GE Toshiba Silicones Product Data Sheet

Understanding the material properties

Rev1.6 060511

Objective

- This pitch serves as a reference guide for our commercial team and distributors to have a better understanding of the various technical properties of silicones
- The scope covers most of our GES, GEBS and GETOS materials.

Properties in Product Datasheets

<u>Uncured Properties</u>

1. Viscosity (Pa.s, cps)
2. Thixotropic Index
3. Specific Gravity
4. Tack Free Time (condensation cure)
5. Pot Life

<u>Cured Properties</u>

6. Glass Transition Temperature (degC)
7. Coefficient of Thermal Expansion (ppm/degC)
8. Hardness and Penetration
9. Refractive Index
10. UV Transmitivity (%)
11. Tensile Strength (MPa), Elongation (%) & Tear Strength (MPa)
12. Adhesion Strength (MPa)
13. Thermal Conductivity (W/m.K)
14. Thermal Resistance (mm^2.K/W)
15. Volume Resistivity (MΩ.m)
16. Dielectric Strength (kV/mm)
17. Dielectric Constant & Dielectric Factor
18. Ionic Content
19. Outgassing
20. Shrinkage
21. UL Status

<u>Material Handling</u>

22. Shelf Life/Storage/Thawing Time

What is Viscosity (η)?

A measure of the resistance of a fluid to flow.

Factors Affecting Viscosity Measurement

- Type of Viscometer
- Model of viscometer
- Type of Spindle /Cone
- Spindle/Cone Number
- Shear Rate
- Temperature

Two competitive materials may have the same viscosity data, but they may actually be different materials because they are measured under different conditions and factors

Dynamic Viscosity Units

1 Poise (P) = 100 centipoise (cps) = 1 $g.cm^{-1}.s^{-1}$ = 0.1 Pascal.second (Pa.s)

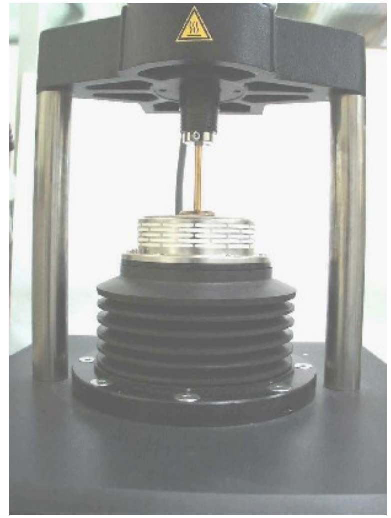
1 P = 100 cps

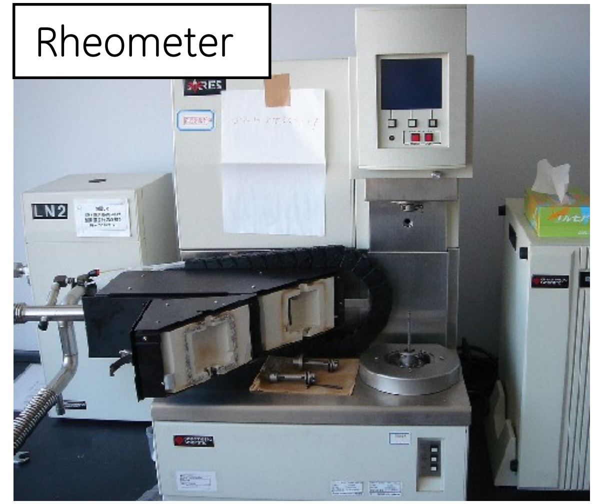
1 Pa.s = 1000 cps (Most common conversion)

Measuring Equipment

Many types, but most common are

1. **Cone/Plate Type Rheometer [example, Haka, Rheometrics]**
   - parallel plates and cone/plate





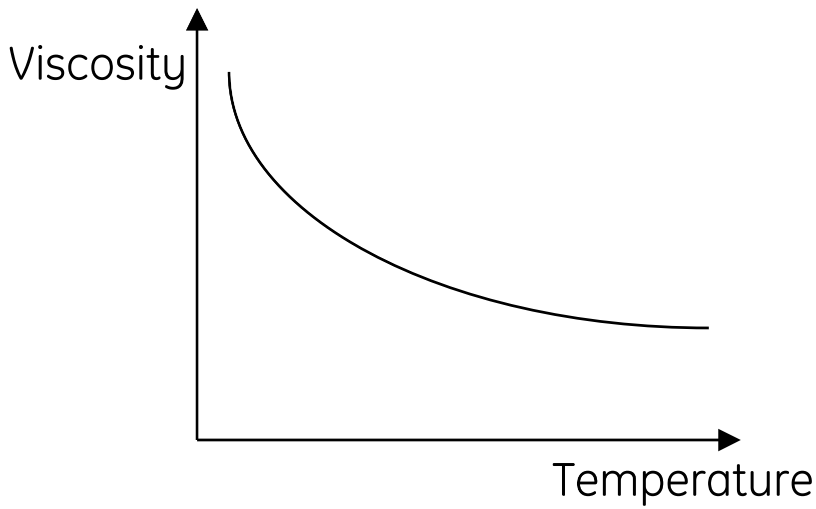
Rheometer

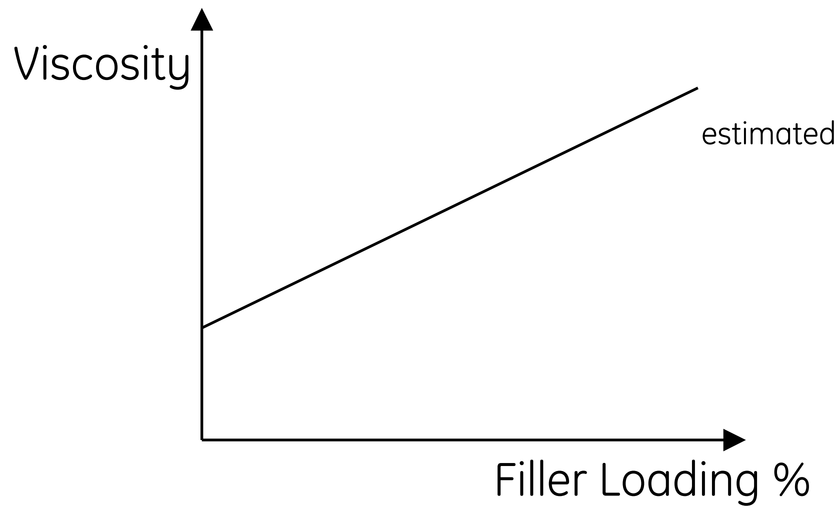
2. **Rotating Spindle Type Viscometer [example, Brookfield]**

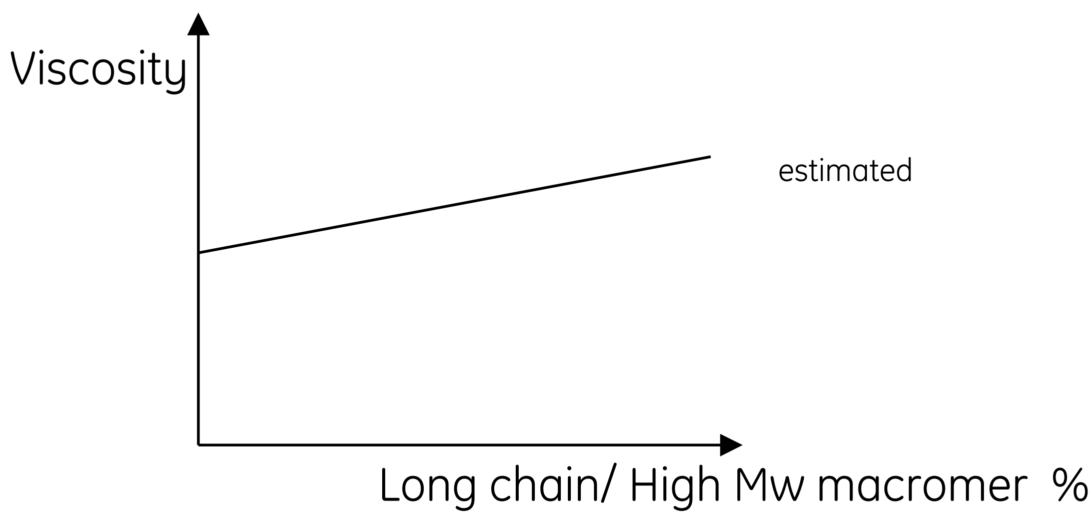
   Test Method: ASTM D3236
   - spindles CP, LV, RV @ various rpm and temp

Viscometers

Factors influencing viscosity





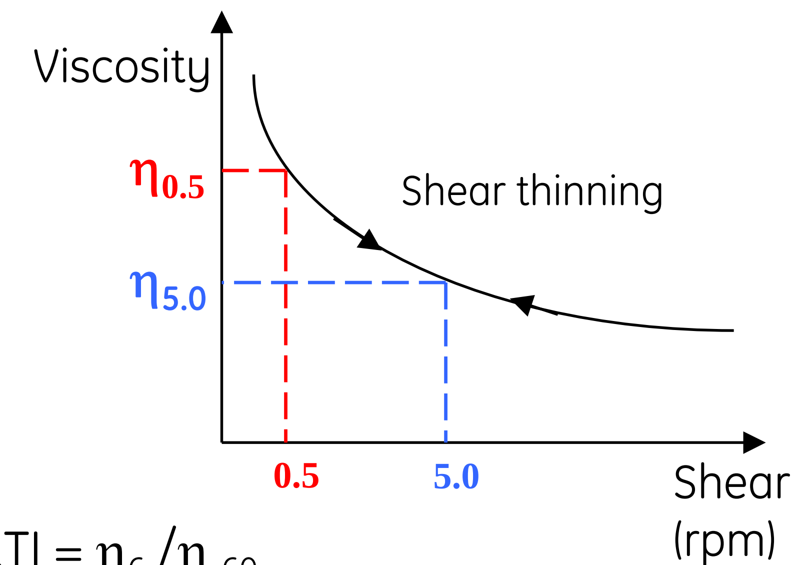


2. Thixotropic Index

Thixotropy: Describes materials that are gel-like at rest but fluid when agitated. It is a time-dependent change in viscosity; the longer the fluid undergoes shear, the lower its viscosity. It is **dependent on temperature, shear rate and time.**

Common test using rotating spindle viscometer or cone&plate rheometer

$$\textbf{Thixotropic Index, TI} = \frac{\textbf{Viscosity at 0.5 rpm, } \eta_{0.5}}{\textbf{Viscosity at 5.0 rpm, } \eta_{5.0}}$$



TI >= 4 good dispensability
TI < 4 tailing occur

GETOS uses various TI test methods, like TI = η_2 / η_{20} .TI = η_6 / η_{60}
Shinetsu and Dow Corning uses TI = η_2 / η_{20}

2. Thixotropic Index

Shape of bead after dispensing

Non Thixotropic material, eg. coatings

Thixotropic material, eg. Glob Tops

Thixotropy is achieved by adding rheology modifiers.

Higher the loading (to a certain %), higher the

- Thixotropy
- Dome shape after dispense
- Viscosity
- Hardness
- Reliability performance (generally)

Increasing thixotropy

3. Specific Gravity

Specific gravity (or relative density) is a measure of the ratio of mass of a given volume of material at 23°C to the same volume of deionized water.

Unit of Specific Gravity: Dimension-less
Unit of Density: g/cm^3 or kg/m^3

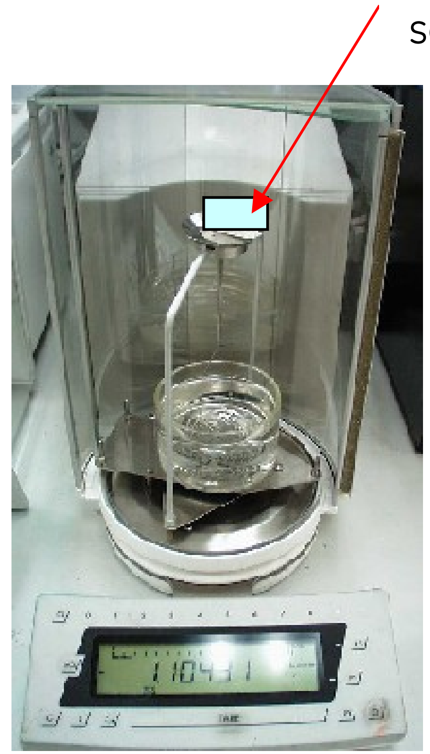
Test method using a densimeter

Cut a piece of silicone rubber with weight 1g-6g, place the material on the densimeter's pan as shown (in the air). Immerse the test piece in a 300ml beaker with 250ml ion-exchanged water and obtain the specific gravity.

Specific gravity = M1/[(M1-M2]

M1 = mass of specimen in air.
M2 = mass of specimen and sinker (if used) in water.

Density, kg/m^3 = (specific gravity) x (997.6)



Densimeter

3. Specific Gravity

Material	Specific Gravity (g/cm3)
Ceramic filler (alumina)	3.41- 3.96
Ceramic filler (boron nitride)	2.27 to 3.48
Metal (silver) filler	10.5 –10.51
Metal (gold) filler	17.19 – 19.31
Silicone without filler	0.98 – 1.1
Epoxy without filler	1.0 – 1.1
Silicone with thermally conductive metal filler (Al203)	1.5 – 3.0
Silicone with electrically conductive metal filler (Ag, Au)	> 3.5

Higher the ceramic/metal filler loading, generally higher the

- Density
- Conductivity
- Viscosity
- Hardness
- Modulus
- Glass Transition Temp, Tg
- ...Others

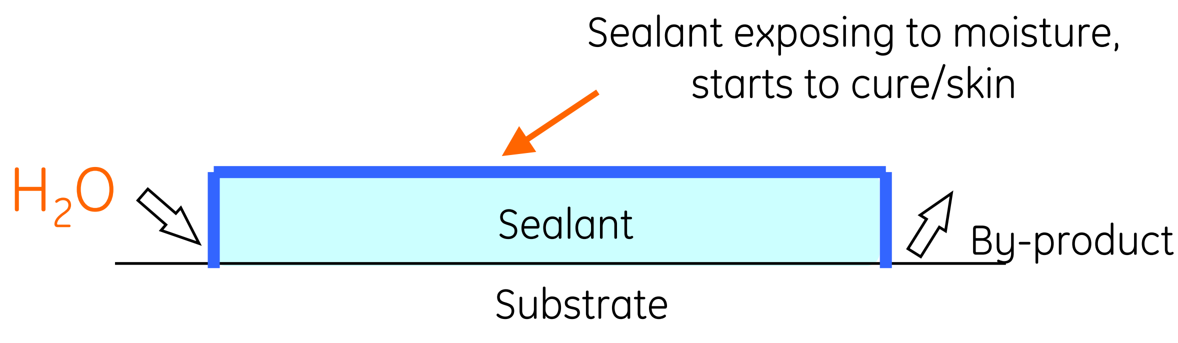
4. Tack Free Time

Tack Free Time (TFT) applies to 1-part condensation cure RTV silicone product to form a cured outer layer.

Time taken for the surface of a 2mm condensation cured silicone extrudate to cured at 23degC/50%RH, this applies to only condensation cured sealant.

Test Method:

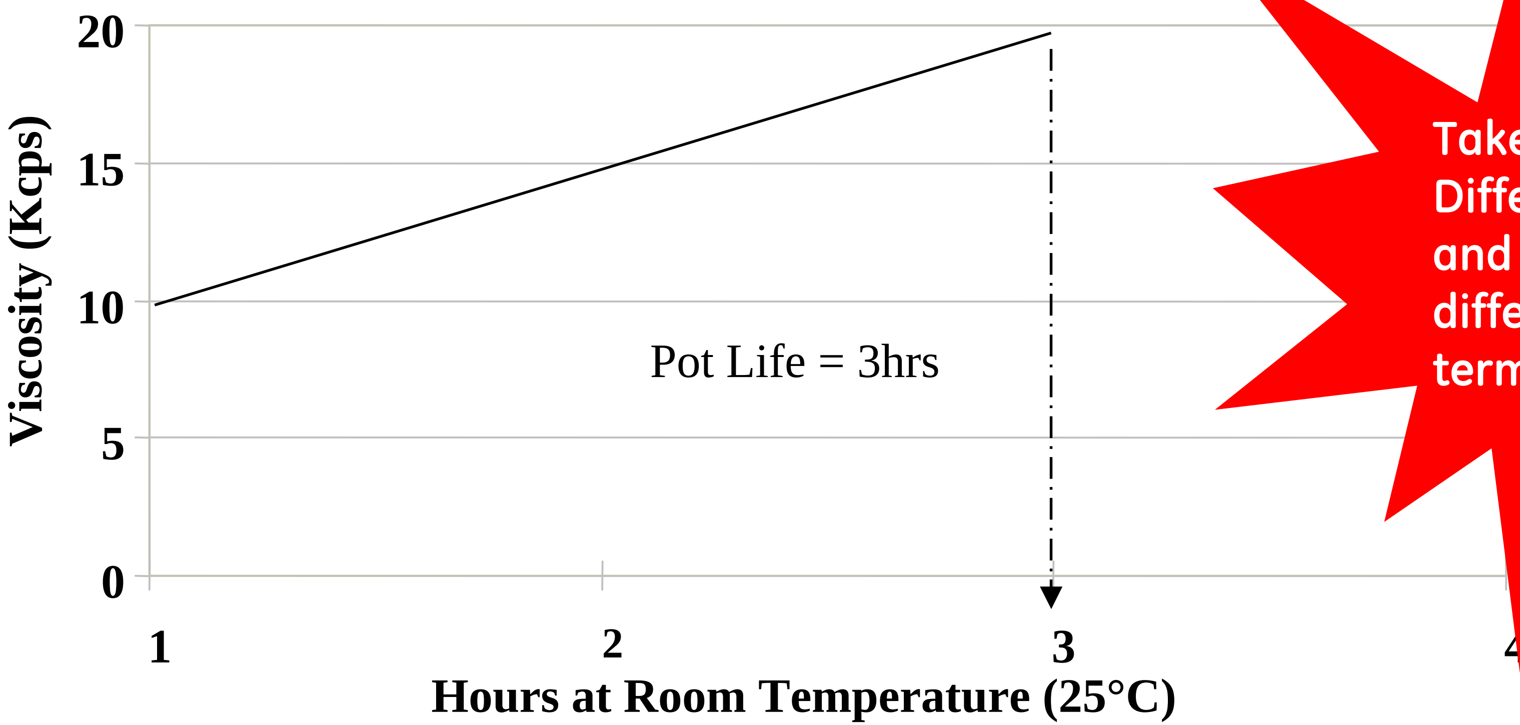
Use finger lightly touch the surface of the sealant every 1 minute. When the sealant does not stain your finger, this is the tack free time.



Pot Life is the time taken for viscosity to **double** after mixing two or more components of room temperature cure sealant.

The amount of time after a 2-part RTV is mixed with its curing agent that it will remain useful or liable (also applicable to 1-part addition cure products).

Please refer to product data sheet for more details:



Take note:
Different suppliers and customers use different terminology

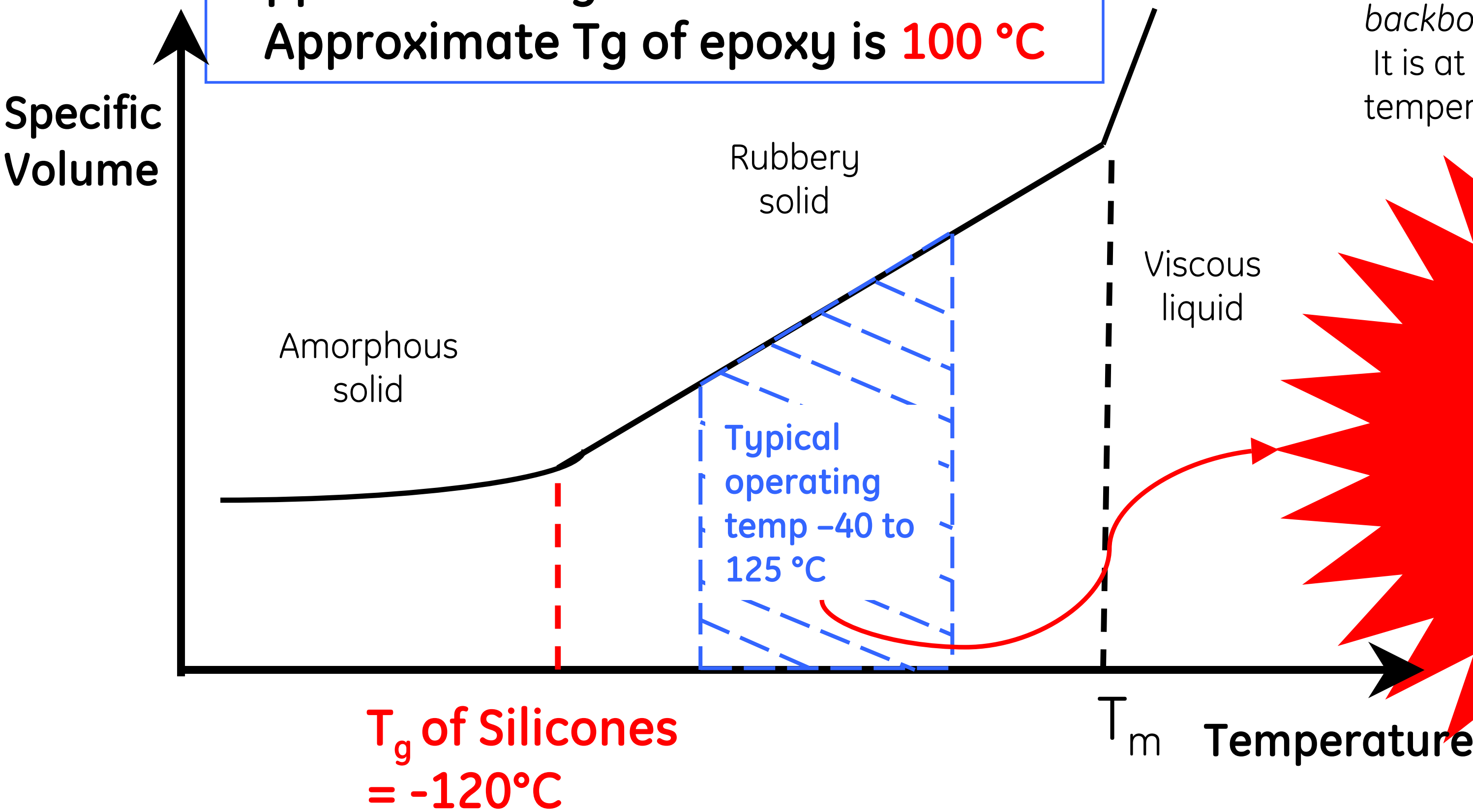
6. Glass Transition Temperature, T_g

Glass transition temperature, T_g, is the transition temperature

- Below which the material is glassy (molecules have little relative mobility)
- Above which, the material is rubbery (molecular chains are flexible)

Approximate Tg of silicone is –120 °C
Approximate Tg of epoxy is 100 °C

Polydimethylsiloxane has a *flexible backbone, so Tg is –120degC.* It is at rubbery state at room temperature.



So during the typical operating temperature range, there will not be drastic changes to the specific volume of the material to affect the bond.

6. Glass Transition Temperature, Tg

Commonly measured by

- **Thermomechanical Analysis (TMA)**
  - To measure the change in the dimension of the specimen as it passes through its glass transition temperature while being heated at a constant rate

- **Differential Scanning Calorimetry (DSC)**
  - To measure the sudden change in heat flow as it passes through the glass transition temperature

- **Dynamic Mechanical Analysis (DMA)**
  - To measure the sudden change in modulus of the specimen as it passes through its glass transition temperature.

Cautions: TMA, DMA and DSC can produce different Tg for the same materials

7. Coefficient of Thermal Expansion (CTE)

Materials expand when heated, contracts when cooled. This response to temperature change is expressed as its **Coefficient of Thermal Expansion**.

Units: parts per million per °C or K (ppm/°C)

Test method (ASTM E831)

Linear Thermal Expansion by using Thermomechanical Analysis (TMA)

Factors that affect CTE of material

- Chemical composition
- Filler loading (alumina, silica reduce CTE but increase viscosity)
- Cure cycles

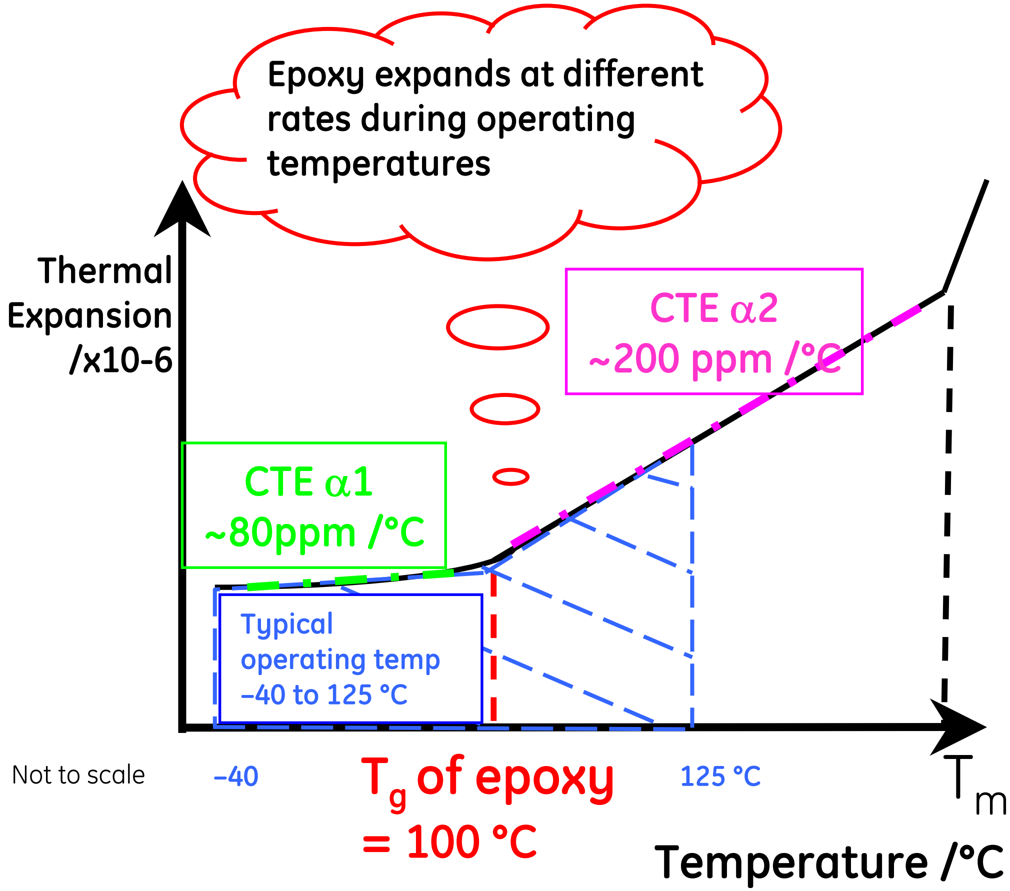
Materials	CTE (10-6(cm/cm)/°C)
Unfilled silicone	**300**
Filled silicone	**125-275**
Unfilled epoxies	**80-200**
Filled epoxies	**30-125**
PWB (xy axis)	**12-16**
Silicon	**2.4**
Polyimide	**28**

Materials	CTE (10^{-6}(cm/cm)/°C)
Mercury	60
BCB	42
Lead	29
Aluminum	23
Brass	19
Stainless steel	17.3
Laminate FR4	17-24
Copper	17
Gold	14
Nickel	13
Concrete	12
Iron or Steel	12
Carbon steel	10.8
Platinum	9
Glass	8.5
GaAs	5.8
InP	4.6
Tungsten	4.5
Glass, Pyrex	3.3
Silicon	3
Diamond	1
Quartz, fused	0.59

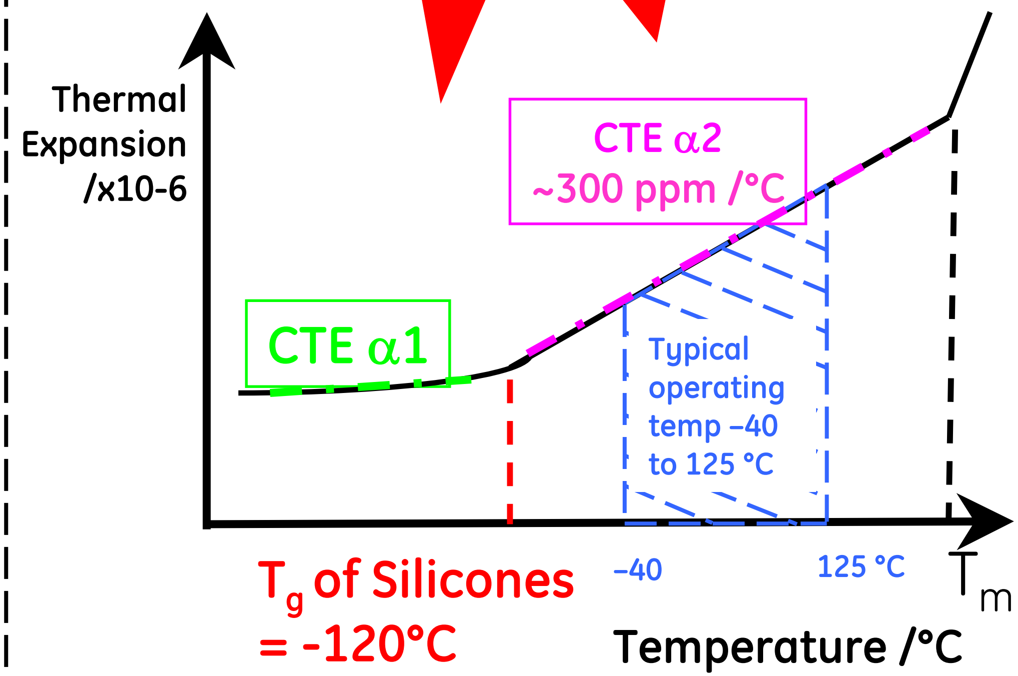
7. Coefficient of Thermal Expansion (CTE)

CTE (ppm/°C) is gradient of slope

CTEα1 is the CTE before Tg
CTEα2 is the CTE after Tg



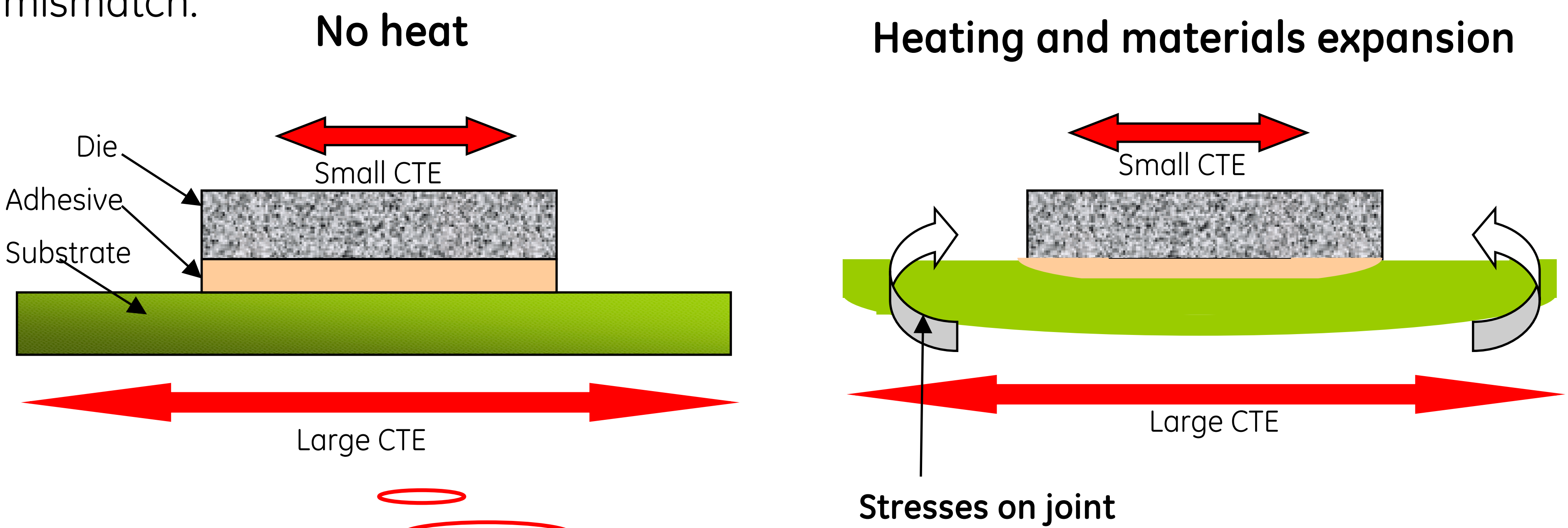
CTE of unfilled silicones is constant throughout typical operating temperature range. It means that there is no drastic change in material expansion to affect the bond.



7. Coefficient of Thermal Expansion (CTE)

Point to note:

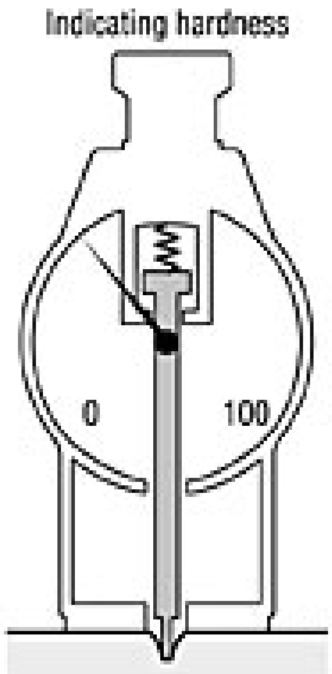
CTE mismatches between substrates and adhesive may lead to reliability issues. It is important to select materials with closer CTEs to minimize this mismatch.

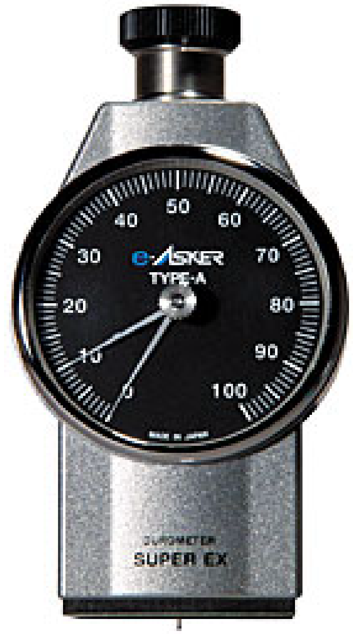


For some semiconductor applications, it is crucial to have adhesives filled with fillers to lower the CTE and minimize CTE mismatches.

8. Hardness & Penetration

Shore A Hardness is a measure of the resistance of silicone material to indentation.
The higher the number, the harder the material.

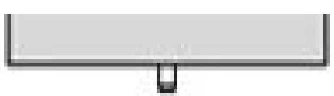




Manually press into material for 1s and take reading

Cured sealant

6mm

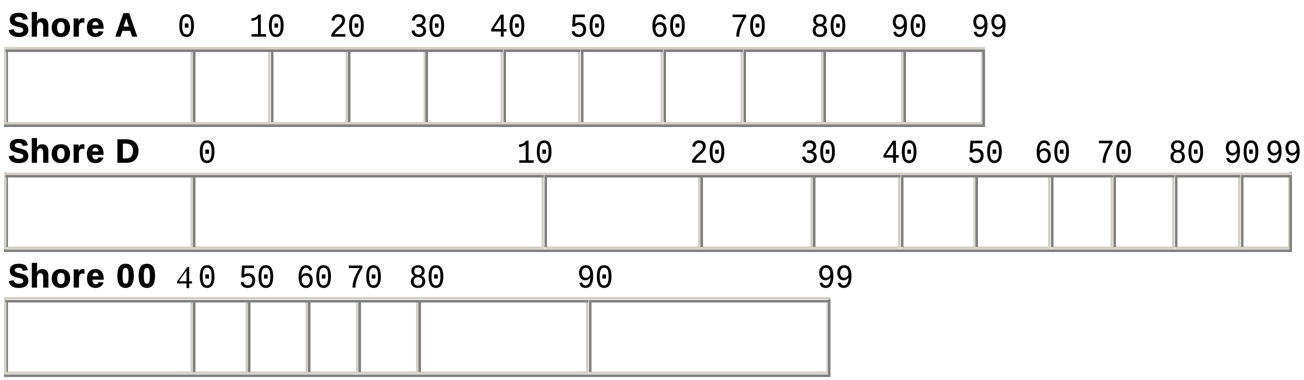


Indenter Type

Test Method ASTM D2240, JIS6249

Shore A Hardness (Different types of indenters)

Shore Hardness Conversion Charts

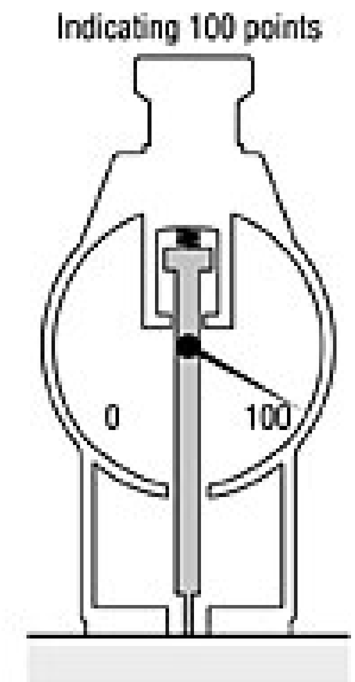


Approximate Durometer Hardness Comparisons

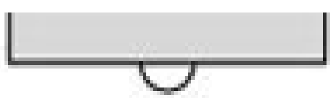
Shore A	Shore D	Shore 00
100	58	
95	46	
90	39	
85	33	
80	29	98
75	25	97
70	22	95
65	19	94
60	16	93
55	14	91
50	12	90
45	10	88
40	8	86
35	7	83
30	6	80
25		76
20		70
15		62
10		55
5		45

8. Hardness & Penetration

Penetration tests are performed on gels and greases to determine the consistency and shear stability. A higher penetration material is a 'softer' material.



Cone type



Indenter Type

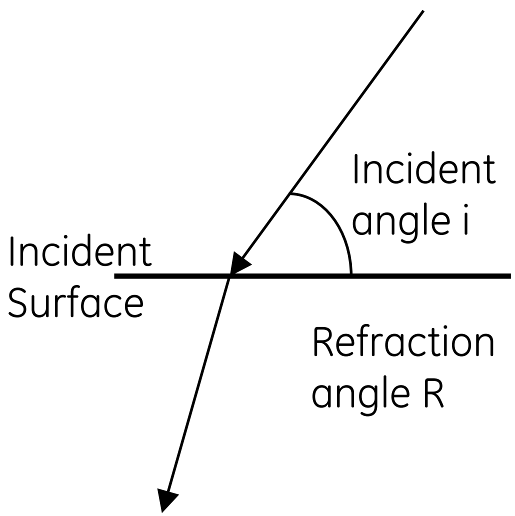
Test Method ASTM D1403

Penetration (Hemispherical type, cone type)

The **refractive index or RI** is a physical property of a liquid, which is proportional to the concentration. The RI can be described as the bending power of light at the surface of a liquid.

$$n = \text{Sine I} / \text{Sine R}$$

Where ***n*** is the refractive index
Sine I is the sine of the angle of incidence, and
Sine R is the sine of the angle of refraction.

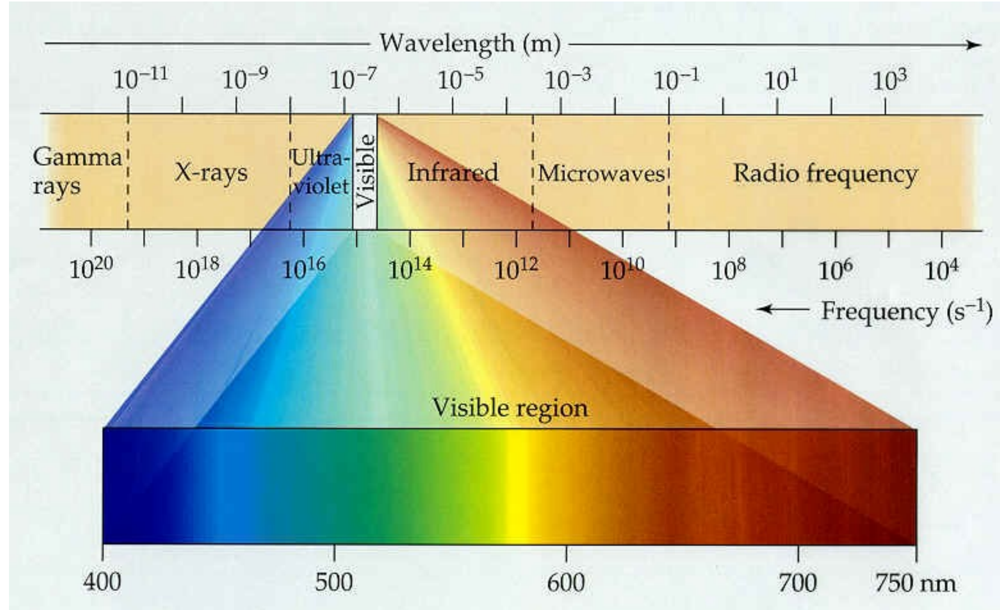


For optical applications, it is important for the adhesives to match the RI of the substrates for good transmittance

Material	n at λ=589.3 nm
Vacuum	1 (exactly)
Helium	1.000036
Air at STP	1.0002926
carbon dioxide	1.00045
water ice	1.31
liquid water (20°C)	**1.333**
ethanol	1.36
Optical grade silicones	**1.4-1.55**
glycerine	1.4729
rock salt	1.516
polycarbonate	**1.59**
bromine	1.661
glass (typical)	**1.5 to 1.9**
cubic zirconia	2.15 to 2.18
diamond	2.419
moissanite (silicon carbide)	2.65 to 2.69
cinnabar (mercury sulfide)	3.02
gallium phosphide	3.5
gallium arsenide	3.927
silicon	4.01

10. UV Transmittance

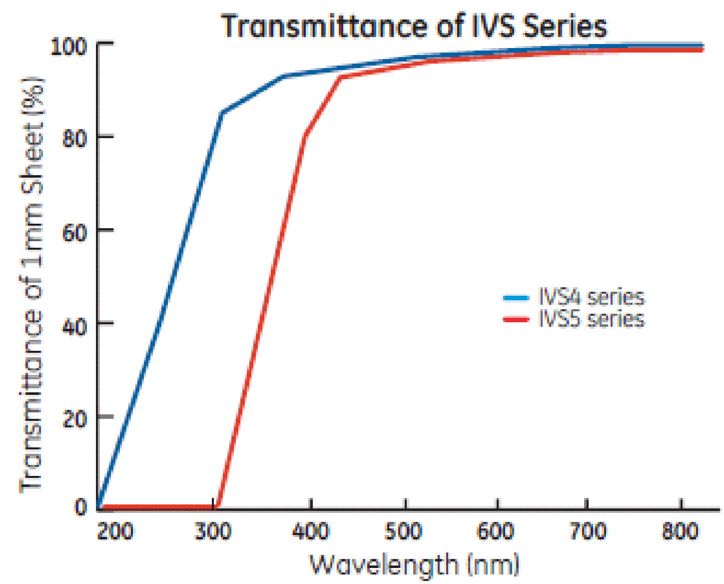
% Transmittance is a measure of the optical transparency of the material.
The higher the %, the clearer the material.



Test method using a
UV/Vis spectrophotometer.

- Ultraviolet or visible light at a certain range of wavelengths is transmitted through the sample.
- The intensity of incident light is symbolized by I_0.
- The intensity of light passed through the sample is symbolized by I.
- Light transmittance is **(I / I_0)**, which is usually expressed as a percent **Transmittance (%T).**

Some optical materials, like in LEDs require UV transmittance % of 95-99%, 400-800nm.



11. Tensile Strength, Elongation & Tear Strength

Tensile strength of a material is the maximum amount of tensile stress that it can be subjected to before failure.

Tear strength tests are conducted on soft films and very flexible elastomers.

Tensile strength = Max Load (Force) / X-sectional Area

Units
- N/m2
- Pascals (Pa)
- lbs/in2 (PSI)

Conversion

1 lbf/in^2 (psi) = 0.07 bar =70 mbar = 0.07 kgf/cm^2 = 0.007N/mm^2 =0.007 MPa

1 lbf = 4.45N = 0.45kgf

% Elongation is the percentage of maximum extension of a material under tensile stress, before breaking.

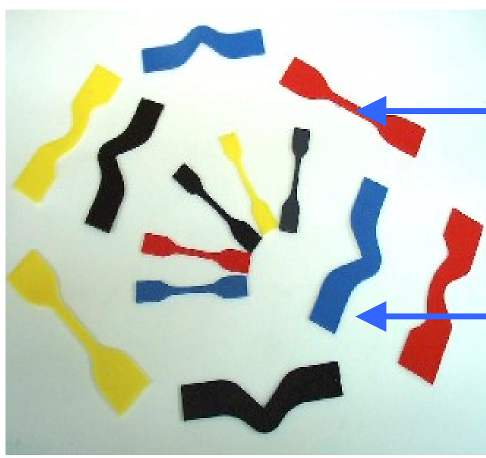
Elongation = (L1 – L0) / L0 x 100%

L0: Gauge length

L1: Length between indicators at the time of breaking

11. Tensile Strength, Elongation & Tear Strength

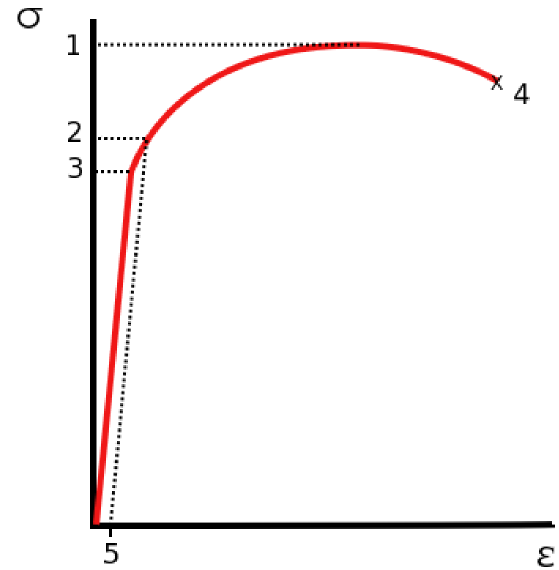
Press cure for addition cure silicone only at 170 degC



Dumbell shape silicone rubber for Tensile Strength & Elongation

Silicone rubber for Tear Strength

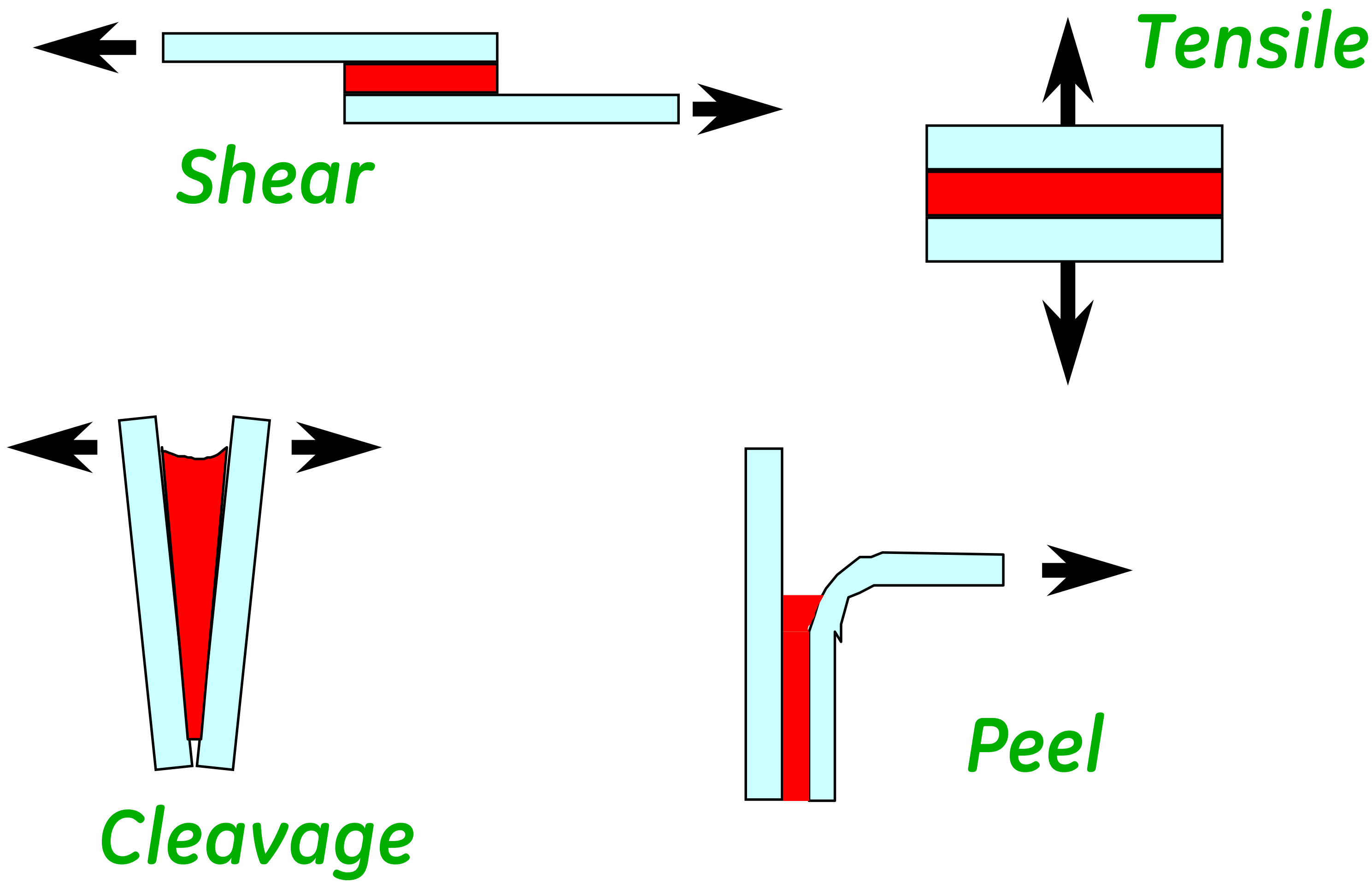
Test Method ASTM D638



1. Ultimate Strength
2. Yield Strength
3. Proportional Limit Stress

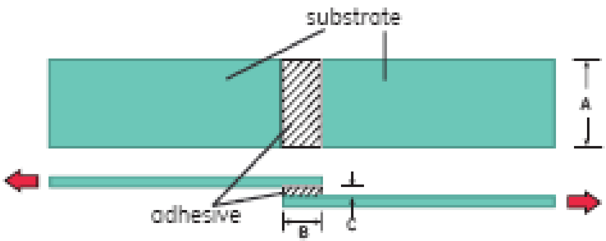
12. Adhesion Strength

Types of Stresses

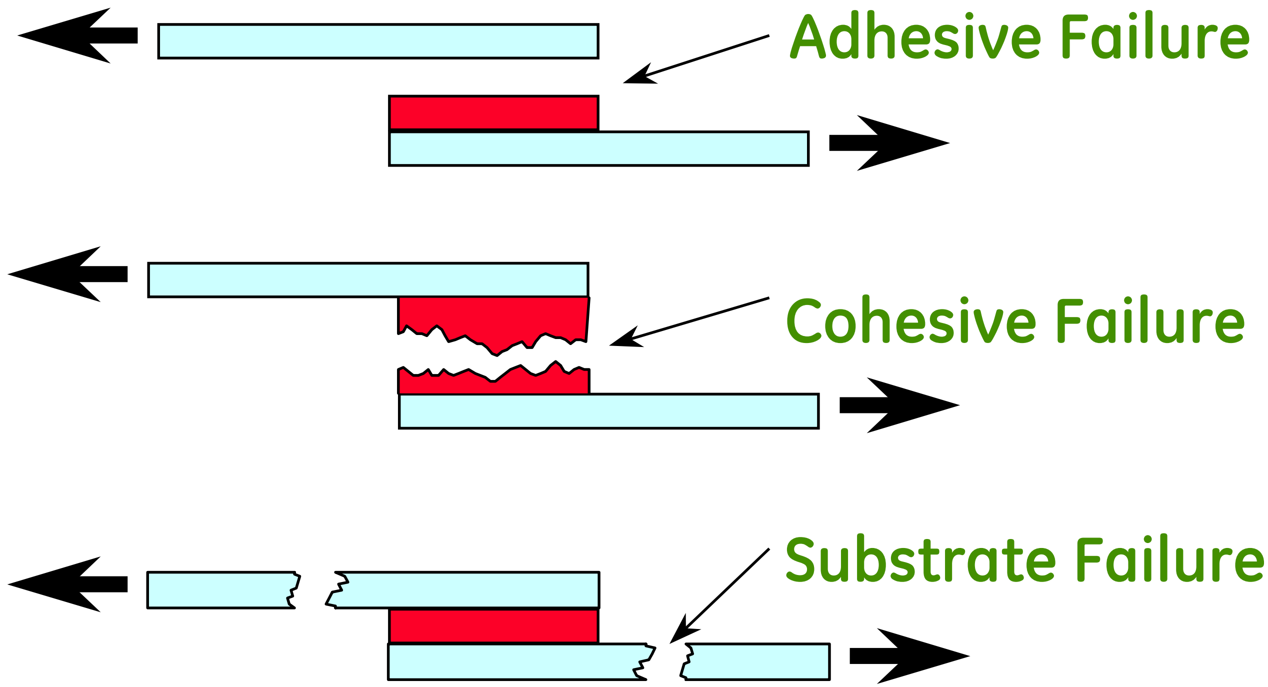


OverLap Shear (OLS) Test and Failure Modes

GE JIS Test substrate size 25mm x 10cm. Bond area 25mm x 25mm x 1mm.
Crosshead pull speed 10mm/min.



	JIS Method	ASTM Method
A:	25mm	1"
B:	10mm	0.5"
C:	1mm	-
Pull Rate:	10mm/min.	1"/min.



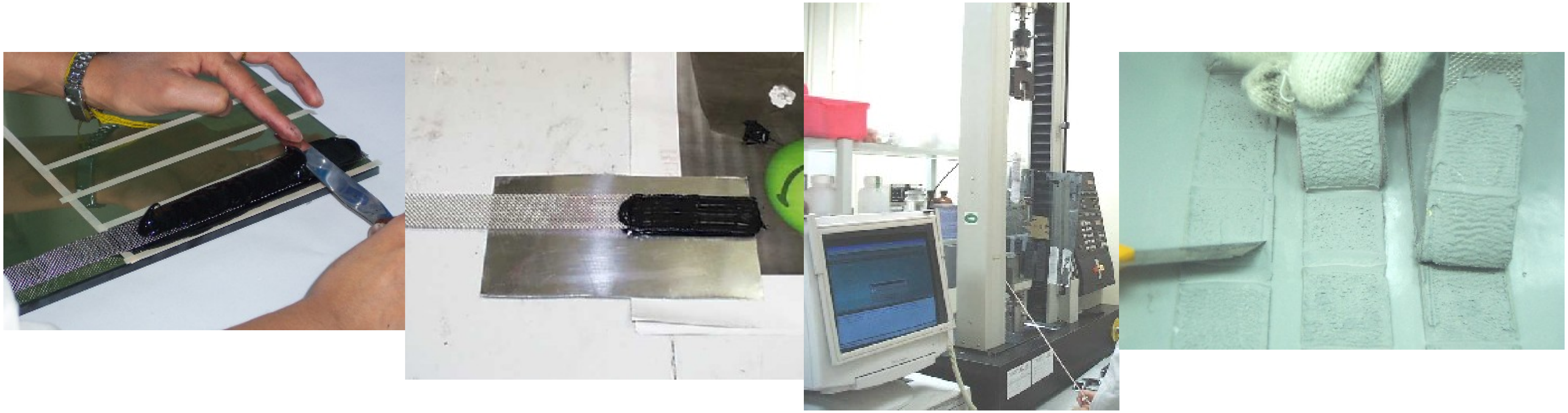
Units

1 Pa = 1 N/m² = 1 kgf/cm²

1 MPa ~ 145 lbf/in² (psi)

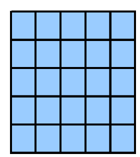
12. Adhesion Strength

Peel Strength Test

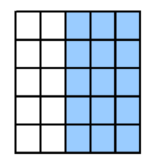


Bond area 25mm x 125mm x 2mm.
Crosshead pull speed 1 in/min.

Determining the Cohesion %
(% of area adhere well to the substrate)



Before Peel Adhesion Test - 100% cohesion

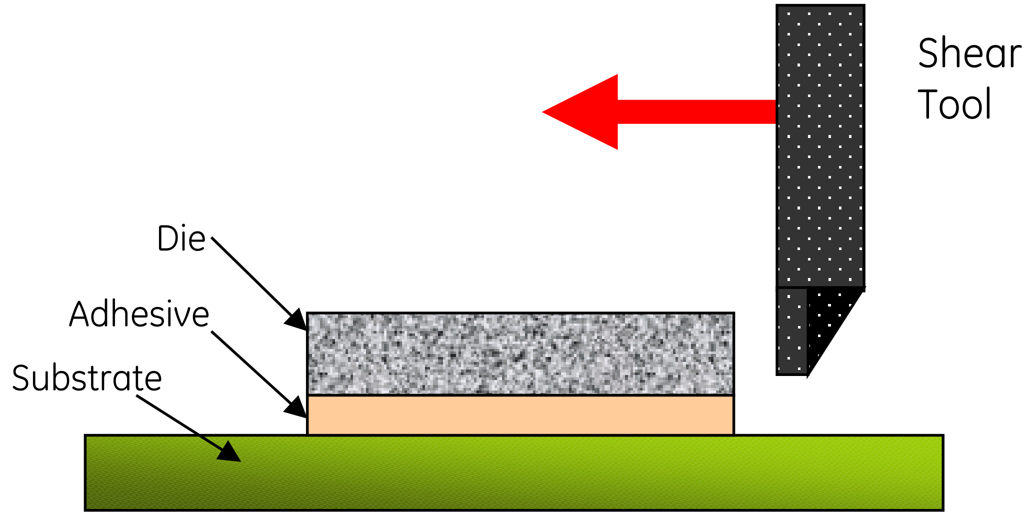


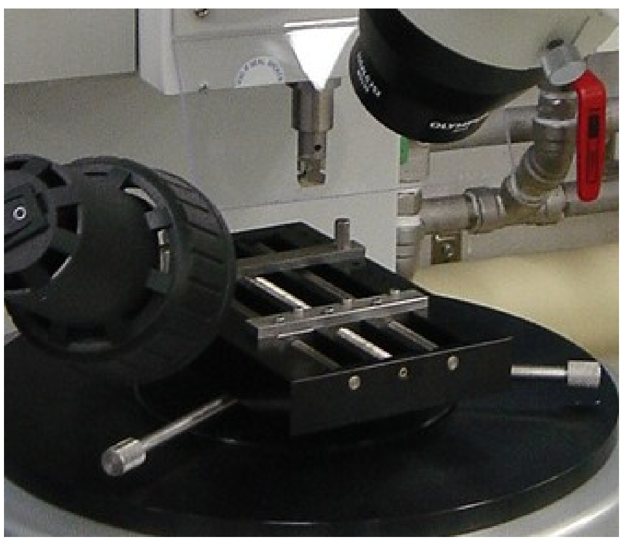
After Peel Adhesion Test - 60 % cohesion

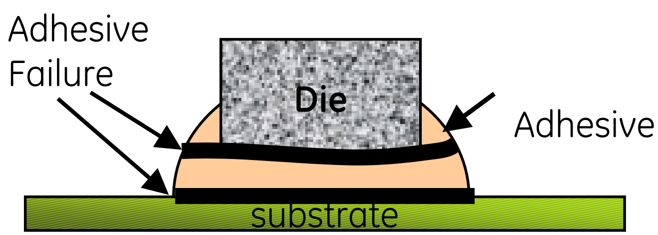
12. Adhesion Strength

Die Shear Strength Test (Units: N/m^2, MPa or Psi)

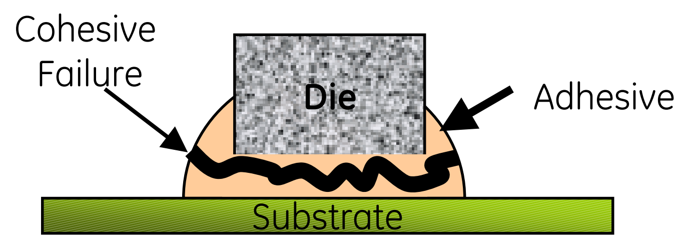
Test Method SEMI-G63







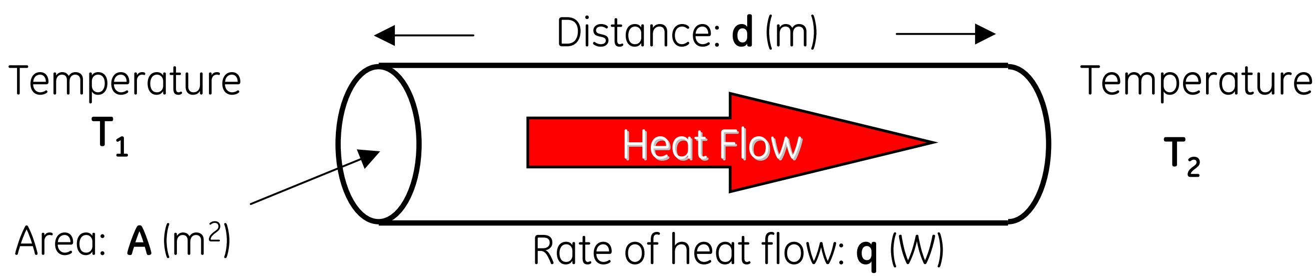
Rupture of an adhesive bond, such that the separation appears to be at the adhesive-adherend interface (Failure in adhesion)



Rupture of an adhesive bond, such that the separation appears to be within the adhesive

13. Thermal Conductivity

Thermal conductivity (W/m.K), λ or k, relates to the material's ability to conduct heat.



$$q = k \cdot A \cdot (T_1 - T_2) / d$$

It is the quantity of heat, *Q*, transmitted through a distance *d*, in a direction normal to a surface of area *A*, under steady state conditions and when the heat transfer is dependent only on the temperature difference Δ*T* temperature gradient.

Thermal Conductivity:

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

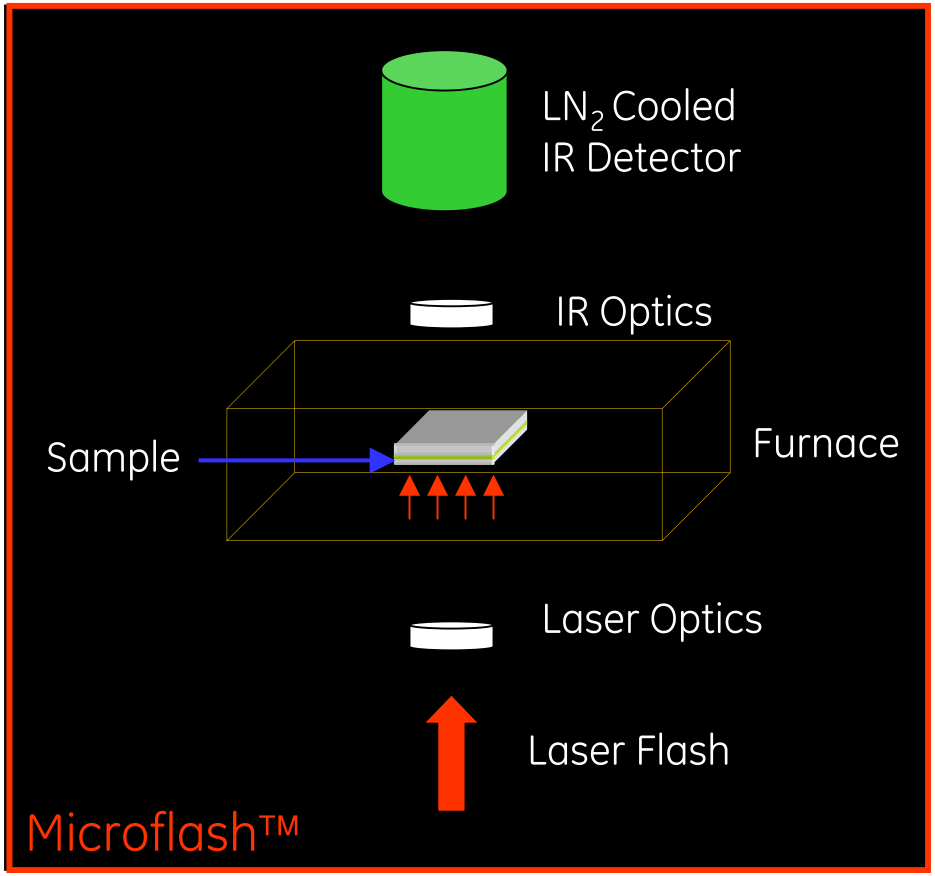
Unit Conversion

From	W/mK		cal/cm·s·°C		BTU-in/hr·ft2·°F	
Multiplier	2.4×10^{-3}	6.94	4.2×10^{2}	2.9×10^{3}	0.14	3.4×10^{-4}
To	cal/cm·s·°C	BTU-in/hr·ft2·°F	W/mK	BTU-in/hr·ft2·°F	W/mK	cal/cm·s·°C

Thermal Cond. of Common Materials

	W/mK
Silver	406.0
Copper	385.0
Brass	109.0
Aluminum	205.0
Steel	50.2
Lead	34.7
Concrete	0.8
Oxygen	0.023
Styrofoam	0.01
Cork	0.04
Air (@0°C)	0.024

Measurement – Thermal Diffusivity



$$k = (\alpha)(C_p)(\rho)$$

k = Thermal Conductivity (W/mK)
α = Thermal Diffusivity (cm^2/s)
Cp = Specific Heat Capacity (J/gK)
ρ = Density (g/cm^3)

- Thermal Diffusivity is Measured by Monitoring the Temperature Increase of a Sample Caused by NanoLaser Flash (JIS K2220)
- IR Detector Measures Temperature Rise on Opposite Face of Sample
- Specific Heat and Density of Bulk Material must be measured
- Thermal Diffusivity is measured on Bulk Material
- Effective Thermal Conductivity is Computed Using the Equation

Measurement – Thermal Resistance

- Calculate **Thermal Conductivity**

$$k = (\alpha)(C_p)(\rho)$$

k = Thermal Conductivity (W/mK)
α = Thermal Diffusivity (cm^2/s)
Cp = Specific Heat Capacity (J/gK)
ρ = Density (g/cm^3)

  - Measure Thermal Diffusivity -> Given as 0.0052 cm^2/s
  - Measure Specific Heat Capacity
  - Measure Density -> Given as 2.48 g/cm^3
  - Multiply (Thermal Diffusivity * Specific Heat Capacity * Density)*100
    - Equals Bulk Thermal Conductivity [=] W / mK
- Calculate **Thermal Resistance**
  - Measure Sample Thickness -> Given as 3.4 mm
  - Multiply (Thickness / Bulk Thermal Conductivity) *1000
    - Equals Thermal Resistance [=] mm^2 K / W

14. Thermal Resistance

Thermal resistance is the opposition to flow of Heat Energy. It is the reciprocal of thermal conductance.

Thermal resistance has two different meanings:

1. temperature difference across the structure when a unit of heat energy flows through it in unit time **(K/W)**, or
2. temperature difference across a unit area of a material of unit thickness when a unit of heat energy flows through it in unit time. **(mm^2.K/W)**

$R = L/(k \cdot A)$ (Units: K/W)

$R = L/k$ (Units: mm^2.K/W)

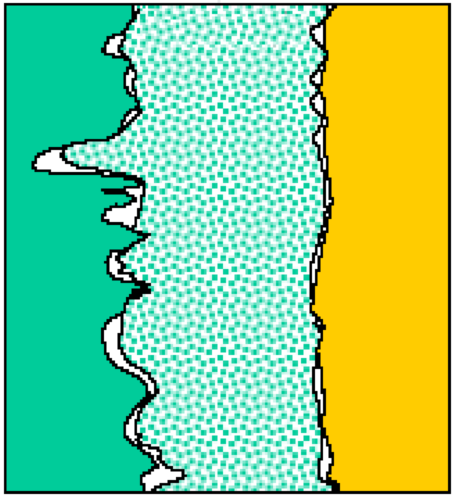
thermal conductivity k, thickness L, surface area A

Generally, the higher the k, the lower the R……BUT (next pg pls)

Thermal Impedance ($mm^2.K/W$)

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 ($mm^2.K/W$) for homogeneous materials is directly proportional to thickness. For non-homogeneous materials, resistance increases with thickness but the relationship is not necessarily linear.



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.

It is MOST important to consider the overall thermal impedance of the system (thermal resistance + contact resistance) for efficient thermal transfer

Thermal and Electrical properties of common materials

Material	Specific Gravity (gms / cm³)	Thermal Conductivity (Btu / hr °F ft² / ft)	Thermal Conductivity W/m.K	Volume Resistivity (ohm-cm)	Dielectric Strength kV/mm
Diamond	3.5		1000		
Silver	10.5	240	403.2	1.6×10^{-6}	
Copper	8.9	220	369.6	1.8×10^{-6}	
Beryllium Oxide		130	218.4		
Aluminum	2.7	110	184.8	2.9×10^{-6}	
Carbon	2.3		119-165		
Aluminum Oxide	3.4-4.0	20	33.6		
Boron Nitride	2.3-3.5		20-65	10^{8}-10^{13}	35
Unfilled Epoxies	1-1.1	0.1-0.15	0.17-0.25	10^{14}-10^{15}	
Alumina Filled Epoxy	1.5-3.0		0.3-2.0	1-10^{6}	
Aluminum Filled Epoxy (50%)	1.5-3.0	1-2	1.7-3.4	1-10^{6}	
Silver Filled Epoxy	1.5-4.0	1-4	1.7-6.7	1×10^{-3}	
Unfilled Silicones	1-1.1		0.17-0.34	10^{14}-10^{15}	20-25
Alumina Filled Silicones	1.5-3.0		0.5-2.5	1-10^{6}	15-25
Aluminium Filled Silicones	1.5-3.0		2.0-5.0	1-10^{6}	15-20
Silver Filled Silicones	1.5-4.0		1.7-6.0	1×10^{-3}	15

Volume resistivity (Ω.m) is the resistance to leakage current through the body of an insulating material. The higher the volume resistivity, the lower the leakage current and the less conductive the material is

Test Procedure (JIS K6249)

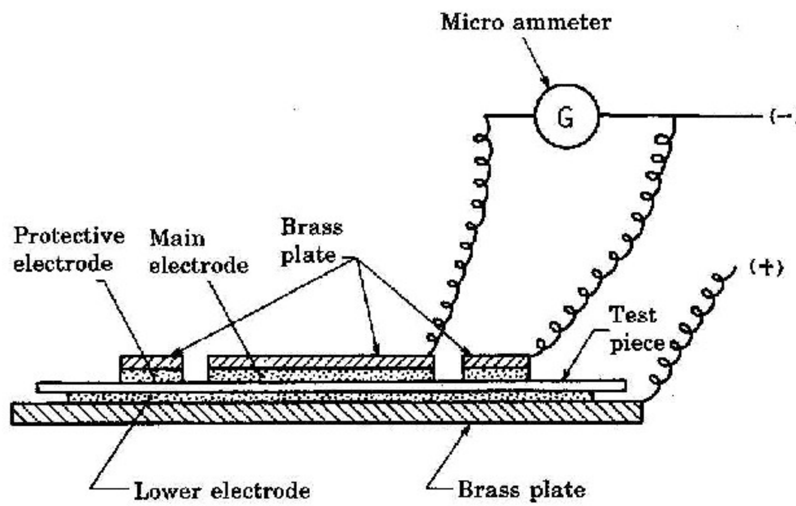
- Specimen is placed between two electrodes. A
- 500V voltage is applied for 1 minute
- Resistance is measured.
- Volume resistivity is calculated as below.

Specimen size:

12cm x 12cm x 1mm

Volume Resistivity, $\rho = \pi.d^2.R / 4t$

ρ: Volume Resistivity (M Ω.m)
R: Measured resistance (Ω)
t: Thickness of test plate (m)
d: Diameter of main electrode (m)

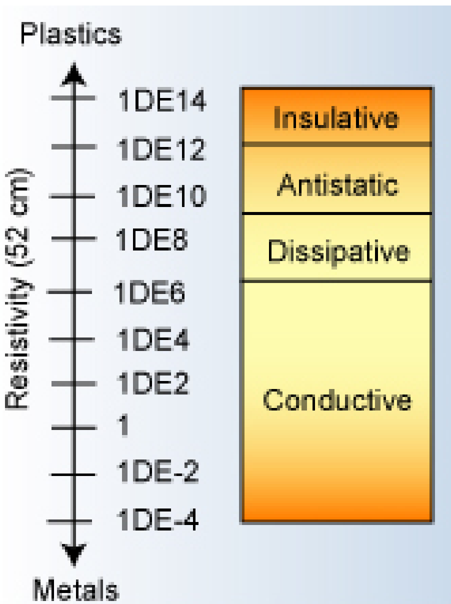


15. Volume Resistivity

Typical Volume Resistivity (Ω.m) values

Electrically Conductive Metals: 10^{-6} Insulative Materials: 10^{13}- 10^{15}

Conductive Adhesives: 10^{-4} – 10^{2}



Dielectric Property	Units	Epoxy	Acrylic	Polyimide	Silicone Elastomer	Polyamide
Volume Resistivity	Ohm-cm	6.1x10^{15}	>10^{15}	10^{15}-10^{16}	10^{14}-10^{16}	4.5x10^{13}
Dielectric Strength	V/mil	>400	450-530	310-560	400-700	385
Dielectric Constant,	Unitless					
60Hz		4	3.4-4.5	3.6-4.1	2.95-4.0	4.0-5.3
1MHz		3.4	2.7-3.2	3.5-3.9	2.95-4.0	3.9-5.4
Dissipation Factor,	Unitless					
60 Hz		0.0074	0.05-0.06	0.002-0.003		0.06-0.14
1MHz		0.032	0.02-0.03	0.004-0.011		0.03-0.04
Arc Resistance	Secs	100	No Track	152-230		

16. Dielectric Strength

Dielectric Strength (kV/mm) (electrical breakdown strength) is a

- Measure of the electrical strength of a material as an insulator.
- The maximum voltage required to produce a dielectric breakdown through the material
- The higher the dielectric strength of a material the better its quality as an insulator.

Test procedure (ASTM D149):

- Test specimen placed between two electrodes.
- Voltage is applied across the two electrodes and
- Raised from zero to dielectric breakdown at a uniform rate.
- Breakdown is when an electrical burn-through punctures the sample, or decomposition occurs in the specimen.

Specimen size:

4 inch plaque or larger, thickness is between 0.8 to 3.2 mm (0.032 to 0.125 inch). Specimens over 2 mm thick are typically tested in oil to decrease the chance of flashover before breakdown.

17. Dielectric Constant & Dissipation Factor

Dielectric Constant (ASTM D150) is used to determine the ability of an insulator to store electrical energy.

Ratio of the capacitance induced by two metallic plates with an insulator between them to the capacitance of the same plates with air or a vacuum between them.

$$\varepsilon_r = C_x / C_0$$

C_x : Capacitance of test capacitor with dielectric in between

C_o : Capacitance of test capacitor in air

Dissipation factor (ASTM D150)

- Reciprocal of the ratio between the insulating materials capacitive reactance to its resistance at a specified frequency.
- Measures the efficiency of an insulating material.
- Desirable to have a low value of dissipation factor in order to minimize the conversion of electrical energy to heat energy and reduce the effect of power loss

Ionic Content

Very low Ionic Impurity reduces risk of **corrosion** and ensure superior stability in semiconductor devices

Major ions of concern

- Sodium (Na+)
- Potassium (K+)
- Chloride (Cl-)
- Fluoride (F-)

Test Method: Ion Chromatography Analysis

Semiconductor grade Silicones 2-5ppm

Semiconductor grade Epoxies ~2-20ppm

19. Outgassing

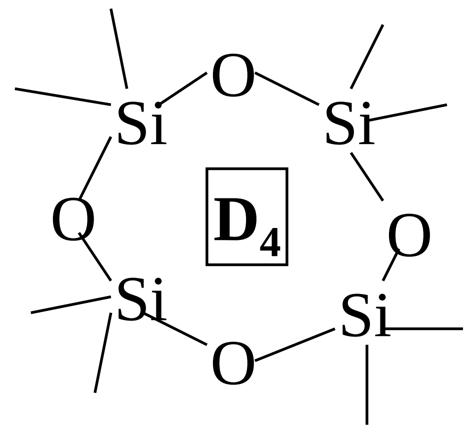
Outgassing is an industry term to describe the amount of volatile content left in the material even after it is cured. These volatiles may be emitted out subsequently during the operating life of the device and affect the device.

This is especially true for sealed applications like hermetic packages or hard disk drives.

Typical test method is the **GC/MS** (Gas Chromatography/Mass Spectrometer

Typical volatiles measured are

- **Low Molecular Weight Siloxane D_3-D_{10} wt %**
- Hydrocarbons
- Amine
- Other derivatives



D_4: 4 Si-O groups in a cyclic chain

Outgassing can also be sometimes referenced by the amount of weight loss (e.g. from moisture absorbed in material) when the material is heated up. Weight loss % can be detected by use of **Thermogravimetry Analysis (TGA)**

20. Shrinkage

Shrinkage in adhesives are common during the curing process. The compression stresses induced from shrinkage may either be beneficial in giving support to the bond [e.g. to prevent movement], or detrimental to the bond [e.g. wire breakage]

There are linear and volumetric shrinkages. Both methods are difficult to measure accurately.

GETOS do not have a current test method to measure shrinkage.
But we can provide estimated shrinkages of materials:

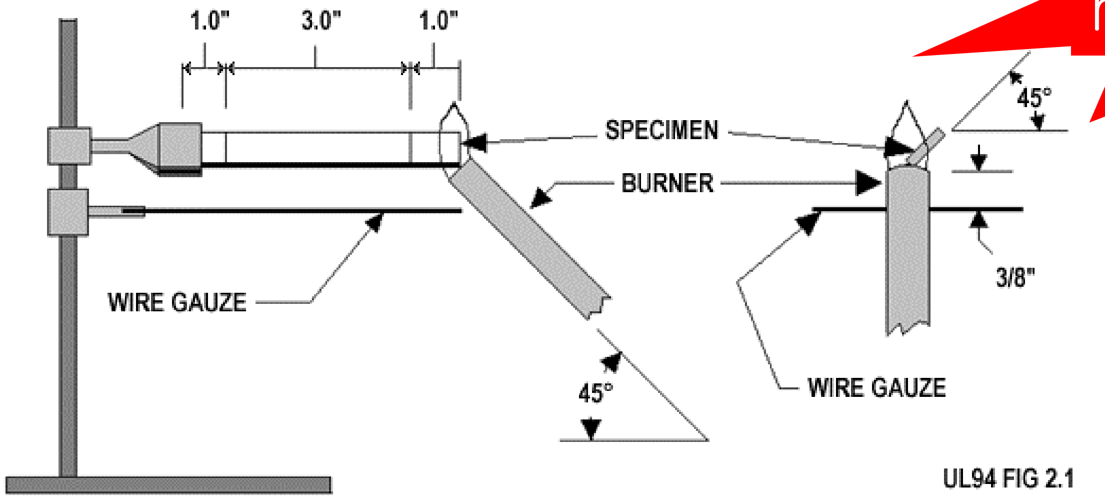
- **Silicone: 1-5%**
- **Epoxy: 3-5%**
- **Acrylic: 5-15%**

Shrinkages will generally decrease with filler loading.

Underwriters Laboratories Inc. (UL) is a globally recognized third party product compliance tester. UL94 is a test method for **flammability** of plastic materials.

Flame Retardant Property (UL94 HB) (Horizontal burn)

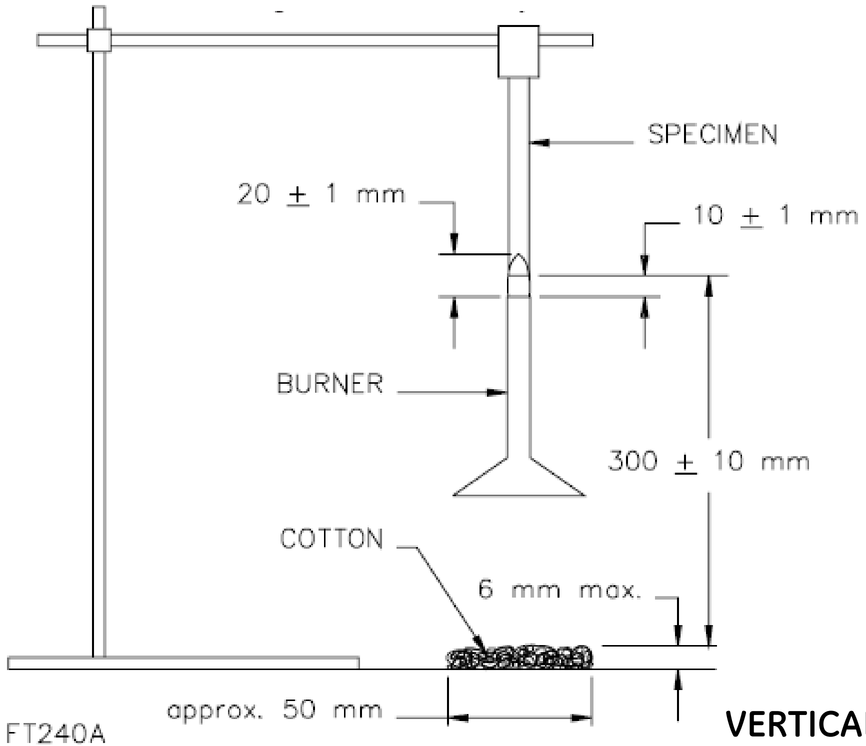
Most liquid RTVs meet UL94 HB



UL94 FIG 2.1
HORIZONTAL BURNING TEST FOR 94HB CLASSIFICATION

Slow horizontal burning on a 3mm thick specimen with a burning rate is less than 3"/min or stops burning before the 5" mark. H-B rated materials are considered "self-extinguishing".
This is the lowest (least flame retardant) UL94 rating.

Flame Retardant Property (UL94 V) (Vertical Burn)



Flame retardant performance

Low → High

UL94HB   UL94V-1   UL94V-0

VERTICAL BURNING TEST FOR 94V CLASSIFICATION

Criteria conditions	V-0	V-1	V-2
Afterflame time for each individual specimen t_1 or t_2	≤10s	≤30s	≤30s
Total afterflame time for any condition set (t_1 plus t_2 for the 5 specimens)	≤50s	≤250s	≤250s
Afterflame plus afterglow time for each individual specimen after the second flame application (t_2+t_3)	≤30s	≤60s	≤60s
Afterflame or afterglow of any specimen up to the holding clamp	No	No	No
Cotton indicator ignited by flaming particles or drops	No	No	Yes

UL746 Relative Thermal Index

The Relative Thermal Index (RTI) is the temperature at which a specific property will decrease to half of its original value after 100,000 hours of exposure at that temperature.

Recognized Product

TSE3826 (1-P,Oxime condensation)	RTI : 200 C
TSE3260 (1-P,Addition)	RTI : 190 C

22. Shelf Life/Storage/Thawing Time

Please refer to product data sheet for more details:

Typical **shelf life:**

One and two parts:	**12 months** from the date of manufacturing. Exceptions (3 mths, 6 mths), please refer to the PDS of individual product.
Semiconductor grades:	**6-9 months** from the date of manufacturing Refer to the PDS of individual product.

22. Shelf Life/Storage/Thawing Time

Please refer to product data sheet for more details:

Storage:

- General sealant : **25deg C**
- One part heat cured sealant, needs refrigeration during transportation and storage at **0 to 10deg C**.
- Semiconductor grade, e.g. NFU, please store **–20degC to –40deg C,** please refer to the product data sheet for further details.

22. Shelf Life/Storage/Thawing Time

Please refer to product data sheet for more details:

Thawing time is necessary for cold storage material for about **one hour to half a day** prior to use depending to packaging size.

For semiconductor grades, please thaw it at room temperature for one hour with the syringe standing upright, tip pointing downwards.