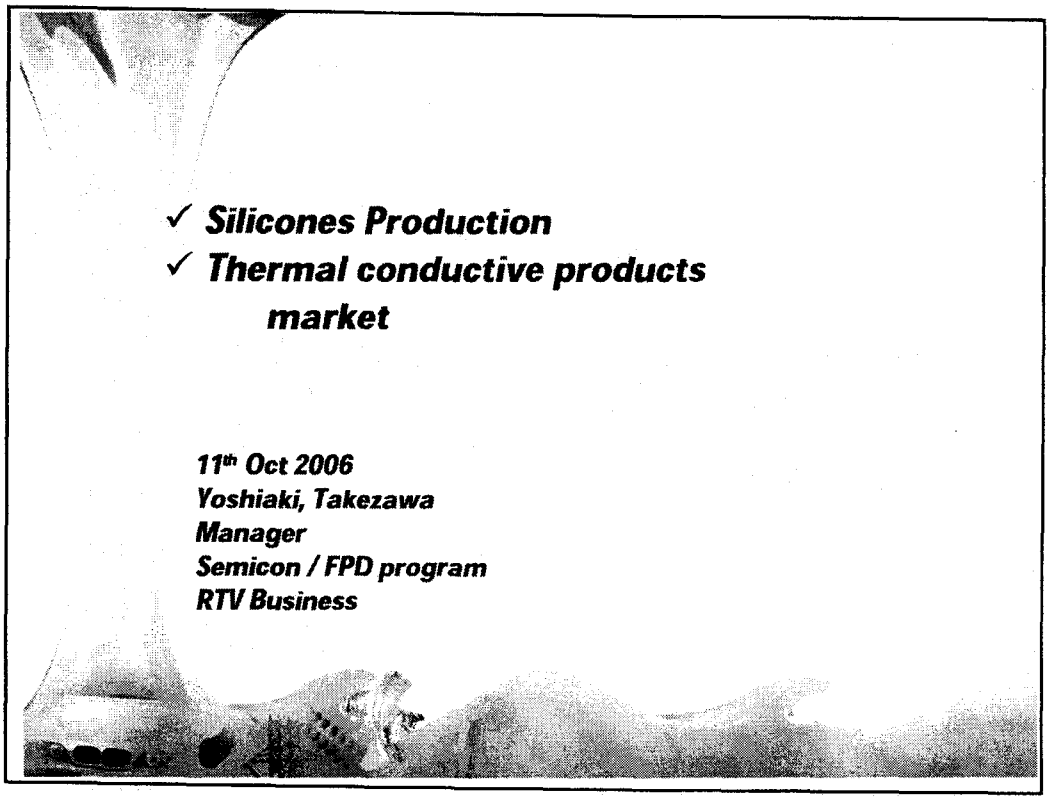
General Silicone Introduction &Thermal Conductive Product

Yoshiaki Takezawa

(GE-Toshiba Silicones/Japan)



Industrialization of Silicones (Development of the direct technique)

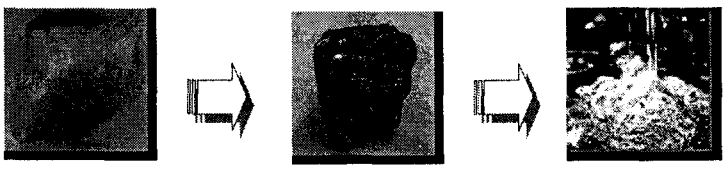
'1940 : E.G.Rochow (GE)

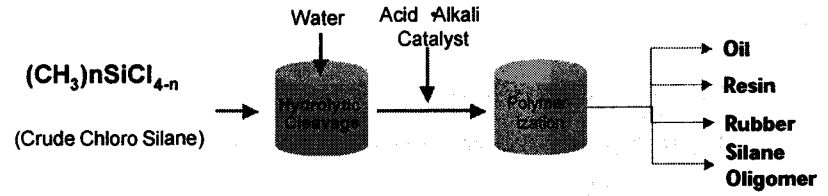
$$Si + n\,CH_3Cl \xrightarrow{Cu} (CH_3)nSiCl_{4-n}$$

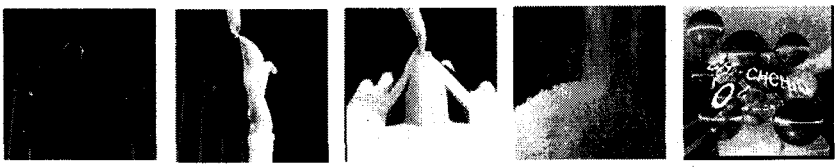
From Metallic Silicon to Silicones

High-Yield Synthesis of Silane Materials (methyl chloro silane) from Metallic Silicon

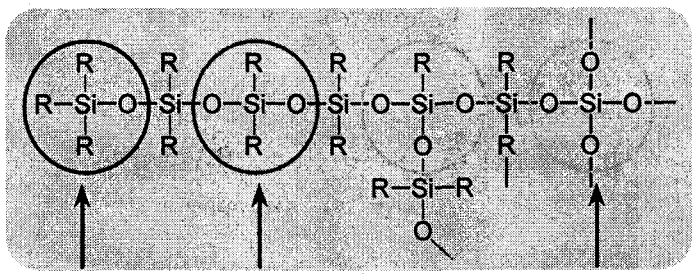
1947~ Commenced Production of Silicones (GE)







Resin properties can be changed in various ways according to the properties of the molecules (functional group) that are bonded to the Si Chain.
For example, Silicones with opposing properties such as Foaming vs Non-Foaming, Adhesion vs Release can be created. The ability to create a wide range of properties is the greatest characteristic of Silicones. Silicones generally are also colorless, transparent, tasteless, odorless, have high resistance to heat and cold, and are chemically stable, making their properties stable over a long period of time.

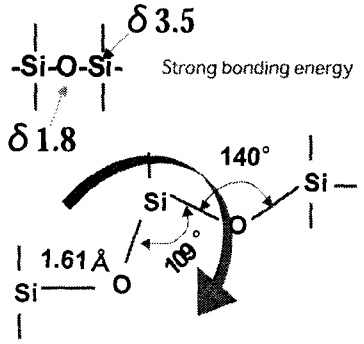


Termination **Linear Unit** **Branching, Cross linking**

Silicones are resins created from stones. Silicon, next to oxygen, is the second most prevalent element in the earth's crust. White stones (silica based stones) contain silicon in large quantities. Silcon is a resin created from these stones. A siloxane bond composed of alternating Silicon (Si) and Oxygen (O) is the fundamental structure of Silicones. Various elements and molecules can bond with the Si contained in this chain. Also, the type of links in this chain alter the properties, such as oil, resin, and rubber.

Characteristics / Benefits of Silicones

- ***Heat Resistance***
- ***Weather Resistance***
- ***Cold Resistance***
- **Water Repellent**
- **Insulation**
- **Foam Resistance**
- **Release**
- **Gas Permeability**



Limitations of Silicones

- **Steam Resistance**
- **Alkali Resistance**

- Mid-point between covalent binding and ionic bonding
  -C-C- 83kcal/mol
  -Si-O-Si- 101 kcal/mol
- Large movement of molecules - occupy a large volume when rotated
- Energy relaxation at molecular movement

How difference between Silicones and Other Organic compounds which contain carbon-carbon bond (-C-C-) ?

@ Smaller properties change in low to high temperature from -Si-O-
Viscosity, Physical and Electrical Properties
@ Excellent high temperature, UV, and Ozone resistance from -Si-O- and -Si-CH_3
UL746 RTI (Relative Temperature Index) 200°C
No surface crack generation after 30 years outdoors use
@ Excellent water repellency from -Si-CH_3
@ High permeability from -Si-O-
Humidity permeability
Organic Plastics << Organic Rubbers << Silicone
@ Low ionic impurity from Process
Na^+ ,Cl^- Silicone 0.01 ~ 5ppm << Epoxy 5 ~ 40ppm
@ Constant electrical property in various Hz from no polarity function
Low dielectric loss in MHz
@ Low toxicity from no Cl, CN, and S in polymer
@ No halogen compounds use as flame retardant agents

Comparison between Silicones & Other Materials

Materials	Silicone	Epoxy	Acrylic-Urethane
Product style	1-P / 2-P	1-P / 2-P	1-P / 2-P
	Non-Solvent	Non-Solvent Solvent	Non-Solvent Solvent
Cure mechanism	Condensation Addition	Condensation	Condensation / UV
Ionic impurity Na, K, Cl	< 2ppm	< 40ppm	< 50ppm
Viscosity control	Controllable	Controllable by Solvent	Controllable by Solvent
Thixotropy control	Controllable	??	??
Low Toxicity	Yes	??	??
Operating temperature Limit (Maximum)	400(70) 200(600)	~50 - 150	~30 - 120
Water repellency	Excellent	Good	Good
Heat resistance	Excellent	Poor	Poor
UV / Ozone resistance	Excellent	Poor	Poor
Strength	Good	Excellent	Excellent
Elastic Modulus	Small	Large	Large
Adhesive force	Good	Excellent	Excellent
Burning Quality	UL 94 HB	Non	Non
Permeability	Excellent by Low Surface tension	Good	Good
Corrosion Test MIL-A-46146B	Non corrosion to metals		

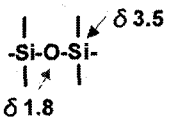
Characteristics

Benefits of Silicones

- ✓ Heat Resistance
- ✓ Weather Resistance
- ✓ Cold Resistance
- ✓ Water Repellent
- ✓ Insulation
- ✓ Foam Resistance
- ✓ Release
- ✓ Gas Permeability

Limitations of Silicones

- ✓Steam Resistance
- ✓Alkali Resistance

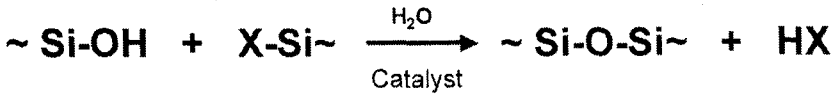


Strong bonding energy

Position of liquid silicone rubber

- **Silicone** — Silane / Origomer
  - **Silicone oil**
  - **Silicone varnish**
  - **Millable silicone rubber**
  - **Liquid silicone rubber**
    - **Condensation cure type**
      - RT cure — 1-P : Adhesive, Potting, Coating; 2-P : Adhesive, Potting, Mold making
    - **Addition cure type**
      - Heat cure — 1-P : Adhesive, Potting, Coating; 2-P : Adhesive, Potting, Coating
      - RT cure — 2-P : Potting, Mold making
    - **UV cure type**
      - 1-P : Adhesive, Coating

Curing Mechanism of Condensation Cure RTV



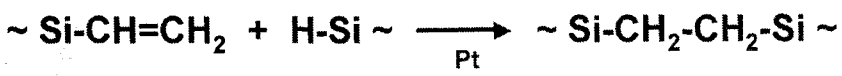
Requires moisture to cure / Room temperature cure

Curing to rubber on exposure to atmospheric moisture Generally, no special tools or equipment are called for Causing no thermal stress to the substrate

Cure proceed from the surface in contact with air (moisture)

Poor deep section cure
Not usable in closed system

Curing Mechanism of Addition Cure RTV



Heat accelerates curing

High curing speed
Need >100C heating for adhesion

No by-product

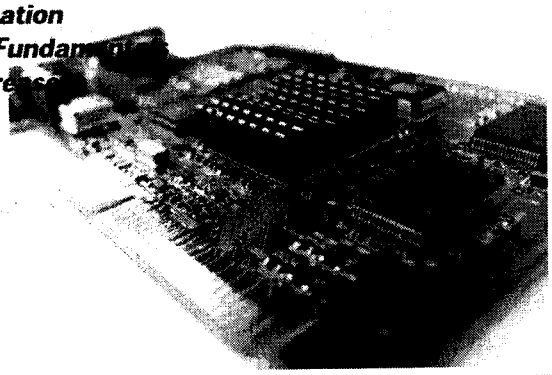
Low linear shrinkage
No corrosion to metals

Can be contaminated by exposure to certain materials

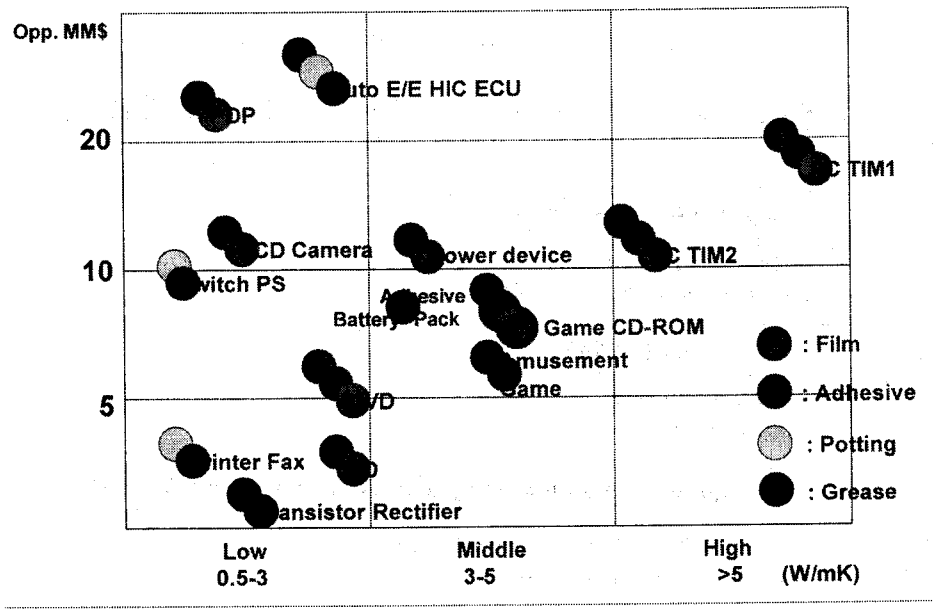
Water,sulfur,nitrogen compounds, organic metallic salts, phosphorus compounds,etc.

Thermal management Silicones
- SilCool -

- ✓ Thermal Market Information
- ✓ Thermal Management Fundam
- ✓ Silicone Compound (Gre
- ✓ Silicone Adhesive



Thermal management Application Portfolio

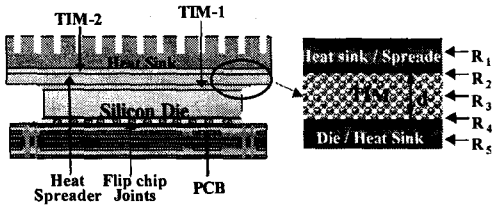


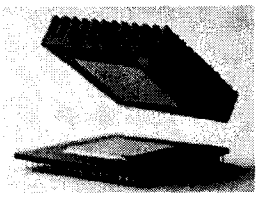
Overview:

Thermal Management is critical in ensuring the long-term reliability and performance of electronic components. The combined effect of increased component performance, miniaturization, and constrained space, result in higher amounts of heat generation.
With these advances in technology, system designers struggle to keep ahead of the increase in thermal output.

The Thermal Mgmt. products in the GE portfolio consist of Thermal Interface Materials that provide either an adhesion and/or gap filling function between the heat generating device and the device used to cool, and are used in 2 key areas:

1. Heat transfer within the heat generating component package (ie. semiconductor)]
2. Heat transfer from the package to a heat dissipater (ie. heat sink)





Thermal Management Fundamentals

Thermal Conductivity:

Thermal Conductivity is an intrinsic property of a material that describes the material's ability to conduct heat.

The unit of measure commonly used is W/mk, but other units are also used.

Unit Conversion

W/mk	**1**
Cal/cm.sec.℃	**2.388 x 10-3**
Kcal/m.h.k	**0.8598**
Btu/ft.h.deg F	**0.5778**
Btu/in.h.deg F	**6.933**

Measurement of thermal conductivity
- ✓ **Laser Flash**
- ✓ **Hot wire**

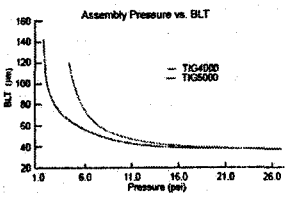
Measurement of thermal resistance
- ✓ **Laser Flash**

Thermal cond. of common Materials

Materials	W/mk
Silver	**406**
Copper	**385**
Aluminum	**205**
Silicon	**126**
Brass	**109**
Steel	**50.2**
Water	**0.6**
Cork	**0.04**
Air	**0.024**

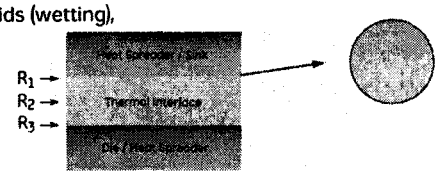
Thermal Impedance:
Thermal conductivity alone does not insure thermal performance, as other factors such as thickness and contact area, can create thermal impedance affecting heat transfer.

Thermal Resistance for homogeneous materials is directly proportional to thickness. For non-homogeneous materials, resistance increases with thickness but the relationship is not necessarily linear. The ability to control & reduce thickness (BLT) of the thermal interface is a key factor in the component assembly process. Increases in assembly pressures are known to contribute to reductions in BLT, & subsequently, reduced thermal resistance.



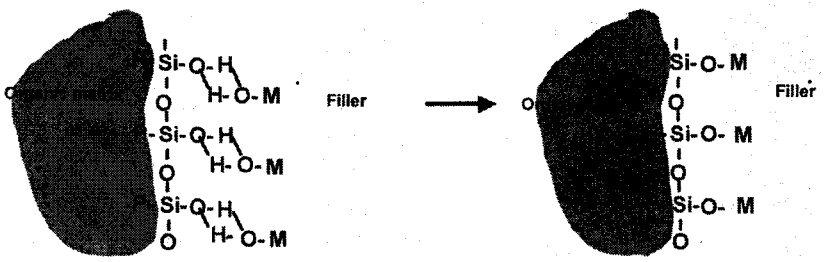
Contact Resistance occurs because surfaces are not completely smooth. Actual contact occurs at high points, while gaps create voids that adversely affect the flow of heat. A key objective of Thermal Silicone Grades is to fill the voids (wetting), thereby limiting contact resistance.

Thermal Impedance is the sum of thermal resistance & contact resistance.



Technical approach for Product

- ✓ **Filler design and functionalization**
- ✓ **Interface technology (mechanical, chemical)**
- ✓ **Assembly process technology**



Silicone Grease compound

GE's family of SilCool series silicone grease compounds feature outstanding thermal conductive and dielectric properties, excellent workability, virtually no oil separation, and minimal weight loss at elevated temperatures. These high-performance grease products were formulated to help address heat management challenges resulting from higher frequencies, power, and miniaturization in the development of electric and electronic devices.

Silicone grease compounds feature out standing thermal conductive and dielectric properties

Key features:
- Highly workable – excels in automated dispensing, screen printing and stamping applications
- High thermal conductivity
- Wide operating temperature range from -50°C to +170°C
- Low oil separation and minimal weight loss at elevated temperatures
- Minimal ionic impurities & excellent dielectric properties

Key features :

Silicone Adhesive products

The SilCool series silicone adhesives from GE Advanced Materials offer 1-Part, heat curable materials that bond well to a wide variety of substrates without the need for primers. They help deliver outstanding thermal conductivity, low thermal resistance, excellent dielectric properties, and low stress.
SilCool adhesives are excellent candidates for addressing the heat management challenges arising from the higher frequencies, power, and miniaturization in today's electronic devices. Designed to efficiently conduct heat, these materials are valuable additions to semiconductor packages that incorporate heat-generating chips, heat spreaders, and heat sinks (TIM1 & TIM2).

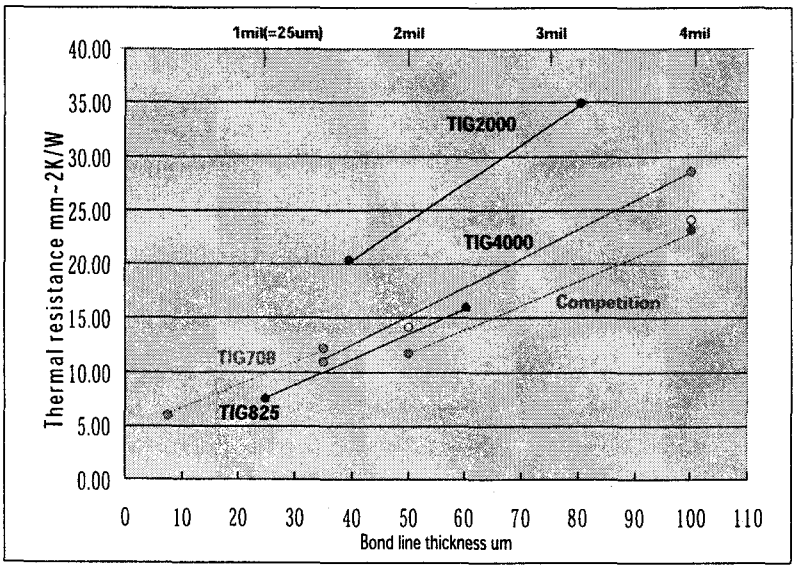
Key features:
- Ready to use - one component
- Highly workable – excels in automated dispensing, screen printing and stamping applications
- Fast cure & good adhesion
- High thermal conductivity
- Low thermal resistance
- Low modulus & stress
- Reliable in a wide temperature range
- Compatible with high-temperature lead-free processing
- Minimal ionic impurities & excellent dielectric properties

TIG Greases

TIG series are silicone oil-based grease compounds that feature high thermal conductivity and low thermal resistance, excellent resistance to heat and moisture.

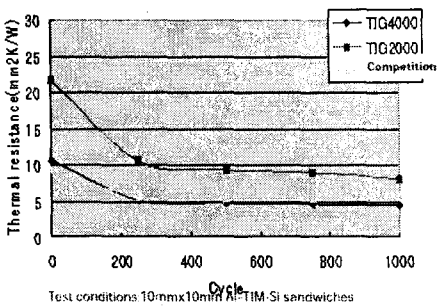
Product name	TIG2000	TIG4000	TIG5000
Properties			
Appearance	Blue	Grey	Grey
Density Mg/m^3 (23deg C)	2.8	2.8	2.6
Thermal conductivity W/mK	**2.0**	**4.0**	**5.0**
Thermal resistance (mm^2 K/W)	**20**	**11**	**14**
Penetration (23deg C)	400	280	250
Bleed (150C X 24h) %	0.1	< 0.1	<0.1
Evaporation (150C X 24h)	0.1	< 0.1	<0.1
Volume receptivity (MΩ m)	0.2X10^7	0.2X10^7	2X10
Dielectric Strength (kV/0.25mm)	4.9	4.9	4.9
LV content (D4-10) ppm	30	30	30
Na, K, Cl ppm	<2	<2	<2
Operating Temperature Range (C)	-40 to 150	-40 to 150	-40 to 150

Grease Thermal Resistance Comparison

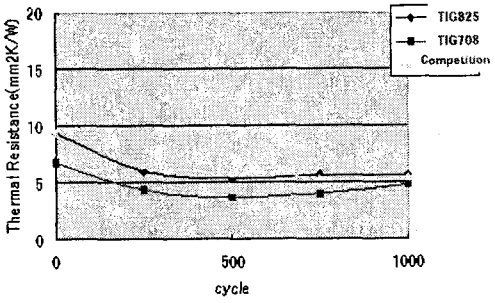


Excellent property & Wide variety of Thermal Resistance

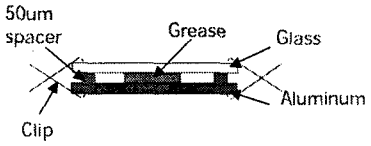
Thermal Shock Test (-55~125℃)



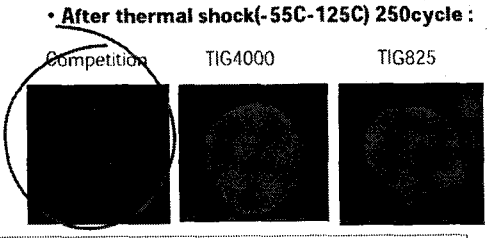
Test conditions 10mmx10mm Al-TIM-Si sandwiches



• **New Dry-out test:**

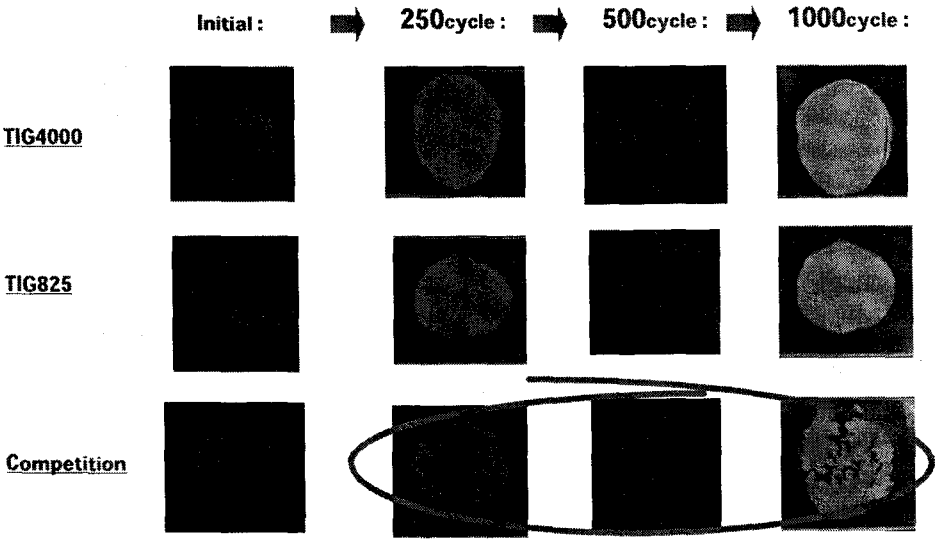


• **After thermal shock(-55C-125C) 250cycle :**



TIG4000 & TIG825 shows better performance than competition by our method

Thermal Shock Test (-55~125℃)



TIG4000 & TIG825 shows better performance than competition by our method

Addition cure products

Feature		SDC5003	XE13-C1822	XE13-C1862
Product		1-P	1-P	1-P
Cure system		Addition cure	Addition cure	Addition cure
Appearance		Silver paste	Gray paste	Gray paste
Viscosity	Pa·s	30	100	160
Cured property				
Cure condition	1h X 150℃			
Appearance		Silver rubber	Gray rubber	Gray rubber
Hardness	(Type A)	70	96	68
Specific gravity	(23℃) g/cm³	3.8	3.1	2.9
Lap Shear Adhesion	MPa	1.2	6.5	1.8
Elongation	%	140	10	**80**
Adhesion strength	(Al) MPa	0.9	**4.8**	1.5
Volume Resistivity	MΩ·m {Ω·cm}	**2.0X10^{-12} {2.0X10^{-4}}**	5.0X10^{6} {5.0X10^{14}}	5.0X10^{6} {5.0X10^{14}}
Dielectric Strength	kV/mm	-	15	15
Dielectric Constant	(60Hz)	-	5.2	5.2
Dissipation Factor	(60Hz)	-	0.001	0.001
Thermal conductivity	**W/mK**	**3.1**	**3.2**	**2.5**
Thermal resistance	**mm²K/W**	**10**	-	-
LV content	(D4-10) ppm	<100	<100	<100
Cl	ppm	< 2	< 10	< 10
Na, K	ppm	< 2	< 10	< 10

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Condensation cure products

Feature		TSE3941	XE11−B5320	XE11-C2148
Product		1-P	1成分	1成分
Cure system		Condensation	Condensation	Condensation
Appearance		White paste	White paste	Gray paste
Viscosity	Pa·s	-	-	320
Cured property				
Cure condition	23℃ 55%RH			
TFT	min (RT)	5	5	10
Appearance		White rubber	White rubber	Gary rubber
Hardness	(Type A)	65	80	88
Specific gravity	(23℃) g/cm³	1. 65	2.6	2.86
Lap Shear Adhesion	MPa	2.9	3.6	5.1
Elongation	%	100	40	30
Adhesion strength	(Al) MPa	1. 4	1.3	**4. 2**
Volume Resistivity	MΩ·m {Ω·cm}	4.0X10^{6} {4.0X10^{14}}	2.0X10^{7} {2.0X10^{15}}	1.0X10^{7} {1.0X10^{15}}
Dielectric Strength	kV/mm	22	17	20
Dielectric Constant	(60Hz)	4.0	2.6	4.9
Dissipation Factor	(60Hz)	0. 04	0.005	0.003
Thermal conductivity	**W/mK**	**0. 83**	**1.3**	**2.2**
UL		**94 V-1**		
LV content	(D4-10) ppm	-	<100	<100

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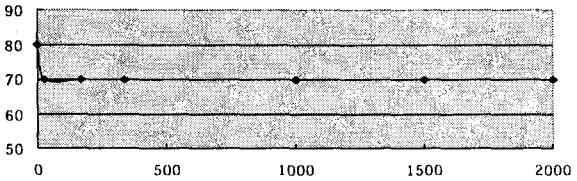
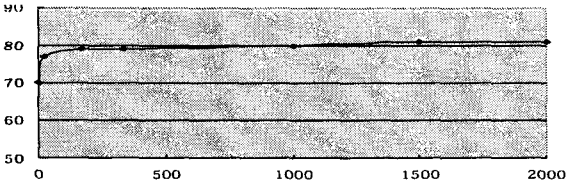
Heat stability of XE13-C1862

170℃

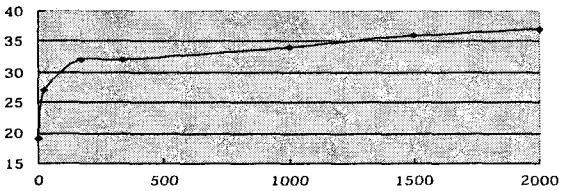
Elongation %



Hardness



Lap Shear Adhesion



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Adhesive Road Map

Current → **New!**

~ 2004

TSE3280G
TC : 0.8W/mK
TR : 53mm²K/W
BLT : 50um

TSE3281G
TC : 1.8W/mK
TR : 53mm²K/W
BLT : 50um

TSE3282G
TC : 2.0W/mK
TR : 51mm²K/W
BLT : 50um

TSE3286G
TC : 4.5W/mK
TR : 13mm²K/W
BLT : 40um

"Extremely High TC"

2006

XE13-C1821
TC : 4.0W/mK
AS : **4MPa**
Vi : 400Pas

XE13-C1822
TC : 3.2W/mK
AS : **4MPa**
Vi : 150Pas

XE13-C1916
TC : 2.5W/mK
AS : **4MPa**
Vi : 70Pas

"High TC& Strength"

XE13-C1862
TC : 2.5W/mK
E : **80%**
Vi : 180Pas

XE13-C1862PT
TC : 2.4W/mK
E : **80%**
Vi : **60Pas**

"High TC& Elongation"

2007 ~

TC : >6W/mK
TR : < 8mm²K/W
BLT : <20um

TC : >10W/mK
TR : < 5mm²K/W
BLT : <20um

XE13-C2610
TC : 2.2W/mK
E : **130%**
Vi : **90Pas**

Next Gen.
TC : 3.0W/mK
E : 200%
Vi : 200Pas

"Low temp. cure"

- TC : Thermal Conductivity
- TR : Thermal Resistivity
- BLT : Bond Line Thickness
- AS : Adhesion Strength
- Vi : Viscosity

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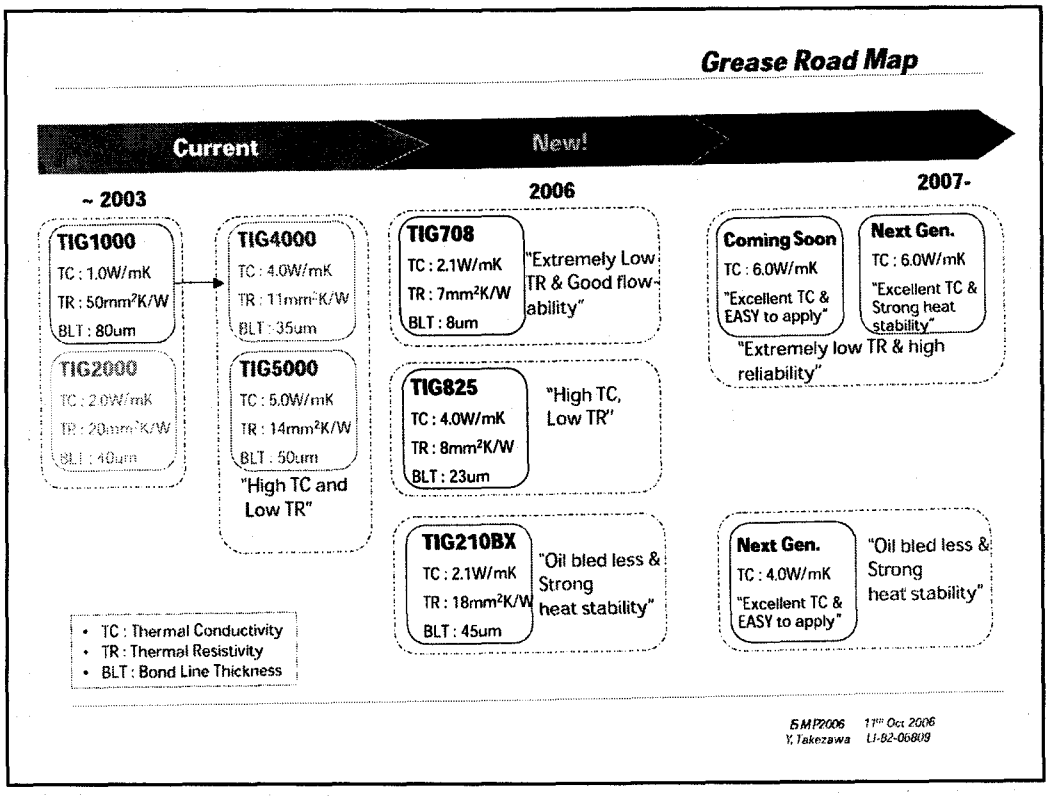
Grease Road Map
Current
New!
~ 2003
2006
2007-
TIG1000
TC : 1.0W/mK
TR : 50mm²K/W
BLT : 80um
TIG2000
TC : 2.0W/mK
TR : 20mm²K/W
BLT : 40um
TIG4000
TC : 4.0W/mK
TR : 11mm²K/W
BLT : 35um
TIG5000
TC : 5.0W/mK
TR : 14mm²K/W
BLT : 50um
"High TC and Low TR"
TIG708
TC : 2.1W/mK
TR : 7mm²K/W
BLT : 8um
"Extremely Low TR & Good flow-ability"
TIG825
TC : 4.0W/mK
TR : 8mm²K/W
BLT : 23um
"High TC, Low TR"
TIG210BX
TC : 2.1W/mK
TR : 18mm²K/W
BLT : 45um
"Oil bled less & Strong heat stability"
Coming Soon
TC : 6.0W/mK
"Excellent TC & EASY to apply"
Next Gen.
TC : 6.0W/mK
"Excellent TC & Strong heat stability"
"Extremely low TR & high reliability"
Next Gen.
TC : 4.0W/mK
"Excellent TC & EASY to apply"
"Oil bled less & Strong heat stability"
• TC : Thermal Conductivity
• TR : Thermal Resistivity
• BLT : Bond Line Thickness
S.M.P2006 11th Oct 2006
Y. Takezawa LI-B2-06809