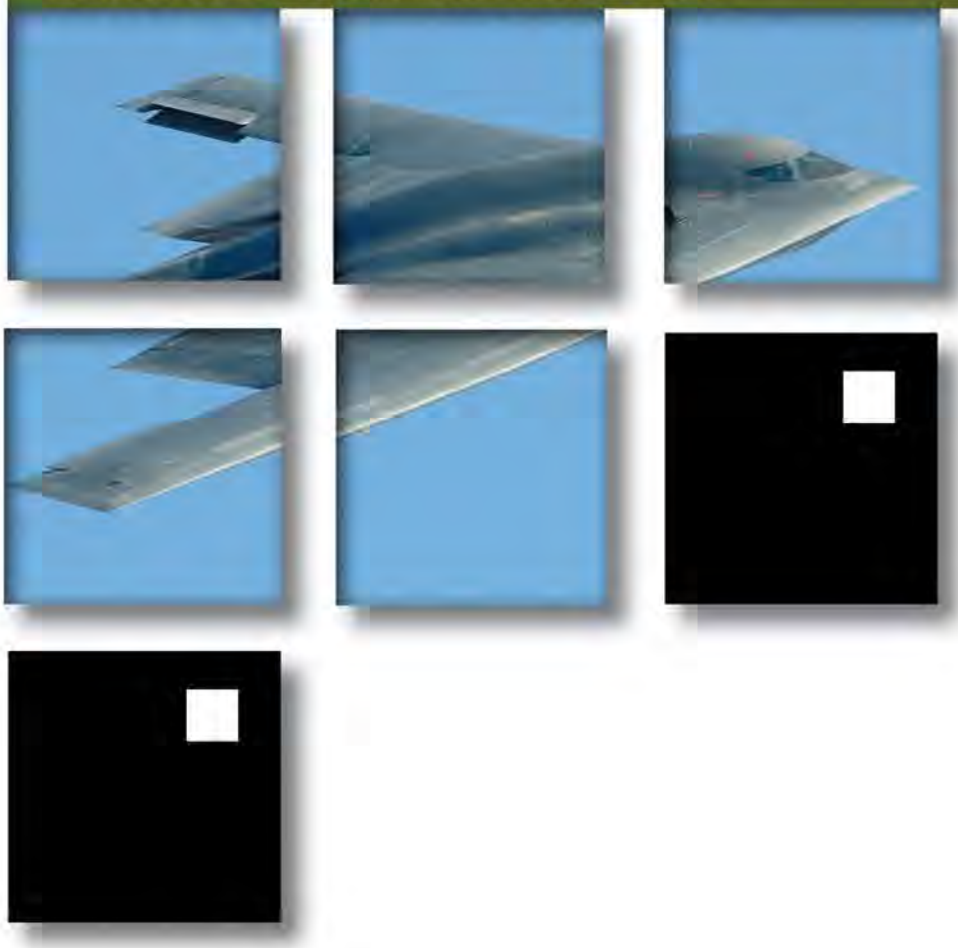
Aircraft Materials Selection Guide



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NuSil Technology is the cutting edge manufacturer of silicone products for the aircraft industry requiring precise, predictable materials. NuSil's silicone materials deliver adhesives, potting compounds, encapsulants, and fast-curing silicones.

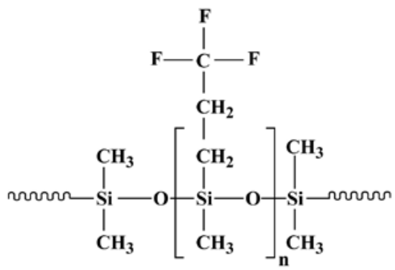
ISO 9001 certified since 1994, and AS 9100 certified since 2008, NuSil operates state-of-the-art laboratories and processing facilities in North America and provides on-site, in-person application engineering support worldwide.

Benefits of Silicone Materials for Aircraft

The Aircraft Industry has used silicone adhesives and coatings for over five decades. Silicone's ability to maintain its elasticity and low modulus over a broad temperature range provides excellent utility in extreme environments. Recent advances in material technology provide more opportunities for the Aircraft engineer in choosing the best material for an intended application. Examples of NuSil's capabilities in custom silicones for Aircraft are demonstrated in the following sections.

Fuel Resistance

A standard requirement for the aircraft industry is to use materials that are fuel resistant. The breadth of material choices for these types of applications is attributable to advances in Fluorosilicone technology, which are based on trifluoropropyl methylpolysiloxane polymers. The trifluoropropyl group contributes a slight polarity to the polymer, resulting in swell resistance against hydrocarbons (i.e. gasoline, jet fuels, hydraulic fluids, etc.) While some Fluorosilicones contain 100% trifluoropropyl methylpolysiloxane repeating units, other systems contain a combination of the fluorosiloxane units and dimethyl units to form a co-polymer. Adjusting the amount of trifluoropropyl methyl siloxane units in the polymerization phase provides optimal performance in specific applications. Functional fillers can be added to Fluorosilicone materials and used as gap fillers, coatings, molded parts, repair butters, or for other applications and they can also be calendared into sheets or ribbons.



Fluorosilicone

Operating Temperature

The operating temperature range of a silicone in any application is dependent on many variables, including but not limited to: temperature, time of exposure, type of atmosphere, exposure of the material's surface to the atmosphere, and mechanical stress. In addition, a material's physical properties will vary at both the high and low end of the operating temperature range. Silicone typically remains flexible at extremely low temperatures and has been known to perform at -140 ˚C as well as resist breakdown at elevated temperatures up to 315 C. The user is responsible to verify performance of a material in a specific application.

Static Dissipation and Electrically Conductive Silicones

Progression in technology has greatly influenced the use of lightweight composite materials to replace aluminum aircrafts. Aluminum has long been used for the skin and frames of aircraft, acting as a Faraday cage by spreading electrical impact along the external skin, fuselage and wings. Faraday cages protect electronic equipment from light-ning strikes, electrostatic discharges, or radar signatures. The downside to using composite materials is their inability to deflect electric charge.

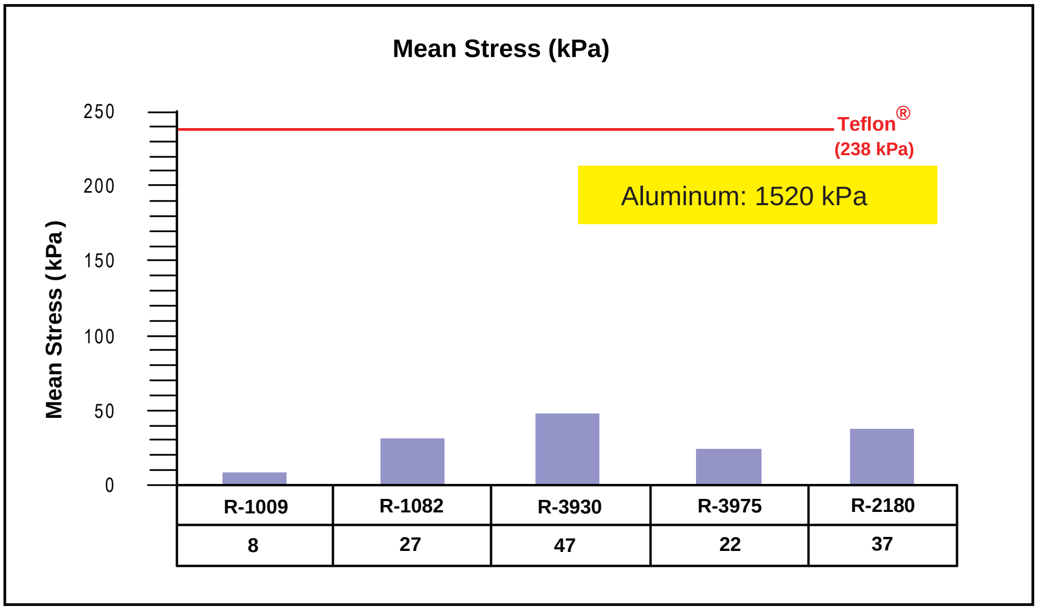
Electrically conductive additives incorporated into NuSil's silicones provide protection against static accumulation and discharge that can damage sensitive electronic components. The static is allowed to dissipate continuously rather than accumulate and discharge rapidly. The electrical conductivity is measured by volume resistivity (Ω·cm) and is used to gauge the shielding effectiveness of the material. Electrically conductive fillers are typically metal particles (<0.1 ohm·cm) or carbon black (>1 ohm·cm). It is important that an electrically conductive silicone maintain its shape and conductivity under stress (i.e. elongation or compression). This provides stress relief during thermal cycling between substrates with different Coefficient of Thermal Expansions (CTEs).

Ice-Phobic Coatings

Ice build up is a serious problem and major economic impact in the aircraft industry. Silicone has the ability to remain elastic at low temperatures and resistant to breakdown at high temperatures, thus making it valuable in harsh environments. Compared to other Ice-Phobic coatings and materials known to have non-stick properties such as Teflon®, select silicone coatings can significantly reduce ice adhesion when applied to aerodynamic surfaces. Ice-Phobic coatings are useful in many applications where surfaces and structures are exposed to icing conditions:

Aerodynamic Surfaces – Aircraft Wings and Control Surfaces, UAV Structures, Engine Cowlings, Wind Turbines
Hydrodynamic Surfaces – Marine Vessels (i.e. Naval Ships, Fishing, Cargo, Ice-breakers), Lock Walls
Structures – Above Ground Power Lines, Roof Tops, Observatories, Antennas

In a recent study, the ice adhesion strengths of Ice-Phobic coatings were tested and compared using a method developed to measure the bond strength of ice to a substrate. The force required to break the ice from the substrate surface is measured as mean stress. In the graph below, NuSil's Ice-Phobic coatings show very favorable performance against the industry standard - Teflon® and bare aluminum.



*Coating thickness = 0.010 inches

NuSil's ability to custom formulate has advanced efforts to develop alternate formulations to further accommodate Ice-Phobic applications. Currently, NuSil is evaluating new formulations that increase contact angle.

References

- EM 1110-2-1612, Engineering and Design – Ice Engineering, U.S. Army Corps of Engineers, Department of the Army, October 20, 2002, Updated Version September 2006.
- Mulherin, ND, RB Haehnel, JF Jones (1998) Toward developing a standard shear test from ice adhesion. Proceedings, 8th International Workshop on Atmospheric Icing Structures, Reykjavik, Iceland, June 8-11, 1998. IWAIS '98.

Properties listed are typical - Do not use as a basis for preparing specifications. Please contact NuSil Technology for assistance and recommendations

General Purpose	NuSil Product Number	Comments	Cure System	Work Time	Tack Free Time	Cure Time / Temp °C	Specific Gravity	Durometer Type A	Tensile psi (mPa)	Elongation %	Tear ppi (kN/m)	Lap Shear psi (MPa)	Dielectric Strength V/mil	Flow (Inches) Viscosity (cP/mPa·sec) Extrusion (g/min)	Mix Ratio	Color
FLUOROSILICONES – ADHESIVES & SEALANTS	CF1-3510	Fuel / Solvent Resistant	Platinum	6 h	-	30 m / 150	1.50	25	175 (1.2)	150	-	-	-	A:70,000 / B:10	10:1	Red
	CF2-3521	Fast Cure	Platinum	-	-	30 m / 150	1.30	35	750 (5.2)	325	-	-	-	-	1:1	Trans
	CF2-3521-2	Fuel Resistance	Platinum	60 m	-	48 h / R.T.	1.28	35	600 (4.1)	265	-	*4) 350 (2.4)	-	Paste	1:1	Black
	R7-3521-11	Solvent Resistance	Platinum	60 m	-	48 h / R.T.	1.27	30	500 (3.4)	260	35 (6.2)	-	-	-	1:1	Gray
	FS-3730	Available in Gray / Black / Translucent	Acetoxy	-	30 m	72 h / R.T., H	1.40	35	850 (5.9)	425	60 (10.6)	*3) 380 (2.6)	-	Thixotropic	-	White
	FS-3730-2	Lap Shear after 7 days *3) 300 psi (2.1 MPa)	Acetoxy	-	10 m	72 h / R.T., H	1.41	40	600 (4.1)	300	50 (8.1)	See Comments	-	Thixotropic	-	Black
	FS-3730-11	Lap Shear after 7 days *1) 275 psi (1.9 MPa)	Acetoxy	-	15 m	72 h / R.T., H	1.48	40	700 (4.8)	275	50 (8.1)	See Comments		Thixotropic	-	Dk. Gray
	FS1-3730	Bonds Aggressively	Acetoxy	-	30 m	7 d / R.T., H	1.40	35	850 (5.9)	425	60 (10.6)	275	-	150 g/min	-	Trans
	FS3-3730	Fuel Resistance, 100 m%, Fast Cure	Acetoxy	-	15 m	72 h / R.T., H	1.35	35	850 (5.9)	400	55 (9.7)	-	-	240 g/min	-	Trans
	FS-3775	High Temperature, Fuel Resistant	Acetoxy	-	8 m	72 h / R.T., H	1.29	30	450 (3.1)	400	40 (7.1)	-	-	250 g/min	-	Trans
COATINGS	R-3900	Cure: 8 h / 25 °C : 45 m / 75 °C : 135 M / 150 °C, Dispersion Coating, 20% Solids	Platinum	-	-	See Comments	-	50	1,200 (8.3)	900	275 (48.5)	-	-	1,900	1:1	Trans
	R-3930	Dispersion Coating, 60% Solids	Acetoxy	-	-	72 h / R.T., H	1.36	35	850 (5.9)	400	50 (8.8)	-	-	-	-	Trans
	R1-3930-11	240*3) psi (1.7Mpa) Lap Shear at 7 D @ R.T., H / Fed. Color Standard 36118	Acetoxy	-	20 m	72 h / R.T., H	1.48	40	725 (5.0)	250	40 (7.1)	-	-	Thixotropic	-	Gray
	R2-3930-11	315*3) psi (2.2Mpa) Lap Shear at 7 D @ R.T., H / Fed. Color Standard 36622	Acetoxy	-	20 m	72 h / R.T., H	1.36	40	900 (6.2)	400	60(10.6)	-	-	Thixotropic	-	Lt. Gray
	R3-3930-11	375*3) psi (2.6Mpa) Lap Shear at 7 D @ R.T., H / Fed. Color Standard 36375	Acetoxy	-	20 m	72 h / R.T., H	1.36	40	800(5.5)	400	50(8.1)	-	-	Thixotropic	-	Gray
	R-3975	Dispersion Coating, 60% Solids	Acetoxy	-	-	72 h / R.T., H	1.29	25	425 (2.9)	400	35 (6.2)	-	-	-	-	Trans
FOAM	CF1-3710-2	Fuel / Solvent Resistant Foam, 50 lb/ft^3 (800 Kg/m^3)	Platinum	-	10 m	1 to 4 h / R.T.	-	-	-	-	-	-	-	-	1:1	Gray
FLUIDS	FS-3600	Fuel Resistant Fluid	-	-	-	-	1.28	-	-	-	-	-	-	1,000 to 2,000	-	Trans
	FS-3602	Fluid, Volume Resistivity 1x10^{15} ohms·cm	-	-	-	-	-	-	-	-	-	-	400	350, 1,000 and 12,500	-	Trans
	FS-3606	Fluid, Volume Resistivity 1x10^{15} ohms·cm	-	-	-	-	-	-	-	-	-	-	400	350, 1,000 and 12,500	-	Trans
GEL	GEL-3500	Fuel Resistant Gel, Durometer -Type '00' 50	Platinum	12 h	-	45 m / 150	-	See comments	-	-	-	-	-	A:12,000 / B:10,500	1:1	Trans
LSR	FS-3511	Liquid Injection Molding, Fast Cure	Platinum	24 h	-	30 m / 150	1.39	42	850 (5.9)	240	40	-	-	A:70 g/min / B:180 g/min	1:1	Trans
	CF5-3521-2	Liquid Injection Molding, Fuel Resistance	Platinum	3.5 h	-	48 h / R.T.	1.30	30	550 (3.8)	275	35 (6.2)	-	-	240,000	1:1	Black
HCR	FS-3780	Extrusion or Compression Molding	Peroxide	-	-	5 m / 116	1.44	51	1,442 (9.9)	296	135 (22.9)	-	-	-	-	Trans
	FS-3781	Extrusion or Compresion Molding, Precatalyzed	Peroxide	-	-	30 m / 120	1.33	30	850 (5.9)	300	40 (7.1)	-	-	-	-	Trans
T.C.	CF1-3800	*22) Thermally Conductive 1.25 W/m·K, Fuel Resistance	Platinum	90 m	-	30 m / 150	1.53	50	125 (0.86)	50	-	-	-	Paste	15:1	White

T.C. = Thermally Conductive
HCR = High Consistency Rubber
LSR = Liquid Silicone Rubber

d = day
h = hour
m = minutes

R.T. = Room Temperature
H = Humidity

*1) Primed with SP-120
*3) Primed with SP-130
*4) Primed with CF1-135

g/min = Grams Per Minute
Trans = Translucent

*1) Primed with SP-120
*3) Primed with SP-130
*22) = Tested ASTM C177

General Purpose	NuSil Product Number	Comments	Cure System	Work Time	Tack Free Time	Cure Time / Temp °C	Specific Gravity	Durometer Type A	Tensile psi (mPa)	Elongation %	Tear ppi (kN/m)	Lap Shear psi (mPa)	Dielectric Strength V/mil	Flow (Inches) Viscosity (cP/mPa·sec) Extrusion (g/min)	Mix Ratio	Color
Properties listed are typical - Do not use as a basis for preparing specifications. Please contact NuSil Technology for assistance and recommendations																
GENERAL – ICE PHOBIC	R-1009	Dispersion Coating / Conformal, 33% Solids	Oxime	-	60 m	7 d / R.T., H	1.10	40	1,200 (8.3)	650	95 (16.8)	-	-	6,500	-	Trans
	R-1082	One-Part, 30% Solids	Acetoxy	-	-	5 d / R.T., H	1.09	25	1,425 (9.8)	950	125 (22.0)	-	-	700	-	Clear
	R-2180	Cure: 30 M / 25 °C : 45 M / 75 °C : 135 M / 150 °C, 20% Solids	Platinum	>72 h	-	See Comments	-	40	1,700 (11.7)	1,050	300 (52.9)	-	-	3,600	1:1	Trans
	R-2180-2	Cure: 30 M / 25 °C : 45 M / 75 °C : 135 M / 150 °C, 20% Solids	Platinum	-	-	See Comments	-	40	1,650(11.4)	1,000	300 (52.9)	-	-	3,200	1:1	Black
	R-3930	Fuel Resistant, High Strength	Acetoxy	-	-	72 h / R.T., H	1.36	35	850 (5.9)	400	50 (8.8)	-	-	-	-	Trans
	R-3975	Fuel Resistant, High Temperature	Acetoxy	-	-	72 h / R.T., H	1.29	25	425 (2.9)	400	35 (6.2)	-	-	-	-	Trans
COATINGS	R3-1075	Dispersion Coating / Conformal, 60% Solids	Oxime	-	80 m	7 d / R.T., H	1.06	40	700 (4.8)	350	40 (7.1)	-	1256	3,300	-	Trans
	CF19-2615	Solventless	Platinum	4 h	-	30 m / 150	-	30	120 (0.82)	100	-	-	500	A:1,300 / B:800	1:1	Trans
	R-1182	Low Friction Coating	-	-	-	-	-	-	-	-	-	-	-	-	-	Trans
ADHESIVES & SEALANTS	R-1130	Adhesive, Non-slump	Oxime	-	25 m	7 d / R.T., H	1.10	35	850 (5.86)	325	40 (7.05)	485 (3.6)	-	0.5 Inches	-	Trans
	R-1140	Adhesive, Non-slump	Acetoxy	-	7 m	72 h / R.T., H	1.08	30	600 (4.13)	350	40 (7.05)	625 (4.3)	-	1.5 Inches	-	Trans
	R4-1140	Adhesive	Acetoxy	-	10 m	72 h / R.T., H	1.12	25	1,400 (9.65)	750	100 (17.63)	-	-	2 inches	-	Trans
	R-2145	Extremely Tough , Fast Cure Elastomer	Platinum	15 m	-	2 h / 65	1	45	1,050 (7.20)	400	150 (26.50)	[*4] 600 (4.1)	825	A:275 g/min / B:240 g/min	1:1	Gray
	R1-2145	Longer Work Time, Young's Modulus 300 psi (2.1 MPa)	Platinum	60 m	-	2 h / 65	1.17	45	1,000 (6.89)	400	190 (33.50)	625 (4.3)	825	A:265 g/min / B:250 g/min	1:1	Gray
	R-2160	High Temperature Elastomer	Platinum	50 m	-	30 m / 150	1.20	20	750 (5.17)	625	150 (25.45)	-	500	A:250,000 / B:650	10:1	Red
	R-2550	High Temperature Elastomer	Tin	6 h	-	7 d / R.T., H	1.08	35	500 (3.5)	175	20 (3.5)	-	-	9,000	100:0.5	Trans
	R-2560	High Temperature Elastomer	Tin	2 h	-	7 d / R.T., H	1.41	55	700 (4.8)	125	-	385 (2.7)	-	31,000	100:0.5	Red
SILICONE RESIN	CF-4721	75 Type D with Dicumyl Peroxide Catalyst (Catalyst Not Included)	-	-	-	-	1.10		-	-	-	-	-	125	-	Lt. Amber
	CF2-4721	75 Type D, Precatalyzed	Peroxide	30 d	-	15 m / 150	1.09	See Comments	-	-	-	-	-	130	-	Lt. Amber
MOLD MAKING	R-2200-6	Casting, Creating Molds	Platinum	2 h	-	30 m / 150	1.23	65	850 (5.9)	90	95 (14.1)	-	-	A:135,000 / B:3,750	10:1	Green
	R-2200-11	Casting, Creating Molds	Platinum	>2.5 h	-	30 / 150	1.24	60	800 (5.5)	135	100 (17.6)	-	-	A:140,000 / B:3,000	10:1	Gray
SILICONE FOAM	SFM5-2350	Flame Resistant, 25 lb/ft^3 (0.400 g/cm^3)	Platinum	22 m	-	45 m / 100	0.35	-	-	-	-	-	190	A:55,000 / B:45,000	1:1	Gray
	R-2370	Low Density / Soft, 10 lb/ft^3 (0.16 g/cm^3)	Tin	-	-	10 m / R.T., H	-	-	-	-	-	-	-	4,700	100:6	Tan
	R-2380	Medium Density / Soft, 19 lb/ft^3 (0.31 g/cm^3)	Tin	-	-	10 m / R.T., H	0.34	-	-	-	-	-	-	3,600	100:6	Tan
GEL	GEL-8170	High Purity, Volume Resistivity 1x10^{15} ohm·cm	Platinum	-	-	90 m / 80	0.97	-	-	-	-	-	500	600	1:1	Trans
STATIC DISSIPATIVE	R-1505	8 ohm·cm. Static Dissipation	Oxime	-	10 m	7 d / R.T., H	1.24	75	550 (2.4)	20	-	-	10	Non-slump	-	Black
	R-2630	7 ohm·cm, Low viscosity	Platinum	10 h	-	30 m / 150	1.09	60	700 (4.8)	95	35 (6.2)	-	10	9,400	10:1	Black
	R-2631	50 ohm·cm, Low Durometer, Tough	Platinum	8 h	-	60 m / 65	1.07	40	600 (4.5)	275	50 (8.8)	-	-	100 g/min	1:1	Black
E. C.	R-2634	0.001 ohm·cm, Low / High Temperature	Tin	3 h	-	7 d / R.T., H	3.36	80	250 (1.7)	90	50 (8.8)	195 (1.3)		90 g/min	100:0.5	Tan
	R-2637	0.006 ohm·cm	Platinum	4 h	-	30 m / 150	3.60	60	210 (2.1)	275	-	-	5	Smooth Paste	20:1	Tan
THERMALLY CONDUCTIVE	R-2930	1.46 W/mk Thermal Conductivity	Platinum	3 h	-	30 m / 150	1.55	80	260(1.72)	20	-	-	880	Paste	15:1	White
	R-2939	0.75 W/mk Thermal Conductivity	Platinum	2 h	-	30 m / 150	1.34	70	275(1.9)	80	40(7.05)	-	810	65,000	15:1	White
	R-2940	0.84 W/mk Thermal Conductivity	Platinum	5 h	24 h	30 m / 150	2.41	90	700(4.8)	35	65(11.5)	-	450	Paste	20:1	Gray
	R-2949	0.75 W/mk Thermal Conductivity	Platinum	3.5 h	-	30 m / 150	-	75	275(4.8)	50	45(7.9)	-	920	75,000	15:1	White
PRIMER	SP1-204	1 and 2 Part RTV System, 3.3% S.	Hydrolysis	-	-	1 h / R.T.	0.79	-	-	-	-	-	-	1	-	Trans
	SP-120	General Purpose, 4.1% Solids	Hydrolysis	-	-	1 h / R.T.	0.77	-	-	-	-	-	-	1	-	Clear
	SP-121	General Purpose, 3.5% Solids	Hydrolysis	-	-	1 h / R.T.	0.77	-	-	-	-	-	-	1	-	Red
	CF1-135	Addition Cure Systems,4.5% Solids	Hydrolysis	-	-	30 m / R.T.	0.77	-	-	-	-	-	-	1	-	Clear
	CF6-135	Addition Cure Systems, Inhibiting Enviroments, 8.5% Solids	Hydrolysis	-	-	30 m / R.T.	0.78	-	-	-	-	-	-	1	-	Trans
	CF1-141	Addition Cure Systems, 6% Solids	Hydrolysis	-	-	1 h / R.T.	0.80	-	-	-	-	-	-	1	-	Red
	SP-270	Addition Cure Systems, Difficult Substrates, 15% Solids	Hydrolysis	-	-	1 h / R.T.	0.77	-	-	-	-	-	-	1	-	Trans
	SP-271	Improves Adhesion to Gold and Ceramic PMMA	-	-	-	30 m / R.T.	0.80	-	-	-	-	-	-	1	-	Trans

E. C. = Electrically Conductive
d = day
h = hour
m = minutes
R.T. = Room Temperature
H = Humidity

[*1] Primed with SP-120
[*3] Primed with SP-130
h CF1-135
Primed with SP-270

g/min = Grams Per Minute

Trans = Translucent
Clear = Clear to Transparent

[*1] Primed with SP-120
[*3] Primed with SP-130
[*22] Tested per ASTM C177

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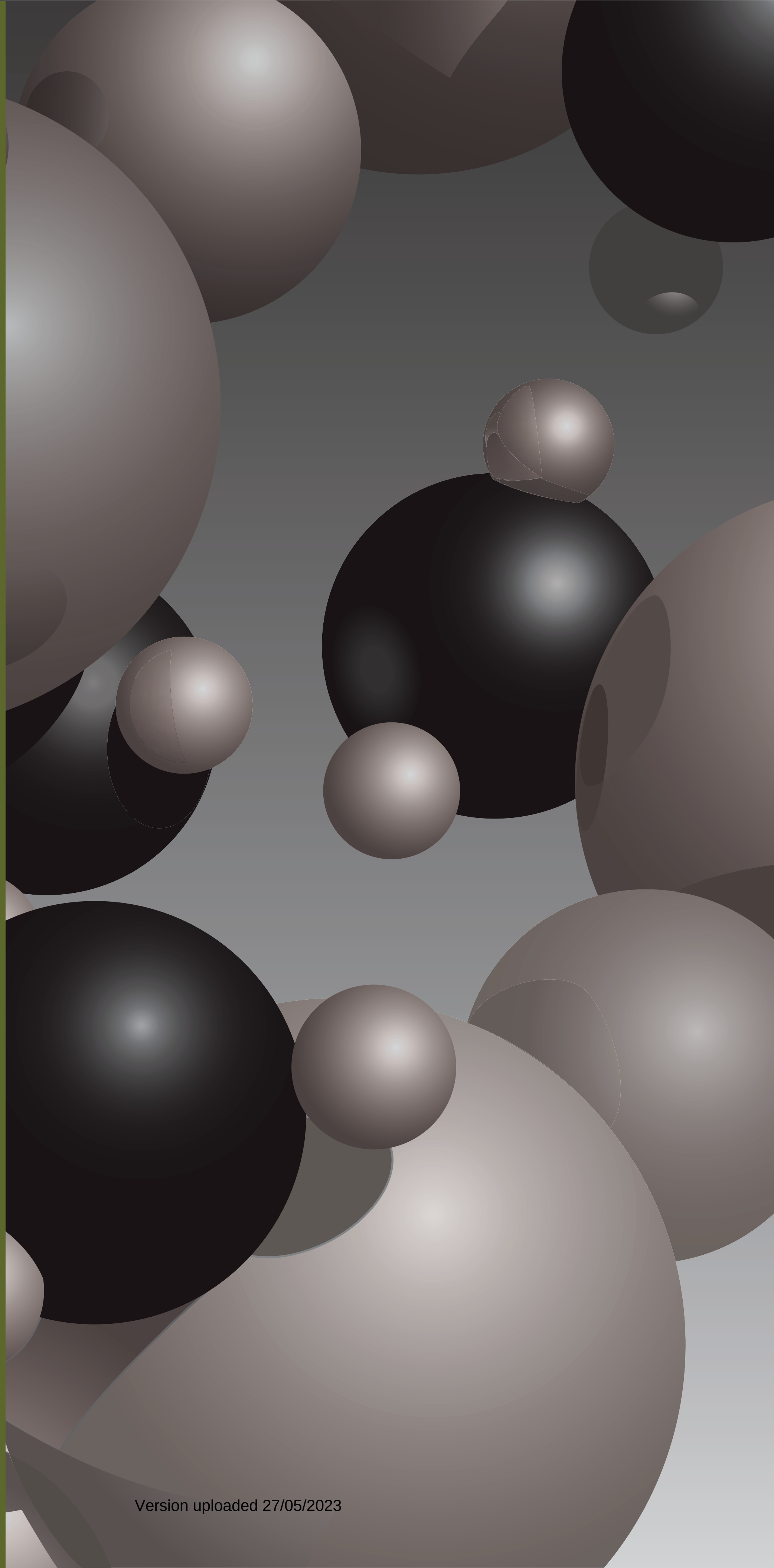
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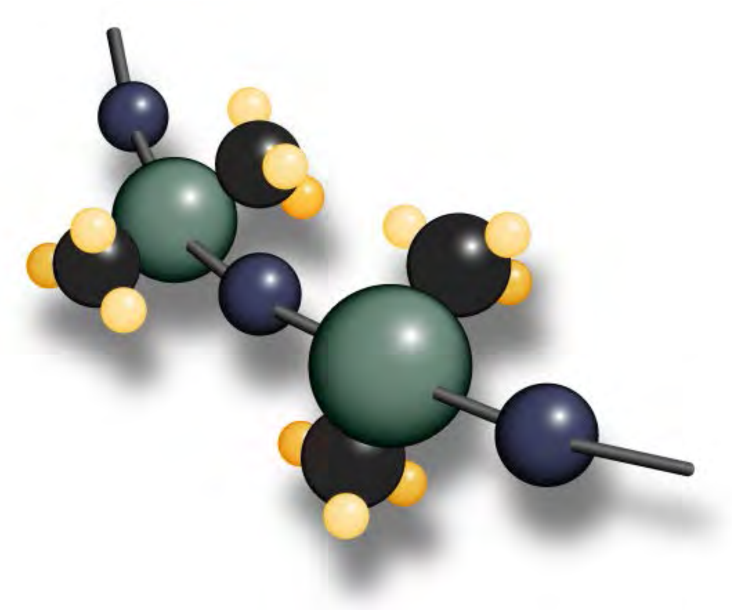

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