Summary of Typical Properties of PLAVIS Polyimide Resin

Property	Temp.	ASTM Method	Unit	PLAVIS-N			PLAVIS-G15			PLAVIS-G40		
				DF	ISO[1]	CM[2]	DF	ISO	CM	DF	ISO	CM
MECHANICAL												
Tensile Strength, Ultimate	23°C	D-1708	kgf/cm² (MPa)	810 (79.4)	900 (88.3)	900 (88.3)	650 (63.7)	680 (66.7)	680 (66.7)	550 (53.9)	580 (56.9)	580 (56.9)
	260°C			400 (39.2)	420 (41.2)	420 (41.2)	330 (32.4)	350 (34.3)	350 (34.3)	270 (26.5)	280 (27.5)	280 (27.5)
Elongation, Ultimate	23°C	D-1708	%	8.5	7.5	8	5.5	4.5	5	3.5	2.5	3
	260°C			7.5	6	6	4.5	3	3	2.5	2	2
Flexural Strength, Ultimate	23°C	D-790	Kgf/cm² (MPa)	860 (84.3)	1,150 (112.8)	1,150 (112.8)	850 (83.4)	1,100 (107.9)		650 (63.7)	900 (88.3)	
	260°C			470 (46.1)	600 (58.8)	600 (58.8)	500 (49.0)	650 (63.7)		400 (39.2)	450 (44.1)	
Flexural Modulus of Elasticity	23°C	D-790	Kgf/cm² (MPa)	26,000 (2,550)	31,000 (3,040)	31,000 (3,040)	32,500 (3,187)	39,000 (3,825)		49,500 (4,854)	49,500 (4,854)	
	260°C			14,500 (1,422)	17,000 (1,667)	17,000 (1,667)	18,000 (1,765)	26,000 (2,550)		28,000 (2,746)	28,000 (2,746)	
Compressive Strength	23°C	D-695	Kgf/cm² (MPa)									
@1% Strain				250 (24.5)	250 (24.5)	250 (24.5)	230 (22.6)	300 (29.4)		250 (24.5)	350 (34.3)	
@10% Strain				1,150 (112.8)	1,200 (127.5)	1,300 (127.5)	1,080 (105.9)	1,400 (137.3)		950 (93.2)	1,100 (107.9)	
@50% Strain												
Compressive Modulus	23°C	D-695	Kgf/cm² (MPa)	24,500 (2,403)	24,000 (2,354)	24,000 (2,354)	23,500 (2,304)	30,000 (2,942)		27,000 (2,648)	34,000 (3,334)	
Impact Strength Izod, Notched	23°C	D-256	kgcm/cm	6.0	6.0	5.0	5.0	5.0				
			J/m	58.8	58.8	49	49.0	49.0				
WEAR & FRICTION												
Wear Rate			m/sx10⁻¹⁰	64	27	27	3.1	2.4	2.4			
Friction Coefficient[3] PV=10kg/cm².m/sec (0.98MPa·m/sec)				0.34	0.32	0.32	0.26	0.23	0.23	0.18	0.16	0.16
THERMAL												
Coefficient of Linear Expansion	23 ~ 260°C	D-696	μm/m/°C (ppm/°C)	50	50	55			45	25		25
Thermal Conductivity	25°C		W/m · °C			0.36	0.45					
	40°C					0.37						
Specific Heat			J/kg · °C			1,042						
			kcal/kg · °C			0.249						
Thermal Decomposition Temperature(on-set point, rate 10°C/min, in air)			°C			565	569			557		
Thermal 50% weight reduction Time (on-set point, rate 10°C/min, in air)			min			154	164			231		
ELECTRICAL												
Dielectric Constant	23, @1GHz	D-150				3.1						
Dielectric Strength		D-149	kV/mm			21.9						
Dissipation Factor	23, @1GHz	D-150	(10⁻⁴)			8.8						
Volume Resistivity	23°C	D-257	Ω-m	1E16-18	1E16-18	1E16-18	1E12-13	1E12-13	1E12-13			
Surface Resistivity	23°C	D-257	Ω/cm²	1E14-16	1E14-16	1E14-16	1E12-13	1E12-13	1E12-13			
OTHER PROPERTIES												
Water Absorption	50%RH(avg)	D-570	%	0.9-1.1	0.9-1.1	0.9-1.1						
24hrs	23°C			0.37	0.23	0.21			0.2			0.2
48hrs	50°C					0.5						
Specific Gravity		D-792	g/cm³	1.33	1.38	1.43	1.41	1.49	1.49	1.56	1.62	1.64
Hardness		D-785	Rockwell"M"	65-90	85-100	90-105	65-85			65-80		

· ISO : Isostatic Molded. · CM : Compression Molded. · Steady State, Unlubricated in the Air

Summary of Typical Properties of PLAVIS Polyimide Resin

Property	Temp.	ASTM Method	Unit	PLAVIS-MS		PLAVIS-C		PLAVIS-ESD		PLAVIS-S	PLAVIS-SG		PLAVIS-S1	PLAVIS-HM
				DF	CM	DF	CM	DF	CM	CM	DF	CM	CM	CM
MECHANICAL														
Tensile Strength, Ultimate	23°C	D-1708	kgf/cm² (MPa)	600 (58.8)	650 (63.7)	800 (78.4)	850 (83.3)	800 (78.4)	850 (83.3)	1,670 (164)	903 (88.8)	1,070 (105.0)	1,670 (164)	1,370 (133)
	260°C					370 (36.2)	400 (39.2)	370 (36.2)	400 (39.2)	650 (64.0)	342 (33.5)	214 (21.0)	650 (64.0)	560 (55)
Elongation, Ultimate	23°C	D-1708	%	4.5	4.0	8.0	7.0	8.0	7.0	8.0	2.5	2.6	8.0	4.0
	260°C					7.0	6.0	7.0	6.0	40.0	4.3	4.3	30.0	16.0
Flexural Strength, Ultimate	23°C	D-790	Kgf/cm² (MPa)	780 (76.5)	800 (78.5)		1,100 (107.9)		1,100 (107.9)	1,800 (176.0)		1,466 (143.8)	2,240 (220.0)	2,040 (200.0)
	260°C			400 (59.2)	450 (44.1)					1,220 (119.6)		928 (91.0)	980 (97.0)	
Flexural Modulus of Elasticity	23°C	D-790	Kgf/cm² (MPa)	33,500 (3,285)	34,000 (3,334)		35,000 (3,432)		35,000 (3,432)	54,620 (5,356)		160,000 (15,690)	59,180 (5,803)	70,400 (6,900)
	260°C			18,500 (1,814)	19,000 (1,863)					35,282 (3,460)		95,850 (9,400)	31,630 (3,100)	
Compressive Strength	23°C	D-695	Kgf/cm² (MPa)											
@1% Strain				350 (34.3)	350 (34.3)	250 (24.5)		250 (24.5)						270 (26.5)
@10% Strain				1,300 (127.5)	1,300 (127.5)	1,500 (147.1)		1,500 (147.1)		2,141 (210.0)				2,400 (235.0)
@50% Strain						3500 (343.2)		3500 (343.2)						
Compressive Modulus	23°C	D-695	Kgf/cm² (MPa)	25,000 (2,452)	25,000 (2,452)	25,000 (2,452)		25,000 (2,452)		82,190 (8,060)				
Impact Strength Izod, Notched	23°C	D-256	kgcm/cm			5.0		5.0		11.7			6.5	
			J/m			49.0		49.0		114.7			64.0	
WEAR & FRICTION														
Wear Rate			m/sx10⁻¹⁰		2.8					11.0	8.3	30.0	1.0	2.8
Friction Coefficient[3] PV=10kg/cm².m/sec (0.98MPa·m/sec)					0.35		0.32		0.32	0.34	0.47	0.39	0.30	0.18
THERMAL														
Coefficient of Linear Expansion	23 ~ 260°C	D-696	μm/m/°C (ppm/°C)	50		45		45		50	47	57	50	30
Thermal Conductivity	25°C		W/m · °C			0.37		0.37		0.30	1.50	1.71	0.29	0.35
	40°C					0.38		0.38		0.31	1.50	1.71		
Specific Heat			J/kg · °C							938	880	964	920	1,020
			kcal/kg · °C							0.224	0.210	0.230	0.220	0.244
Thermal Decomposition Temperature(on-set point, rate 10°C/min, in air)			°C			545		550		567		567	565	
Thermal 50% weight reduction Time (on-set point, rate 10°C/min, in air)			min			145		155		242			250	276
ELECTRICAL														
Dielectric Constant	23, @1GHz	D-150								3.1			3.0	2.9
Dielectric Strength		D-149	kV/mm											
Dissipation Factor	23, @1GHz	D-150	(10⁻⁴)							0.9			1.0	
Volume Resistivity	23°C	D-257	Ω-m							≥ 1E14	1E7-8	1E7-8	≥ 1E14	≥ 1E14
Surface Resistivity	23°C	D-257	Ω/cm²			1E0-3	1E0-3	1E6-9	1E6-9	≥ 1E14	1E5-6	1E5-6	≥ 1E14	≥ 1E14
OTHER PROPERTIES														
Water Absorption	50%RH(avg)	D-570	%											
24hrs	23°C			0.20		0.20		0.20		0.03	0.08	0.07	0.08	0.03
48hrs	50°C									0.20			0.20	
Specific Gravity		D-792	g/cm³	1.55	1.58	1.36	1.44	1.36	1.44	1.45	1.68	1.80	1.46	1.47
Hardness		D-785	Rockwell"M"		70-90	65-95	90-105	65-95	90-105	100-120	80-85	100-105	115	115

· ISO : Isostatic Molded. · CM : Compression Molded. · Steady State, Unlubricated in the Air

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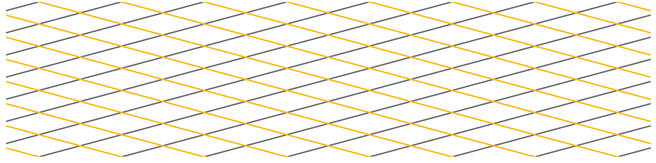
DaelimPlavis

SUPER ENGINEERING PLASTIC
POLYIMIDE

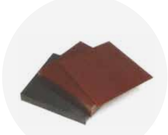


ROD

Diameter		Length
1/4"	(6.35mm)	19.6"(500mm)
3/8"	(9.53mm)	
7/16"	(11.11mm)	
1/2"	(12.70mm)	
5/8"	(15.88mm)	
3/4"	(19.05mm)	
1"	(25.40mm)	
1-1/4"	(31.75mm)	
1-1/2"	(38.10mm)	
2"	(50.80mm)	

PLATE

Dimension	Thickness
12"x12" (304.8mmx304.8mm)	12.7~62(mm)



DAELIM

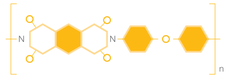
DAELIM CO.,LTD PI DIVISION PI SALES TEAM

22F D-Tower Donuimun Bldg., 134 Tongil-ro(Pyeong-dong), Jongno-gu, Seoul, Korea 03181
TEL : +82-10-8531-5997 / +82-10-8904-9243 / +82-10-2070-9087
e-mail : john@daelimcorp.co.kr / ckcho@daelimcorp.co.kr / tony@daelimcorp.co.kr
Website : https://www.daelimcorp.co.kr
YouTube : (English) https://youtu.be/JrYTiO5vhuo / (Chinese) https://youtu.be/x-qnzEZRjE4

PLAVIS is...

DaelimPlavis

a super engineering plastic which is polyimide resin(Wholly Aromatic Polyimide Resin). PLAVIS is a high-functional plastic with the highest heat resistance among plastic materials, low friction and high wear resistance, electrical insulation, excellent mechanical properties, radiation resistance, chemical resistance, low outgassing, excellent machinability, and is a component material used in high-tech industries such as high vacuum process, electrical/electronics, chemicals, automotive, aerospace, military equipment and various mechanical parts.



PROPERTIES

01 Thermal
Highest heat resistance that can be stably used in high temperature and cryogenic conditions

02 Mechanical
Retains high tensile strength and modulus even at high temperatures
No crack or creep under load

03 Outgassing
Lowest outgassing in high temperature vacuum chamber processing

04 Wear and Friction
High PV limit and low coefficient of friction in a wide range of temperature

05 Particle
Can be used in various operation conditions with low particle generation(Class-10)

06 Insulation
Excellent electrical insulation even under severe conditions of wide temperature range and high radiation

07 Chemical
Retains dimensional stability and mechanical properties even in a condition of long-term exposure to organic solvents

08 Machinability
Excellent machinability enough to enable precision processing

GRADES

Grades		Characteristics
PLAVIS-N	Non filled	Best physical properties, maximum electrical and thermal Insulation, low outgassing, superior radiation resistance
PLAVIS-S	Non filled	Best heat resistance and mechanical properties at high temperatures
PLAVIS-S1	Non filled	Excellent machinability, dimensional stability and laser cleaning stability Suitable for test sockets in semiconductor industry
PLAVIS-G15	Graphite 15wt% filled	High wear resistance and very low coefficient of friction Suitable for rotating parts of rotating equipment
PLAVIS-G40	Graphite 40wt% filled	Extreme wear resistance and very low coefficient of friction
PLAVIS-MS	MoS2 15wt% filled	Very high wear resistance, suitable for vacuum or non-lubricated environments
PLAVIS-C	Conductive	Electrical conductivity, excellent high thermal resistance and mechanical properties Surface Resistivity 10^2~10^3
PLAVIS-ESD	Electrostatic Dissipative	Electrostatic dissipative, excellent high thermal resistance and mechanical properties Surface Resistivity 10^6~10^9
PLAVIS-SG	Filled	Best heat resistance (continuous operational temp. >350), Excellent flexural properties and dimensional stability at high temperatures
PLAVIS-HM	Non filled	Suitable for test sockets in semiconductor industry with excellent heat resistance, dimensional stability and high flexural modulus

APPLICATIONS

01 FPD (Flat Panel Display)

- **Drying Oven(HP/CP, Baking, IR)** Glass Support Pins, Glass Holders, Rollers
- **Cleaning** ESD-EUV Rollers, Bearings
- **PVD/CVD Insulation parts** Inserts, Clamps, Bushings, Caps Susceptor Pins, Ball bearings, etc.
- **Etcher** Screws, Bolts
- **Others** Probe unit, Station Parts

02 Solar Cell

- **Drying Oven(HP/CP, Baking, IR)** Glass Support Pins, Glass Holders, Rollers
- **Cleaning** EUV Rollers, Bearings
- **PVD/CVD Insulation Parts** Inserts, Clamps, Bushings, Caps, Susceptor Pins, Ball Bearings, etc.


03 Semiconductor

- **Wafer Processing** Wafer Clamp Rings, Insulators, Screws & Fasteners, Vacuum Pads, Alignment Pins
- **Wafer Handling** Wafer Guides, Wafer Carriers Vacuum Pickup Strips
- **IC Handling & Testing** Die Pick-up Collects, Test Socket Insulators


04 General Industry

- **Hot Runner** Seal Caps, Insulators
- **Plasma Cutting Torches Parts** Swirl Rings, Insulators, Caps
- **Heat Resistance Materials** Bottle Grippers, V Conveyor Tips
- **Scientific Consumable Parts** GC/Mass Ferrules, HPLC Valve Rotors
- **Textile Machines** Valve Seat, Bearings, Shedder Bushings


05 Automotive / Transportation

- **Transmissions** Thrust Washers, Seal Rings, Valve Seats, Transmission Valve Balls, Check Valves
- **Electrical Motors** Bushings, Washers, Thrust Plugs
- **Brakes** Wear Pads, Valve Seats and Balls in ABS Systems
- **Fuel Systems** Bushings, Seal Rings, Band Springs, Valve Seats
- **Turbo Chargers** Ball Bearing Retainers, Wastegate Bushings
- **Others** Vacuum Pump Vanes, Engine Belt Tensioners, Rubbing Blocks, Door Hinge Bushings, Gear Stick Rollers, Ignition Distributors, Friction Pads for Split-Flywheels

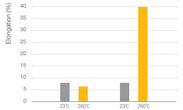

06 Aerospace / Aircraft

Compressor Variable Vane Bushings and Washers, Aircraft Fan Thrust Reversers, Fan Blade Wear Strips, Locking Insert Nuts, Fuel Line Spacers, Reciprocating Shaft Seals for Jet Engine Actuating System

THERMAL PROPERTIES

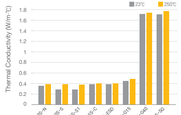
01 Heat Resistance & Deterioration of Properties

PLAVIS has no melting point (Tm) in the atmosphere and can be used continuously up to 300℃. PLAVIS-N takes about 200 hours, PLAVIS-G15 (15wt% Graphite) takes about 220 hours, PLAVIS-G40 (40wt% Graphite) takes about 360 hours until the initial tensile strength reaches 50% at 370℃ in the air. Since the performance reduction over time at 400℃ is mainly due to deterioration due to oxidation, the heat resistance of PLAVIS is improved in an inert atmosphere such as nitrogen or under vacuum conditions.
Unlike most thermoplastic engineering plastics (e.g. PEEK), which performance decreases significantly as the temperature approaches the Tg point, there is very little reduction in strength or modulus due to temperature.
The outstanding heat resistance of PLAVIS, which is different from other high heat resistant engineering plastics, can also be explained by its high Heat Deflection Temperature(HDT). Engineering plastics that can be injection molded such as PAI, PEI, PEEK, etc., are easy to machine but they have a melting point(Tm) or glass transition temperature(Tg), so shape collapse occurs within a higher temperature than Tm or Tg and cannot withstand the operation conditions. PLAVIS is a high molecular material that can withstand operation conditions at high temperatures since it does not have Tm and does not collapse in shape by melting at high temperatures.

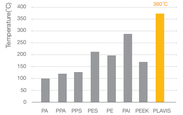


Picture1. Elongation

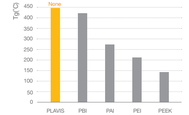
Picture2. Typical Tensile Strength (ASTM-D1708)



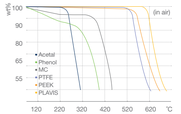
Picture3. Thermal Conductivity



Picture4. Engineering Plastics HDT Comparison(@264psi)



Picture5. Glass Transition Temp.



Picture6. Pyrolysis Temperature (TGA, in air)

Thermal Conductivity (W/m·℃)	PLAVIS-N	PLAVIS-S	PLAVIS-S1	PLAVIS-C	PLAVIS-ESD	PLAVIS-G15	PLAVIS-G40	PLAVIS-SG
23℃	0.36	0.3	0.29	0.37	0.37	0.45	1.73	1.71
250℃	0.39	0.38	0.37	0.4	0.4	0.48	1.76	1.78

Table1. Thermal Conductivity

02 Thermal Expansion

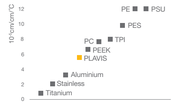
Like the other engineering plastics, PLAVIS changes in dimensions according to temperature, and the degree of thermal expansion depends on the grade. Table 2 shows the thermal expansion coefficients of PLAVIS grades. Carbon-based filler lowers the thermal expansion of molded products, so the filler-added grade has a lower coefficient of thermal expansion than pure PLAVIS-N and S grade.

	PLAVIS-N	PLAVIS-S	PLAVIS-S1	PLAVIS-C	PLAVIS-ESD	PLAVIS-G15	PLAVIS-G40	PLAVIS-SG
CLTE (10^5m/m/℃)	5.5	5	5	4.5	4.5	4.5	2.5	5.7
Water Absorption(%)	0.21	0.03	0.08	0.2	0.2	0.2	0.2	0.07

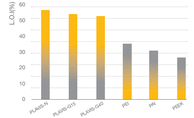
Table2. Average Thermal Linear Expansion Coefficient of PLAVIS (25~260℃)

03 Inflammability

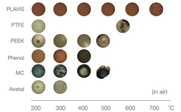
PLAVIS has a UL 94 listing as V0. It does not sustain a flame in air. The Limiting Oxygen Indexes that indicate the minimum oxygen required for continual burning are 55% for PLAVIS-N, 54.15% for PLAVIS-G15 and 53.7% for PLAVIS-G40. In most engineering plastics, aromatic polyester is 36%, polycarbonate is 33%, PPO is 30%, and nylon 66 is 28%, but PLAVIS is a material that is difficult to burn since it has a very high limiting oxygen index. (UL 94 V0)



Picture7. Comparison of Thermal Expansion Coefficient of Various Materials



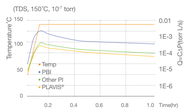
Picture8. Comparison of Limiting Oxygen Index between PLAVIS and various Engineering Plastics



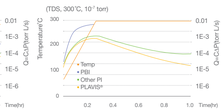
Picture9. PLAVIS-N Exposure Test at High Temperature in the Air (for one minute)

04 Low Outgassing

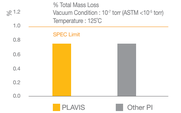
PLAVIS does not degrade at high temperatures or give off volatiles or condensable gasses. In vacuum processing chambers for displays or electronics, PLAVIS is the one and only plastic that can replace ceramics and metals. PLAVIS meets the NASA specifications for total mass loss in space vacuum environments for satellite applications.



Picture10. PLAVIS Out-gassing (150℃)



Picture11. PLAVIS Out-gassing (300℃)



Picture12. Total Mass Loss(%)

FRICTION & WEAR PROPERTIES

PLAVIS graphite filled grades are self-lubricating and can be applied to wear and friction applications such as bearings and wear strips even in high temperature oil/grease starved environments.

01 Friction

The friction coefficient of PLAVIS is affected by the operating temperature, load and speed. For PLAVIS-G15, the coefficient of friction decreases rapidly between 150℃~200℃, and above 200℃, the friction coefficient is constant regardless of temperature. This is due to the intrinsic properties of the material that are not related to wear transfer.

Grade	PLAVIS-N	PLAVIS-G15	PLAVIS-G40
PV=10kg/cm²·m/sec	0.32	0.23	0.16

Table3. PLAVIS Friction Coefficient

02 Wear

PLAVIS achieves the fusion(initial wear) with the mating material in a short time, after that, normal wear follows according to working conditions. The degree of wear depends on the temperature, shape, type of bonding material, hardness, surface roughness and degree of lubrication.

CHEMICAL PROPERTIES

PLAVIS has good resistance to many organic solvents, oils, and greases such as ATF (Automatic Transmission Fluid). Even at high temperatures in these lubricants, the mechanical properties of PLAVIS are not significantly changed. PLAVIS should not be used in strong alkali conditions such as PH over 10 due to the characteristics of chemical structure of PLAVIS.

EUV TEST

POLYIMIDE is known to be the most stable against EUV radiation among existing plastics, and is widely used in rollers and bearings of EUV cleaning equipment due to its excellent wear resistance and low particle generation characteristics.

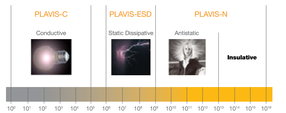
PLAVIS-C & PLAVIS-ESD PROPERTIES

01 Electrical Properties of PLAVIS-C & ESD

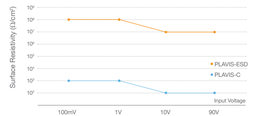
PLAVIS-C is conductive grade and PLAVIS-ESD is electrostatic dissipative grade. PLAVIS-C & ESD show the uniformed surface resistivity under the various input voltages. PLAVIS-C and ESD not only have the best heat resistance and abrasion resistance, but also hardly generate particles, and have extremely low gas emission at high vacuum, so they can be widely used in fields with static electricity issues.

02 Applications

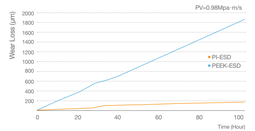
- Wafer Handling
- Flat Panel Display Glass Handling Process
- Electronics Manufacturing Line Fixtures
- Bearing in Electronic Products and Motors
- Burn in and Test Sockets



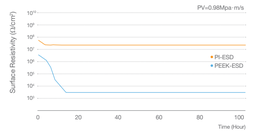
Picture13. Surface Resistivity Spectrum



Picture14. Change of Surface Resistance according to Input Voltage



Picture15. Wear Loss(PI-ESD vs. PEEK-ESD)



Picture16. Surface Resistivity(PI-ESD vs. PEEK-ESD)