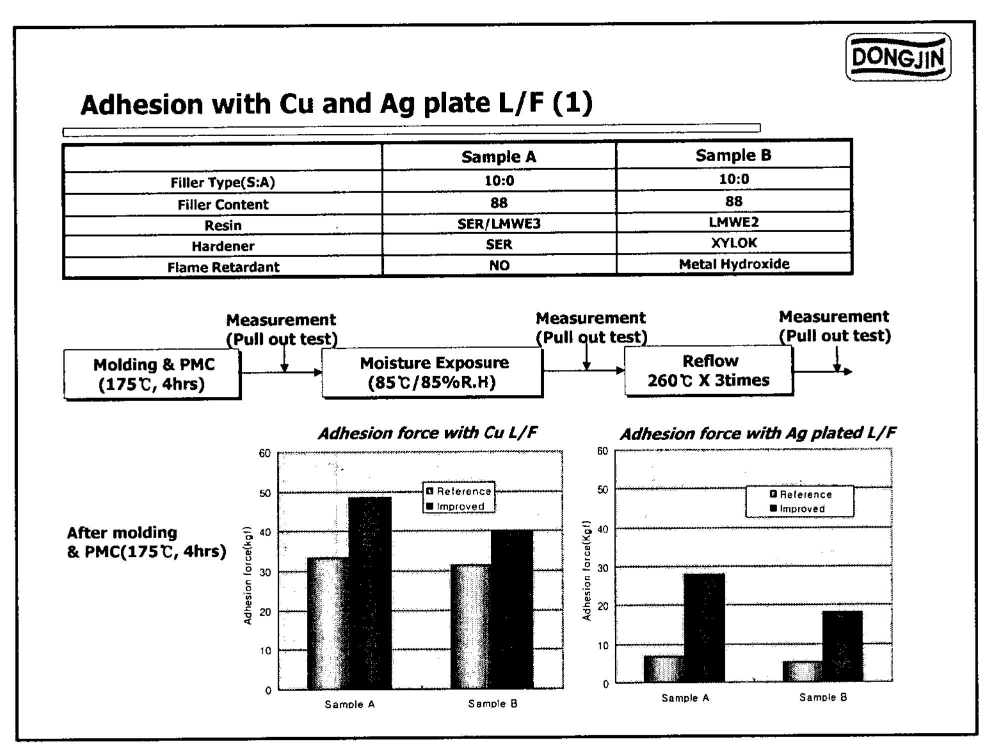
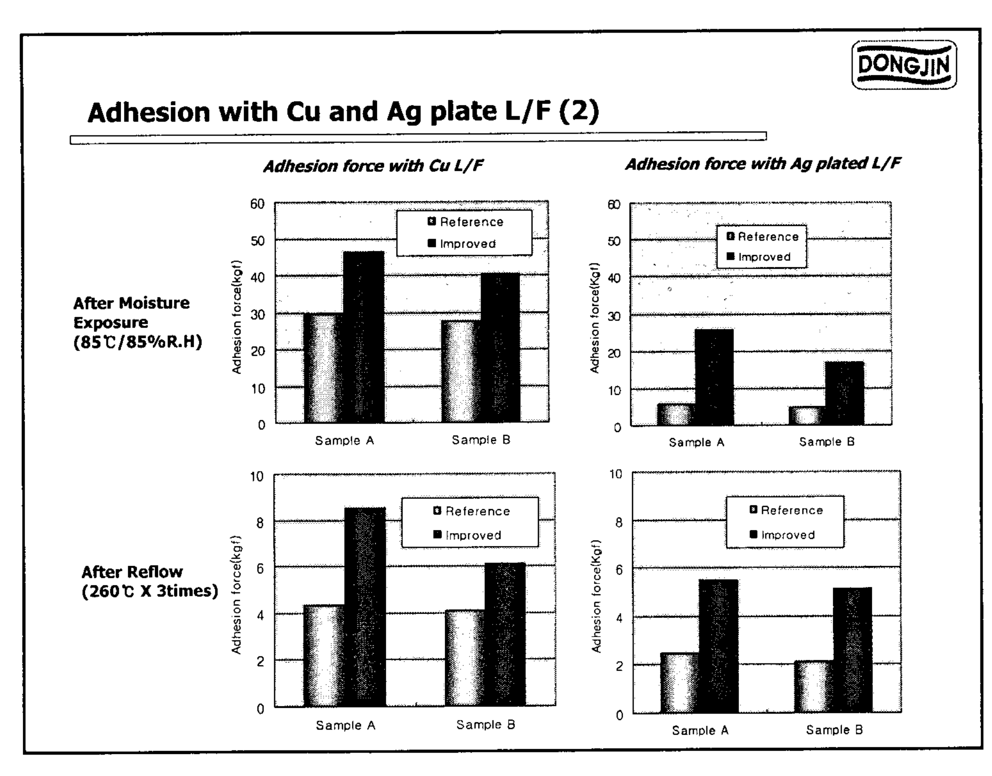
Example of solutions about poor workability
1. Latent Catalyst
For the improvement of curing performance, flowability, storage stability, etc
By Rheometer
New catalyst
Old type
G'
(Pa.s)
Time(sec)
By Curelastomer
New catalyst
Old type
toque
(kgf.cm)
Time(sec)
Long low viscosity range
Stable flow
Rapid cure
Good mold releasing
2. Melt Blending process
Purpose : Optimum homogeneous blending
Effect : Improvement of workability
Equipment & process condition : Know-how of each EMC maker





	Sample A	Sample B
Filler Type(S:A)	10:0	10:0
Filler Content	88	88
Resin	SER/LMWE3	LMWE2
Hardener	SER	XYLOK
Flame Retardant	NO	Metal Hydroxide



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Comparison of Stress factors

SECTION	ITEM	REF	GREEN A	GREEN B
Sample Information	Filler content	85wt%	88wt%	88wt%
	Resin system	OCN+BPE /XYLOK	SER+LMWE3 /SER	LMWE2 /XYLOK
	Coupling Agent	STD	STD +High Adhesion	STD +High Adhesion
	Flame retardant	Br/Sb	No	Metal hydroxide
Comparison of Stress factor	Water absorption (121 ℃, 24Hrs)	1.00	0.65	0.70
	Adhesion Force (R.T)	1.00	1.85	1.55
	Flexural strength (260 ℃)	1.00	1.30	1.20
	Flexural Modulus (260 ℃)	1.00	0.90	1.10

MRT Performance

PKG information
PKG / Lead : LQFP 128L
PKG size : 20 x 20 x 1.4mm
Pad size : 9.0 x 9.0mm
Die size : 7.7 x 7.7mm
Die attach adhesive : 8290(Ablestik)
Die top material : SiN
L/F material : Cu

Pre-condition
PMC : 175℃ / 4hrs
Temp Cycle : 5cycle at (-55 ℃/125 ℃)
Dry bake : 24hrs at 125 ℃
T&H soak
JEDEC L2 : 85℃/60%RH, 168hrs
JEDEC L3 : 30℃/60%RH, 192hrs
IR reflow : 260 ℃ x 3 times

	Crack / Delamination	Ref	Green A	Green B
JEDEC L2	Int. PKG Crack	0 / 22	0 / 22	0 / 22
	Ext. PKG Crack	0 / 22	0 / 22	0 / 22
	Die top surface / EMC	1 / 22	0 / 22	0 / 22
	L/F pad top / EMC	8 / 22	0 / 22	0 / 22
	L/F pad bottom / EMC	3 / 22	0 / 22	0 / 22
JEDEC L3	Int. PKG Crack	0 / 22	0 / 22	0 / 22
	Ext. PKG Crack	0 / 22	0 / 22	0 / 22
	Die top surface / EMC	0 / 22	0 / 22	0 / 22
	L/F pad top / EMC	3 / 22	0 / 22	0 / 22
	L/F pad bottom / EMC	0 / 22	0 / 22	0 / 22

*(Judgment of delamination : Delaminated area is over 20%)

Conclusions

Halogen-free & antimony-free technologies

- Using improved type of metal hydroxide
- Self-extinguish Resin & high filler loading

Resistance at higher reflow temperature for Pb-free soldering

- Low moisture absorption, high adhesion, high strength, low modulus
- High filler loading & low viscosity resin system & suitable additive

Solution of weak workability

- Requirement of control on weak curability, sticking, storage stability, etc
- Know-how of EMC maker such as latent catalyst system, Melt blending process, etc