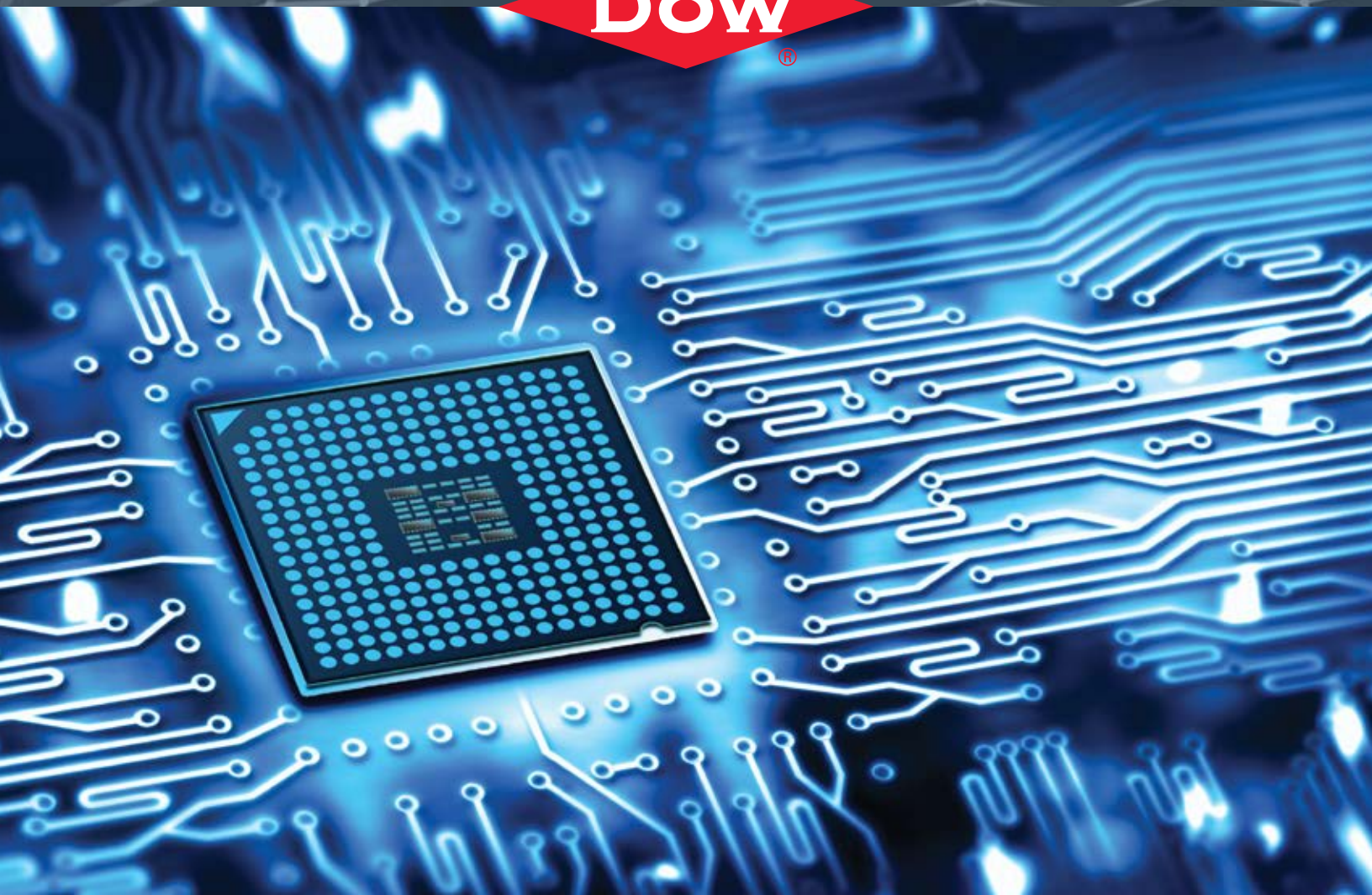
CONSUMER ELECTRONICS

Sensing the market growth of MEMS sensors and actuators

Silicone product selection guide

DOW®



Drive MEMS design innovation with successful silicone technologies

MEMS (microelectromechanical system) sensors and actuators are considered the backbone of many of today's electronics devices for consumers, automotive systems, communications, healthcare, defense and more. The market for these miniaturized devices is growing rapidly.

Whether in smartphones, tablets, smartwatches or advanced home appliances, silicon-based MEMS technology can enhance the performance of your designs while enabling safer, more reliable devices for those using them. On the road, an array of MEMS sensors and actuators can improve the performance of electronic controls, help reduce operating costs and contribute to increased safety. These silicon-based devices deliver key benefits at relatively low cost levels.

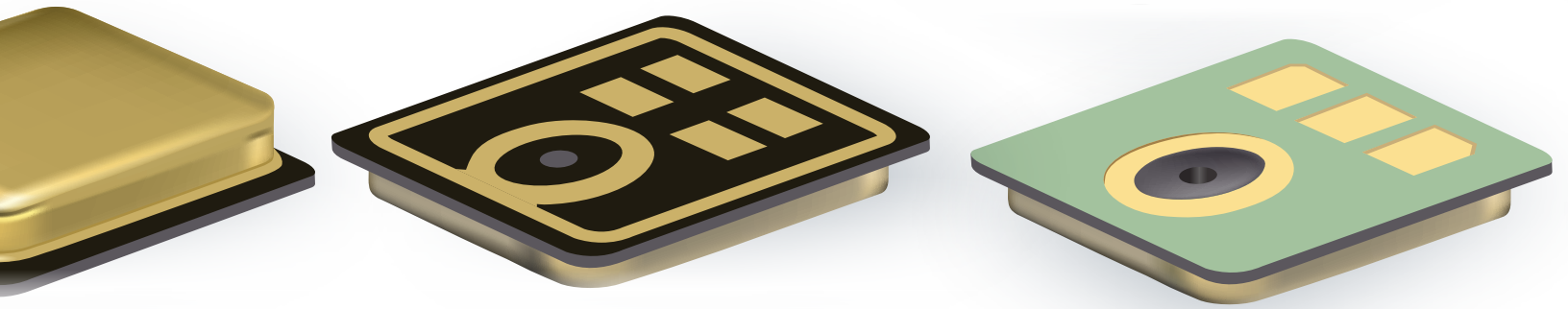
Silicones can help you drive MEMS design innovation and meet performance requirements for a wide array of electronic devices. The functional diversity MEMS sensors and actuators (see tables at right) is valued in countless electronics applications.

Sensors

Movement			Pressure	Sound and ultrasonic	Environment				Optical sensors							
Accelerometers	Gyroscopes	Magnetometers			Gas	Humidity	Particles	Temperature	FTIR	Fingerprint	PIR & thermopiles	Hyperspectral	ALS, RGB	Microbolometers	Vision	3D sensing

Actuators

Optical MEMS			Microfluidics			RF			Microstructures				
Micromirrors	Autofocus	Optical benches	Inkjet heads	Drug delivery	Biochips	Switch	Filter	Resonator	Microtips	Probes	Watch components	µSpeakers	Ultrasonic fingerprint



Why choose Dow Performance Silicones?

Dow Performance Silicones has been a global leader in silicone-based technology for more than 70 years. Headquartered in Michigan, USA, Dow maintains manufacturing sites, sales and customer service offices, and research and development laboratories in every major geographic market worldwide to ensure that you receive fast, reliable support for your processing and application development needs. We can help you drive design innovation and process efficiency.

Unique product technology

Our substantial silicone legacy – showcased though the DOWSIL™ and SILASTIC™ brand names that encompass more than 7,000 silicone products and services – offers a portfolio with breadth and performance that few companies can match.

Extensive know-how

We multiply our product value with deep in-house knowledge and experience and an extended network of industry resources.

Collaborative culture

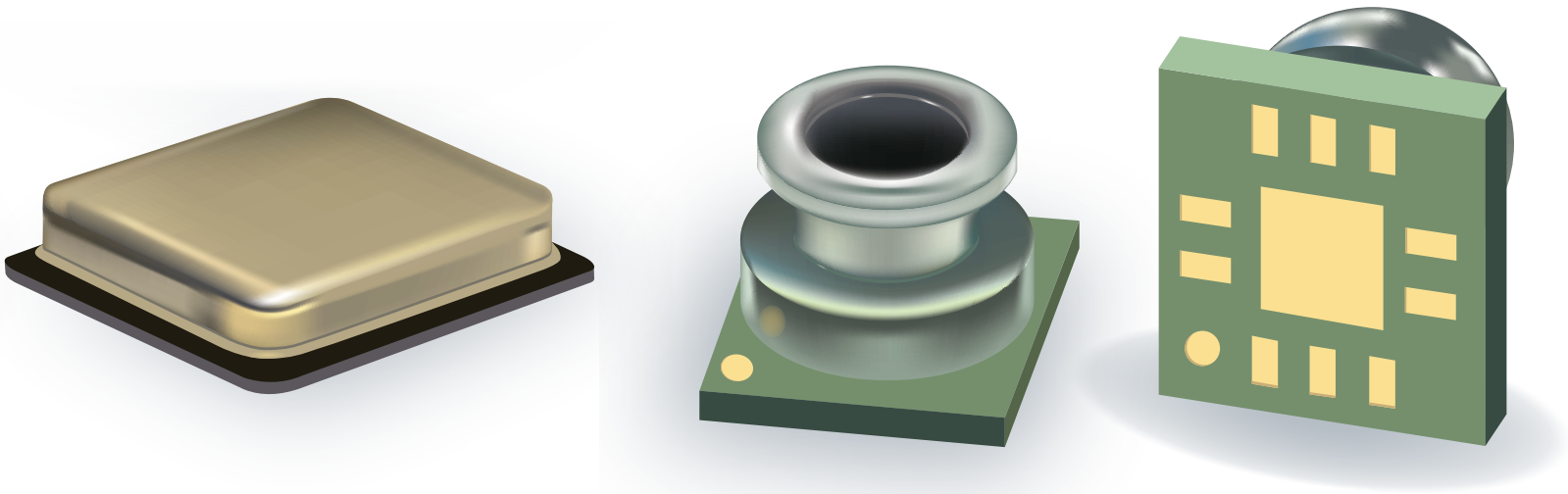
We work closely with you to help reduce time and cost at every stage of your new-product development.

Stability

For more than seven decades, we have been a global leader, investing in manufacturing and quality to help fuel your innovations through a consistent supply of effective silicone products.

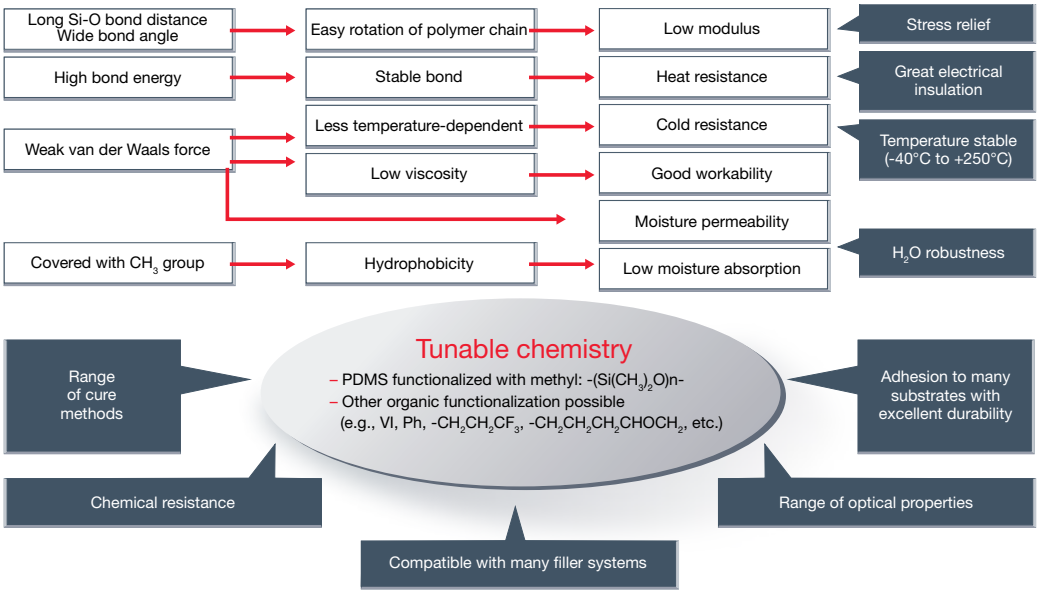
DOWSIL™

silicones by DOW



Characteristics of silicones

When compared to organic materials, DOWSIL™ silicones offer superior stress management while keeping a low and stable modulus over a wide temperature range for sensing accuracy. Silicones also offer chemical and thermal reliability for environmental protection of “open package” sensors.



Bond length
- Si – O : 1.64 Å
- C – C : 1.53 Å

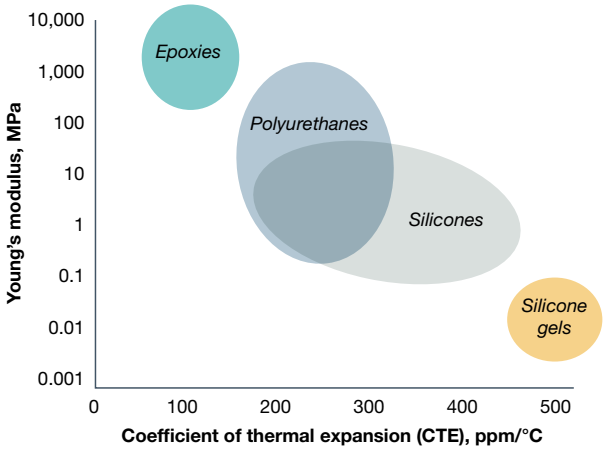
Bond angle
- Si – O – Si : 130-150°
- C – C – C : 112°

Barrier to rotation
- $H_3Si – OH$: 0.4 kcal/mol
- $H_3C – CH_3$: 2.9 kcal/mol

Bond energy
- Si – Si : ~51 kcal/mol
- Si – O : ~106 kcal/mol
- C – O : ~81 kcal/mol
- C – C : ~85 kcal/mol

W. Noll, “Chemistry and technology of Silicones,” Academic Press, London (1968)

Silicone vs. organics: Impact on thermal stress



$$\sigma_{th} = E\,\alpha\,dT$$

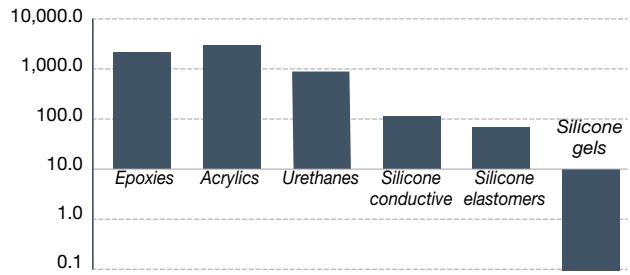
Coeff. thermal expansion:
$\alpha_{silicone} = 3 \sim 10 \times \alpha_{epoxy}$

Young’s modulus:
$E_{silicone} = 0.1 \sim 0.001 \times E_{epoxy}$

Thermal stress:
$\sigma_{epoxy} = 1 \sim 100 \times \sigma_{silicone}$

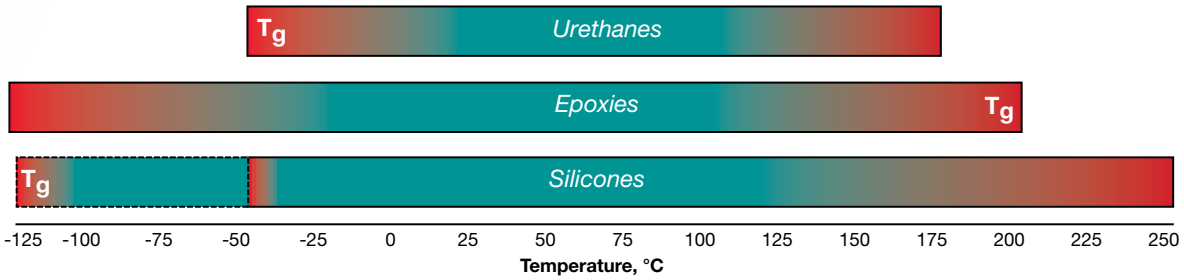
– Lower thermal stress in silicone gels

Relative thermal stress for 25°C to 125°C



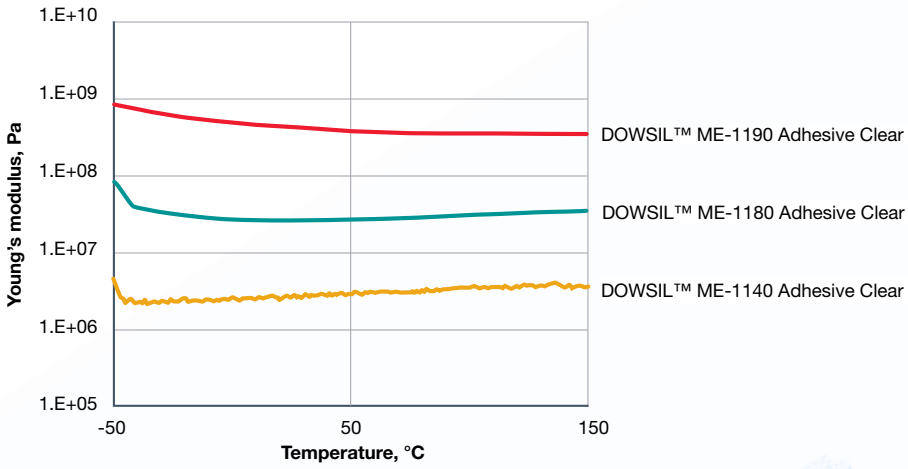
DOWSIL™
silicones by DOW

Silicone vs. organics: Usable temperature range



- Operating temperature should not cross thermal events of material such as glass transition due to changes in physical properties (CTE, modulus, hardness, resistivity, etc.)
- Typical silicones have two transitions at low temperature (-40 ~ -50°C and -110 ~ -120°C)
  - Silicone use above T_g exhibits little change in properties
- Moisture/humidity is an important factor affecting performance
  - Silicones have low water/moisture absorption, unlike organics
  - Water saturation point ~ 0.15 wt.% in silicones vs. >1 wt.% in organics (some can have >5 wt.%)

Stable modulus over wide temperature range (after cured)

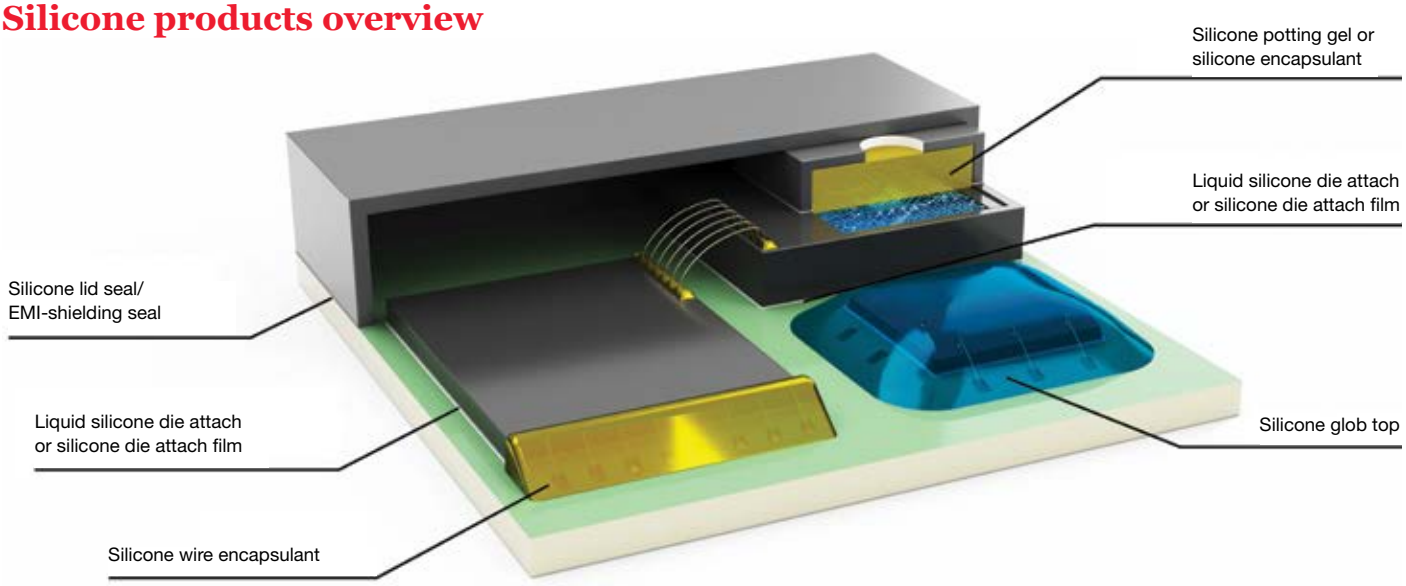


DOWSIL™ silicone technology

Key properties and application benefits

Key properties	Benefits in the application
Low modulus over wide ranges of temperature	– Ability to absorb stress during temperature cycle caused by CTE mismatch
Thermal stability	– Stable electrical and mechanical properties over wide temperature and frequency ranges – Adhesion strength performance at high reflow temperature; high-temperature reliability
Low level of ionic impurities	– Ultraclean; high purity; compatible with microelectronic processing – Reduced risks of ionic contamination causing corrosion
Efficient adhesion	– Flexible to use for a broad range of substrate materials and interconnects
Low moisture uptake	– Prevent issue during reflow temperature – Stable dielectric constant during operation
Accelerated heat cure	– Minimal by-products and minimal shrinkage for enhanced reliability

Silicone products overview



Liquid die attach adhesives

- Stable adhesion to various substrates
- Range of modulus (1-300 MPa), viscosity and thixotropy to meet application needs
- Low bleed; controlled low volatility
- Dielectric and electrically conductive (EMI shield)
- BLT control

Encapsulants

- Wide variety of cure temperatures; UV cure option
- Soft gel protects device, yet transduces environmental changes
- Controlled flowability
- Good durable adhesion and stable low modulus to protect electrical parts

Wire/die coating

- Various cure systems: heat, moisture, UV
- Wide range of modulus: hard coating to gel
- Controlled flowability: conformal coating to spot encapsulation
- Various application process options: spray coating, jetting

Cured film adhesive (die attach film): developmental stage

- Very uniform BLT for 25 to 300 um
- No bleeding; low silicone volatiles
- Wafer backside lamination process capable

Optical materials

- Tunable optical properties: transparent, diffuse, light blocking, reflect
- Hardness tunable from soft gel to Shore D range
- No or less color change due to heat or UV exposure
- Reflow process compatible

DOWSIL™ silicone die attach/lid attach adhesives

Silicone die attach adhesives offer flexible cure options, low modulus for reduced stress and optimized viscosity for ease of application. Electrically conductive materials are available.

Product	Key product features	Viscosity, mPa.s	Modulus, MPa	Shore hardness	Lap shear, MPa	Cure condition	Process
DOWSIL™ ME-2010 Adhesive	High modulus; good light transmission	23,000	—	D 57	8.2	150°C/2 hr	Printing; dispensing
DOWSIL™ ME-1190 Adhesive Clear	Jet dispensable; high modulus	3,500	370	D 59	7.4	130°C/1 hr	Jetting
DOWSIL™ ME-1180 Adhesive Clear	Jet dispensable; good stress relief	5,600	23.4	A 81	5.5	130°C/1 hr	Dispensing; jetting
DOWSIL™ ME-1070 Adhesive Black	High thixotropy; high adhesion strength	37,000	12.2	A 74	11.0	150°C/0.5 hr	Printing; dispensing
DOWSIL™ 7920-LV Die Attach Adhesive	Jet dispensable; high adhesion strength	22,000	7.2	A 68	9.0	150°C/1 hr	Dispensing; jetting
DOWSIL™ ME-1140 Adhesive Clear	Jet dispensable; excellent stress relief	5,400	2.1	A 39	3.8	130°C/1 hr	Dispensing; jetting
DOWSIL™ ME-1030 Adhesive Clear	Outstanding stress relief; very low volatile content	14,000	1.7	A 28	0.8	150°C/1 hr	Dispensing
DOWSIL™ ME-1800 Adhesive	Electrically conductive; thermally conductive	150,000	380	A 81	3.9	150°C/2 hr	Printing; dispensing
DOWSIL™ EC-6601 Electrically Conductive Adhesive	Electrically conductive; thermally conductive	Paste	—	A 80	1.7	RTV	Printing; dispensing

The data reported here are provided per different measurement methods from the method for each standard QA, so values do not necessarily correspond to the data in CoA or TDS.

DOWSIL™ silicone encapsulants

Silicone gel and elastomer encapsulants offer excellent dielectric protection, thermal stability, and strong adhesion. Other benefits include tunable modulus, hardness and cure chemistries.

	Product	Key product features	Color(s)	Viscosity, mPa.s	Hardness	Cure condition	Process
Gel for potting/filling	DOWSIL™ ME-4200 Encapsulant Clear*	Cold resistance (stable modulus at <-60°C)	Clear	3,700	(Gel)	150°C/1 hr	Dispensing; jetting
	DOWSIL™ ME-4201 Encapsulant Clear*	Cold resistance (stable modulus at <-60°C)	Clear	4,400	(Gel)	150°C/1 hr	Dispensing; jetting
	DOWSIL™ ME-4400 Encapsulant*	Solvent resistance; good flowability	Clear; black	1,100	(Gel)	150°C/1 hr	Jetting; spraying
	DOWSIL™ X3-6211 Encapsulant	UV cure	Clear	900	(Gel)	365 nm 4 J/cm^2	Spraying

	Product	Key product features	Color(s)	Viscosity, mPa.s	Modulus, MPa	Shore hardness	Cure condition	Process
Elastomer for glob top and wire encapsulation	DOWSIL™ ME-4120 Encapsulant Clear* or Black*	Jet dispensable; outstanding stress relief	Clear; black	3,400	0.9	A 17	130°C/2 hr	Dispensing; jetting
	DOWSIL™ ME-4139 Encapsulant Dark Grey	High thixotropy for glob top; outstanding stress relief	Black	45,000	—	A 28	125°C/0.5 hr	Printing; dispensing
	DOWSIL™ ME-4320 Encapsulant Clear*	Cold resistance (stable modulus at <-60°C)	Clear	7,700	0.8	A 22	150°C/1 hr	Dispensing; jetting
	DOWSIL™ ME-6820 Microelectronic Encapsulant	Excellent stress relief; high adhesion strength	Black	6,000	1.6	A 50	150°C/1 hr	Dispensing; jetting
	DOWSIL™ ME-1140 Adhesive Clear or Black*	Jet dispensable; excellent stress relief	Clear; black	5,400	2.1	A 39	130°C/2 hr	Dispensing; jetting
	DOWSIL™ 7920-LV Die Attach Adhesive	Jet dispensable; high adhesion strength	Black	22,000	7.2	A 68	150°C/1 hr	Dispensing; jetting
	DOWSIL™ ME-1180 Adhesive Clear or Black*	Jet dispensable; good stress relief	Clear; black	5,600	23.4	A 81	130°C/1 hr	Dispensing; jetting
	DOWSIL™ ME-2201 Optical Adhesive	High transparency; high refractive index (1.55)	Clear	3,100	280.0	D 66	150°C/1 hr	Dispensing

The data reported here are provided per different measurement methods from the method for each standard QA, so values do not necessarily correspond to the data in CoA or TDS.

*Prototype available (developmental).

Jet-dispense-friendly adhesives (developmental)

Benefits of silicone

– Good stress relief
– Stable physical properties over wide temperature range
– Excellent reliability

Benefits of jet dispensing

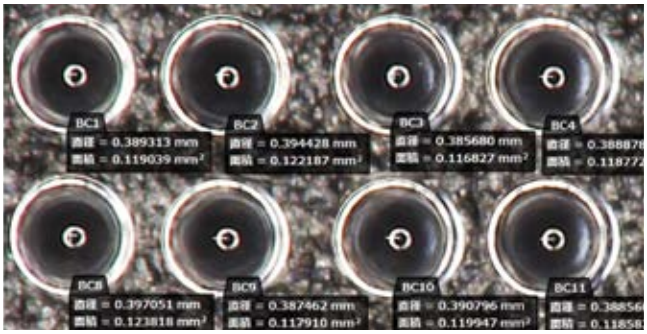
– High-speed dispensing
– Wide process and capability

'Jet dispensability' of silicone was *not* desirable

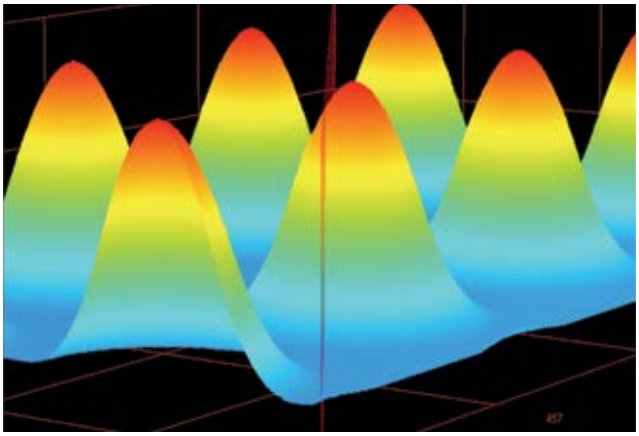
– High viscosity: stringing, clogging
– Low viscosity: too much flow, which disables fine patterning
– Nozzle-heating is not very effective due to less heat thinning compared with organics

Benefits of the DOWSIL™ ME Adhesive Series

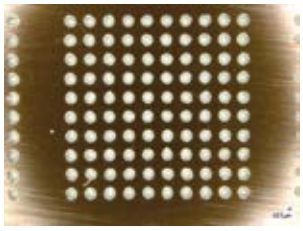
– Good, stable jet dispensability
– Fine, precise patterning
– One-part, solventless, heat-cure material
– Balance of thixotropic and flow properties
– Four different modulus (YM: 0.9, 2.5, 25, 300 MPa)
– "Natural" benefit of silicone
– Electrically conductive option available

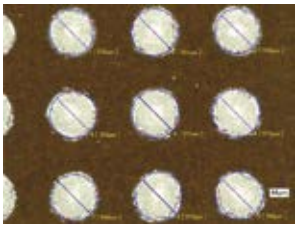


Diameter: 290 µm; height: 40 µm



Jettable electrically conductive adhesive (ECA) (2E-4 ohm.cm): Consecutive 4000 dot w/o failure





Low-bleed-out die attach adhesives (developmental)

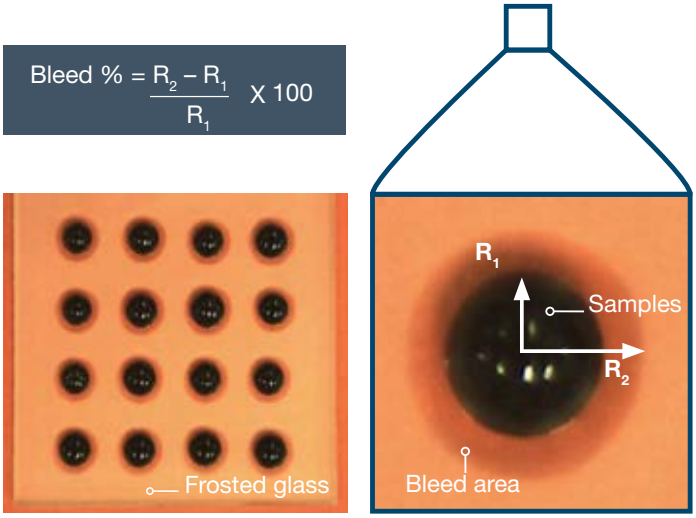
- MEMS die attach requires good stress relief for better sensitivity and accuracy.
  - It tends to need softer materials with larger bond line thickness (BLT) while maintaining stable BLT and tilt control.
- Thanks to the miniaturization and sensor fusion trends, spacing for packaging is getting smaller.
  - The bleeding issue of liquid adhesive is getting more serious.
  - Process queue time is getting longer as well, due to miniaturization (larger number of devices on a printed circuit board [PCB]).
- Dow has various liquid die attach options. DOWSIL™ 7920-LV Die Attach Adhesive has a good track record when used for MEMS/sensor die attach applications, yet some customers have limitations due to bleed issues.

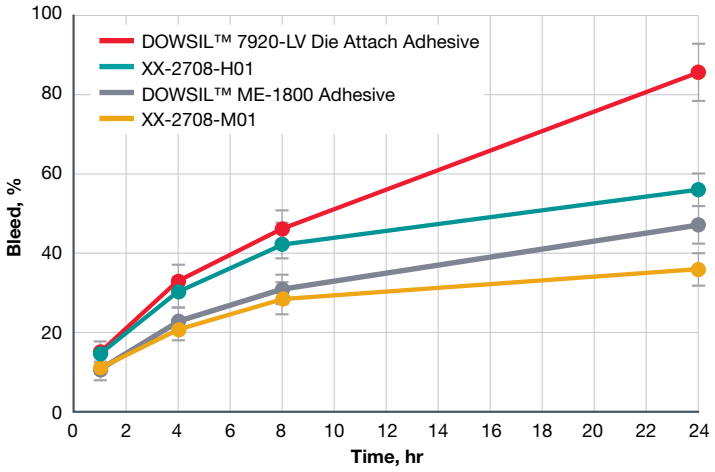
Property	XX-2704-02	XX-2708-M01	XX-2708-H01
Storage condition	-25°C to -15°C		
Viscosity ($10s^{-1}$), Pa-s	48.5	147	102
Thixotropic index ($1s^{-1}/10s^{-1}$)	2.1	1.8	2.8
Standard cure condition	60 minutes at 150°C		
Shore hardness	A52	D45	D59
Elongation, %	295	55	15
Tensile strength, MPa	4.6	5.6	6.9
Die shear strength (Al/GL), MPa	5.2	6.7	6.5
Pot life* at 25°C,%	98	–	–

*Pot life: Change rate of viscosity at 25'C, 24 hr.

Time course of bleed-out on frosted glass at room temperature

$$\text{Bleed \%} = \frac{R_2 - R_1}{R_1} \times 100$$



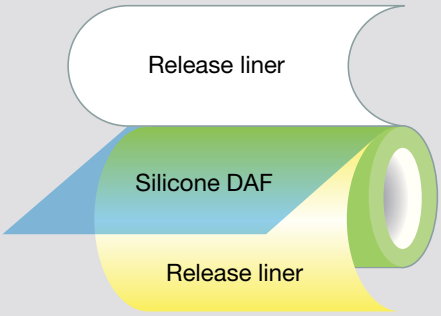


Cured silicone die attach film (developmental)

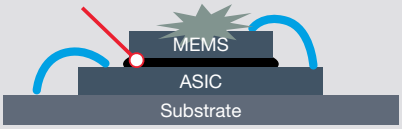
This die attach film (DAF) is “cured” film, yet it has chemical adhesion on the surface

This rather unique technology enables:

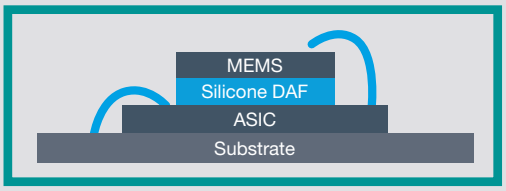
- Relatively thick BLT (range: 25-300 µm, Std. = 25,75) with excellent uniformity
- Excellent stress decoupling: soft elastic (YM: 3 MPa) over -40°C to +200°C range
- Reliable adhesion (no pressure sensitive)
- No fillet; no bleed-out
- Capable of wafer backside lamination process



Epoxy DAF



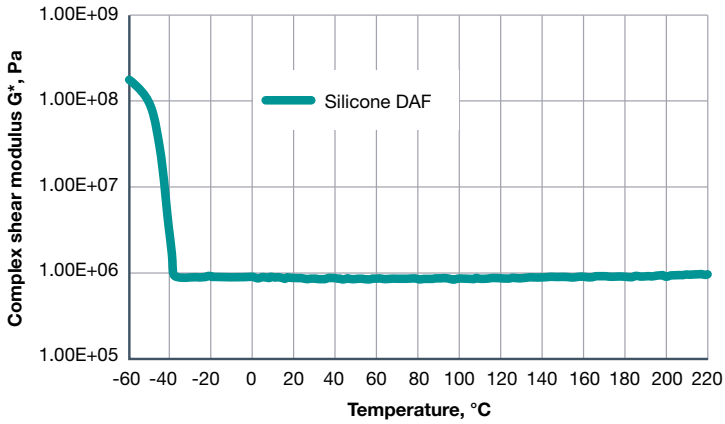
Liquid silicone



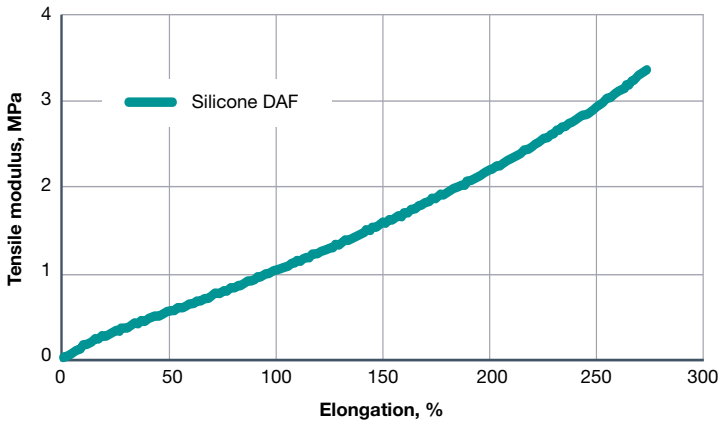
ASIC = application-specific integrated circuit.

	Fillet	Bleed	High BLT	Stress relief	Die tilt/shift	Easy process
Epoxy DAF	Good	Good	*Fair*	Poor	Good	Excellent
Liquid silicone DA	Poor	Poor	Poor	Excellent	Poor	*Fair*
Silicone DAF	***Excellent***	***Excellent***	***Excellent***	***Excellent***	***Excellent***	**Need to modify**

DMA data



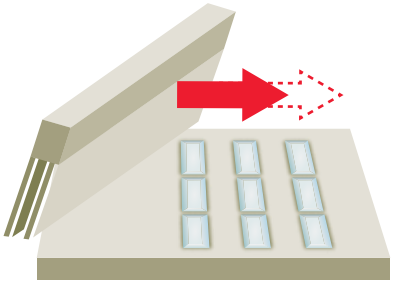
Stress-strain curve of film adhesives (2 mmT)



Processing options

Material options for processing

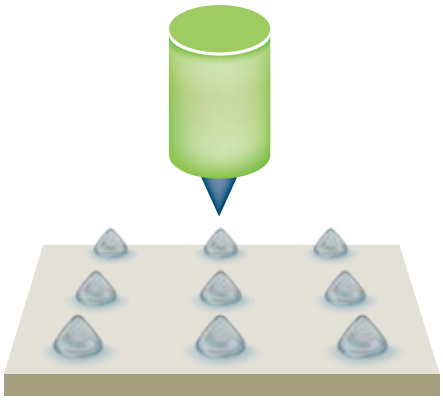
Device processing preferences, equipment availability or cost-based requirements may affect the silicone design materials employed for selected MEMS sensors and actuators. DOWSIL™ silicone products are available to suit various process options and curing choices.



Printing

- **Higher** viscosity
- Medium thixotropic index (TI) for good printability
- Consideration of **area ratio**
- Excellent printing life

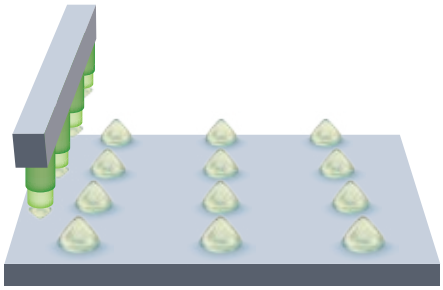
Easy to process



Dispensing/jetting

- **Medium** viscosity
- Higher TI for good anti-slump characteristic
- Stable tackiness force with good dispensing rate

Deposit fix to various patterns

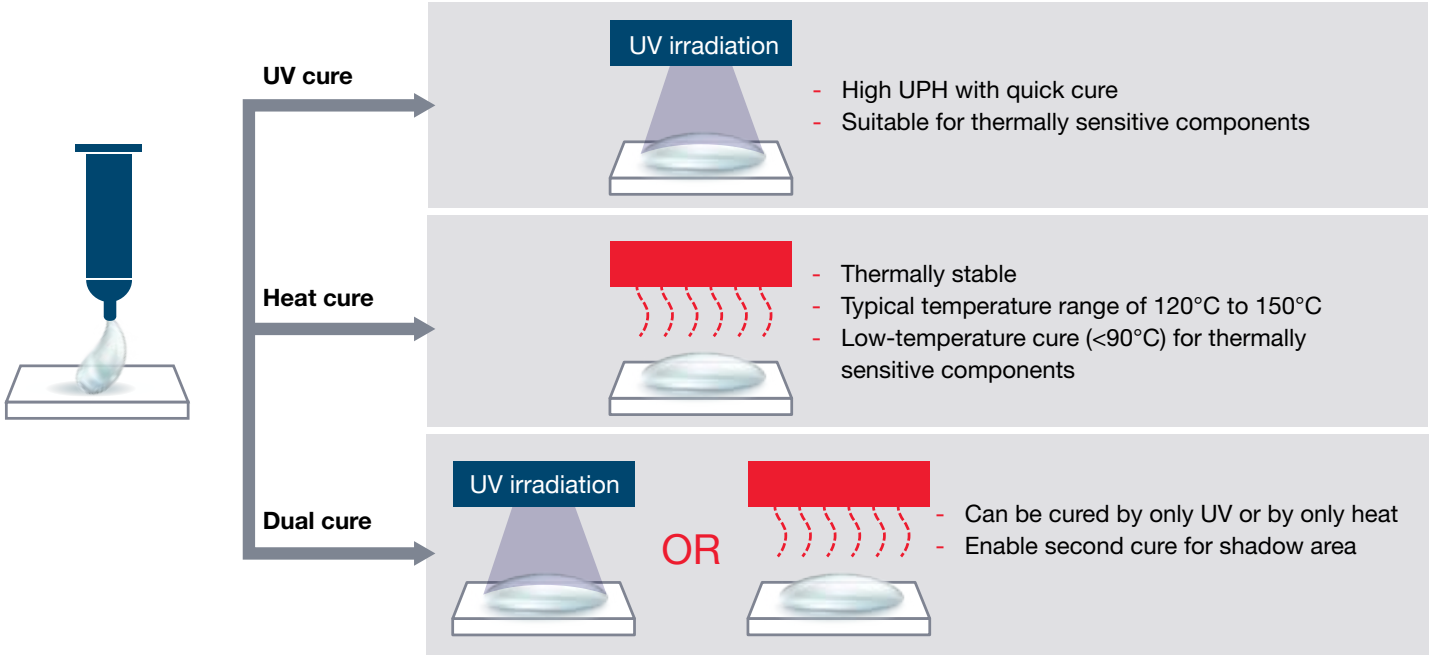


Stamping

- **Lower** viscosity
- Higher TI for good anti-slump characteristic
- Stable tackiness force for uniform dipping volume

Precise deposit; low units per hour (UPH)

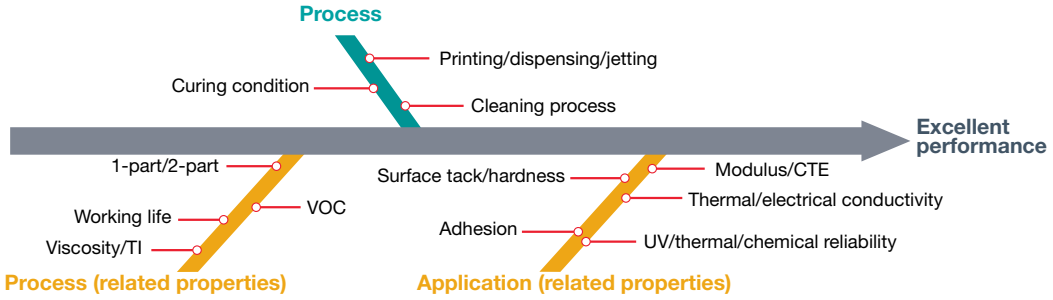
Curing choices for processing



Product selection guidelines

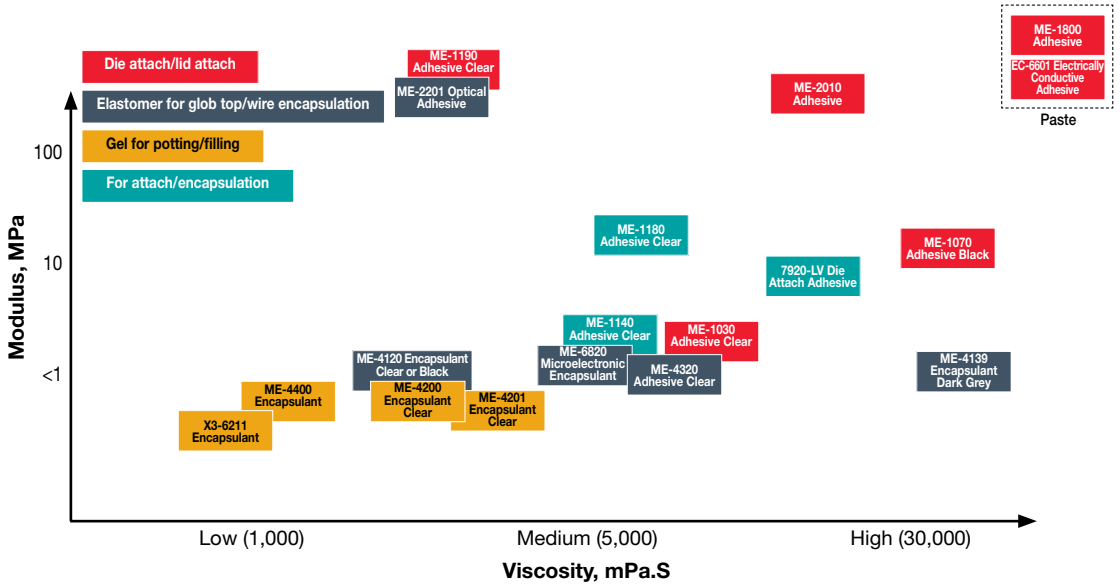
Successful, effective DOWSIL™ silicone products can meet key design requirements for advanced MEMS sensors and actuators that are being widely used across most industries. Some of the basic guidelines for product selection are provided here.

Key pillars for technology choice



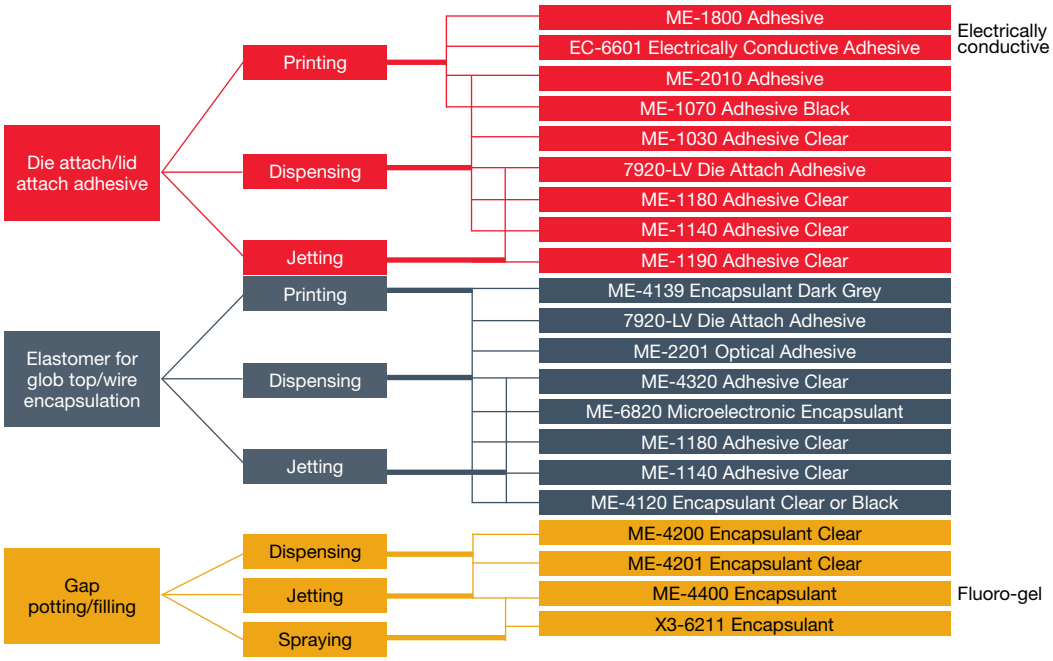
Selection by material property

All products are DOWSIL™ brand.



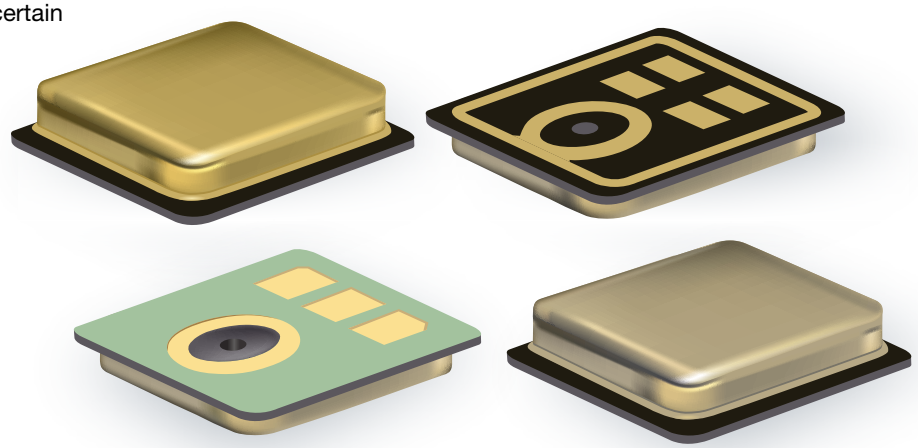
Selection by process and application

All products are DOWSIL™ brand.



Typical MEMS applications

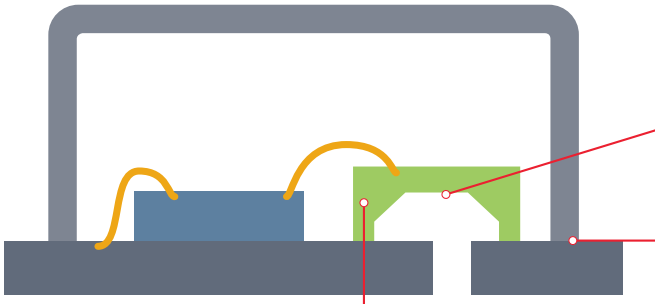
MEMS sensors and actuators generally consist of a central unit that processes data and several components that serve to sense certain external conditions or activate certain control elements. Commercial applications for MEMS technologies include automotive airbag sensors, electronics data storage systems, healthcare pacemakers and blood pressure sensors, defense guidance systems, and communications splitters/couplers. Some typical applications are shown here.



Microphone

MEMS microphones enable dramatic advancements in sound quality, such as low self-noise, a wider dynamic range and low distortions. To replace conventional ECMs (electret condenser microphones), they offer:

- Smaller size
- Easy processing
- Thermal resistance to reflow



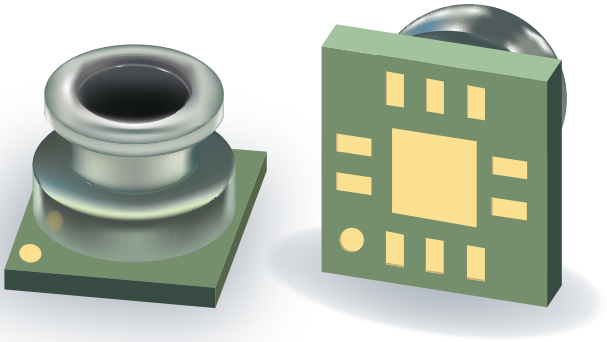
Die coating
DOWSIL™ ME-6820 Microelectronic Encapsulant,
DOWSIL™ 7920-LV Die Attach Adhesive

Cap adhesive
(EMI for HD audio)
DOWSIL™ ME-1070 Adhesive Black,
DOWSIL™ ME-1800 Adhesive

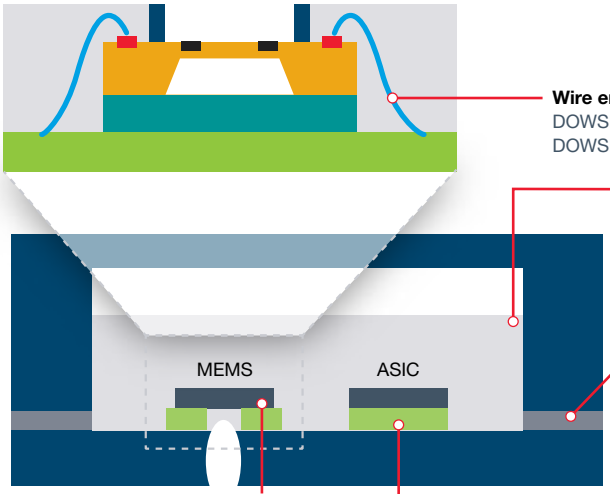
MEMS die attach
DOWSIL™ ME-1070 Adhesive Black,
DOWSIL™ 7920-LV Die Attach Adhesive

Pressure sensor

MEMS pressure sensors work by converting pressure signals into electrical signals. As pressure deflects a thin silicon membrane, it creates mechanical strain, which is then transformed into a change in electrical resistance and read out as a change in voltage.



Side by side



Wire encapsulation
DOWSIL™ ME-4120 Encapsulant Clear or Black, DOWSIL™ ME-4132 Encapsulant Black

Encapsulation
FLUOROGEL™ Q3-6679 Dielectric Gel, DOWSIL™ ME-4039 Protective Coating, DOWSIL™ X3-6211 Encapsulant

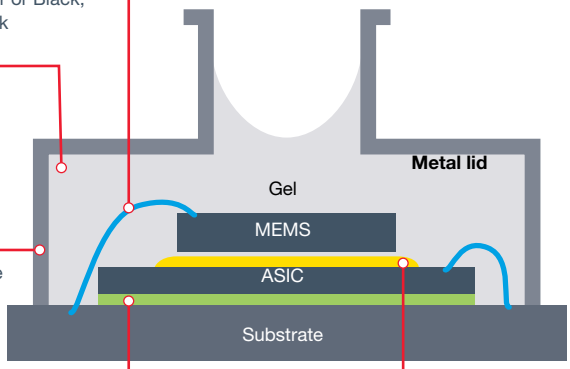
Lid seal
DOWSIL™ ME-1070 Adhesive Black, DOWSIL™ ME-1800 Adhesive

MEMS die attach
DOWSIL™ ME-1070 Adhesive Black, DOWSIL™ 7920-LV Die Attach Adhesive

DOWSIL™ ME-1800 Adhesive, DOWSIL™ ME-1030 Adhesive Clear

ASIC die attach

Die stacking

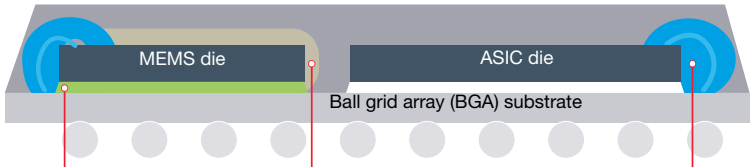


DAF

Inertial sensor

MEMS inertial measurement units (IMUs) or sensors typically are used for complex motion capture and processing in various industrial, healthcare and military/aerospace applications.

Side by side



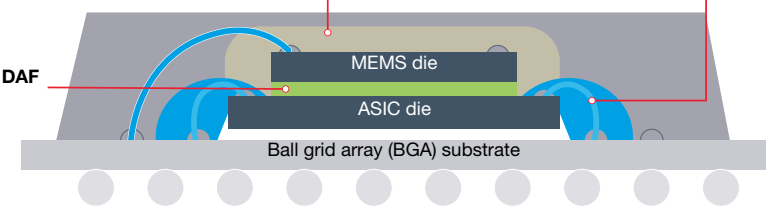
MEMS die attach
DOWSIL™ ME-1070 Adhesive Black, DOWSIL™ 7920-LV Die Attach Adhesive

DOWSIL™ ME-1800 Adhesive, DOWSIL™ ME-1030 Adhesive Clear

Die coating
DOWSIL™ ME-4039 Protective Coating, DOWSIL™ ME-4046 Encapsulant Clear Kit, DOWSIL™ ME-6820 Microelectronic Encapsulant

Wire encapsulation
DOWSIL™ ME-4120 Encapsulant Clear or Black, DOWSIL™ ME-4132 Encapsulant Black

Die stacking



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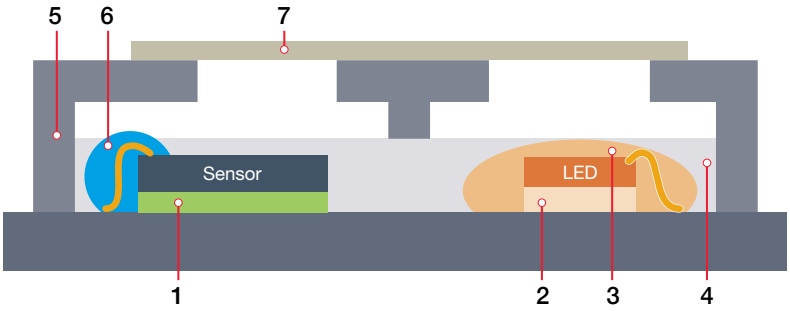
Optical sensor

MEMS optical sensors convert light rays into electronic signals that are then translated by an integrated measuring device. Different types of optical sensors can measure material surface conditions, vibrations or movement, mechanical forces, acoustics, and electric fields.

Typical package for optical sensor



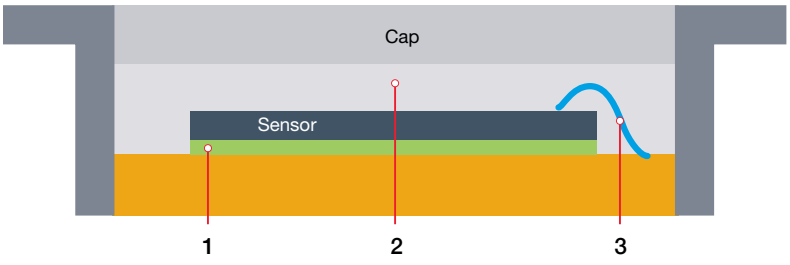
Design material*		CTQ** need(s)	Option(s)
1	Die attach	Less bleeding out; good adhesion	DOWSIL™ ME-1070 Adhesive Black, DOWSIL™ 7920-LV Die Attach Adhesive; DOWSIL™ ME-1030 Adhesive Clear, DOWSIL™ FA-9040 Silicone Elastomer Blend
2	Light-emitting diode (LED) die attach	ECA or solder paste	DOWSIL™ ME-1800 Adhesive; ***
3	Chip encapsulant	Optical requirement; high hardness	***
4	Overmolding	Optical shielding	DOWSIL™ 7920-LV Die Attach Adhesive, DOWSIL™ ME-4039 Protective Coating
5	Lid attach	Black type to avoid light escaping (OD requirement)	DOWSIL™ ME-1070 Adhesive Black, DOWSIL™ ME-1800 Adhesive
6	Wire encapsulant	Thixotropic	DOWSIL™ ME-4120 Encapsulant Clear or Black, DOWSIL™ ME-4132 Encapsulant Black
7	Protective film	Optical requirement	PSA

*All materials are required for good reliability. | **CTQ = Six Sigma Critical To Quality. | ***Refer to LED package options.

Fingerprint sensor

A MEMS fingerprint sensor typically uses pressure differences to distinguish between the ridges and valleys of a fingertip. These silicon-based capacitive film sensors have low-cost processing technology and are widely used in applications from smartphones to corporate security.

Typical package for fingerprint sensor



Design material*		CTQ** need(s)	Option
1	Die attach	Less bleeding out; no creeping to die; good adhesion to substrate	DOWSIL™ ME-1190 Adhesive Clear
2	Gap fill	Well flowability	DOWSIL™ ME-1180 Adhesive Clear
3	Wire encapsulant	Thixotropic	DOWSIL™ ME-4135 Encapsulant Black

*All materials are required for good reliability. | **CTQ = Six Sigma Critical To Quality.

How can we help you today?

A broad selection of successful, effective DOWSIL™ silicone materials is available to meet the demanding performance requirements for MEMS sensors and actuators being used in a diverse range of applications. Dow can help enable innovative design and processing options for MEMS development customers serving consumer and automotive electronics industries. Tell us about your performance, design and manufacturing challenges. Let us put our silicon-based materials and application knowledge and our processing experience to work for you.

Learn more

Dow offers much more than just an industry-leading portfolio of advanced design and assembly materials for MEMS sensors and actuators. As your dedicated innovation leader, we bring process and application experience, collaborative problem-solving, a reliable global supply base, and world-class customer service. To find out how Dow can support your MEMS design and application needs, visit **dow.com/electronics.**

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