

# Materials Property Chart

			Standard Alumina					
			AL74 74%	AL95 95%	AL96 96%	AL96P 95.5%	AL98 98%	
	Property	ASTM Method	Units					
General	Crystal Size (Average)	Thin Section	Microns	13	11	8	9	7
	Color	--	--	White	Ivory	White	Purple	White
	Gas Permeability	--	atms-cc/sec	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>
	Water Absorption	C 20-97	%	0	0	0	0	0
Mechanical	Density	C 20-97	g/cc	3.03	3.65	3.71	3.68	3.78
	Hardness	Vickers 500 gm	GPa (kg/mm <sup>2</sup> )	10.5 (1075)	11.5 (1175)	12.7 (1300)	12.7 (1300)	12.7 (1300)
	Hardness	--	R45N	78	79	81	81	81
	Fracture Toughness	Notched Beam	MPam <sup>1/2</sup>	2 - 5	3 - 4	4 - 5	4 - 5	4 - 5
	Flexural Strength (MOR) (3 point) @ RT°	F417-87	MPa (psi x 10 <sup>3</sup> )	241 (35)	310 (45)	358 (52)	331 (48)	393 (57)
	Tensile Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	117 (17)	151 (22)	200 (29)	159 (23)	221 (32)
	Compressive Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	1378 (200)	1827 (265)	2068 (300)	1965 (285)	2241 (325)
	Elastic Modulus	C848	GPa (psi x 10 <sup>6</sup> )	172 (25)	303 (44)	310 (45)	310 (45)	345 (50)
	Poisson's Ratio	C848	--	0.22	0.22	0.22	0.22	0.23
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10 <sup>-6</sup> /C	5.5	6.1	6.0	6.3	6.2
	C.T.E. 25 - 300° C	C 372-96	x 10 <sup>-6</sup> /C	5.8	7.0	6.8	6.9	6.8
	C.T.E. 25 - 600° C	C 372-96	x 10 <sup>-6</sup> /C	6.3	7.7	7.5	7.6	7.6
	Thermal Conductivity @ RT°	C 408	W/m K	4	19	23	21	29
	Max Use Temp (non-loading) (at high strength)	--	Fahrenheit (°F)	2800	3000	3100	3100	3100
		--	Celsius (°C)	1540	1650	1700	1700	1700
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	225	250	250	250	260
	Dielectric Constant @ 1 MHz	D 150-98	--	7.0	9.0	9.1	9.0	9.5
	Dielectric Constant @ Gigahertz	D 2520-95	--	--	9.2	9.1	8.9	9.4
				--	11.0	10.9	10.8	9.8
	Dielectric Loss @ 1 MHz	D 150-98	--	0.0012	0.0006	0.0004	0.0006	0.0006
	Dielectric Loss @ Gigahertz	D 2520-95	--	--	0.0009	0.0007	0.0006	0.0005
				--	12.5	10.9	10.8	9.8
	Volume Resistivity, 25°C	D 257	ohms-cm	> 1 x 10 <sup>13</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>13</sup>	> 1 x 10 <sup>14</sup>
	Volume Resistivity, 300° C	D 1829	ohms-cm	4 x 10 <sup>10</sup>	5 x 10 <sup>12</sup>	3 x 10 <sup>12</sup>	1 x 10 <sup>11</sup>	8 x 10 <sup>11</sup>
	Volume Resistivity, 500° C	D 1829	ohms-cm	3 x 10 <sup>7</sup>	3 x 10 <sup>9</sup>	7 x 10 <sup>9</sup>	5 x 10 <sup>9</sup>	2 x 10 <sup>9</sup>
	Volume Resistivity, 700° C	D 1829	ohms-cm	2 x 10 <sup>6</sup>	3 x 10 <sup>8</sup>	4 x 10 <sup>8</sup>	4 x 10 <sup>8</sup>	2 x 10 <sup>8</sup>
Volume Resistivity, 1000° C	D 1829	ohms-cm	--	--	--	--	--	

# Materials Property Chart

			High Purity Alumina				
			AL995 99.5%	AL998 NSF51 Certified 99.8%	AL9980 99.8%	AL999 99.9%	
Property		ASTM Method	Units				
General	Crystal Size (Average)	Thin Section	Microns	6	6	6	2
	Color	--	--	Ivory-White	Ivory	Ivory	Off White/ Blush
	Gas Permeability	--	atms-cc/sec	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>
	Water Absorption	C 20-97	%	0	0	0	0
Mechanical	Density	C 20-97	g/cc	3.88	3.91	3.91	3.93
	Hardness	Vickers 500 gm	GPa (kg/mm <sup>2</sup> )	14.3 (1459)	15 (1530)	15 (1530)	19.6 (2000)
	Hardness	--	R45N	82	86	86	90
	Fracture Toughness	Notched Beam	MPam <sup>1/2</sup>	4 - 5	3 - 4	3 - 4	5 - 6
	Flexural Strength (MOR) (3 point) @ RT°	F417-87	MPa (psi x 10 <sup>3</sup> )	338 (49)	379 (55)	379 (55)	455 (66)
	Tensile Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	172 (25)	200 (29)	200 (29)	275 (40)
	Compressive Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	2137 (310)	2240 (325)	2240 (325)	2413 (350)
	Elastic Modulus	C848	GPa (psi x 10 <sup>9</sup> )	379 (55)	379 (55)	379 (55)	393 (57)
	Poisson's Ratio	C848	--	0.23	0.23	0.23	0.23
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10 <sup>-6</sup> /C	6.3	6.5	6.5	6.5
	C.T.E. 25 - 300° C	C 372-96	x 10 <sup>-6</sup> /C	6.9	7.9	7.9	7.9
	C.T.E. 25 - 600° C	C 372-96	x 10 <sup>-6</sup> /C	7.6	8.1	8.1	8.2
	Thermal Conductivity @ RT°	C 408	W/m K	30	30	30	35
	Max Use Temp (non-loading) (at high strength)	--	Fahrenheit (°F)	3047	3047	3047	3100
		--	Celsius (°C)	1675	1675	1675	1700
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	270	290	290	422
	Dielectric Constant @ 1 MHz	D 150-98	--	9.8	9.8	9.8	9.9
	Dielectric Constant @ Gigahertz	D 2520-95	--	9.7	10	10	--
				9.8	9.6	9.6	--
	Dielectric Loss @ 1 MHz	D 150-98	--	0.0002	< .0001	< .0001	< .0001
	Dielectric Loss @ Gigahertz	D 2520-95	--	< .0001	< .0001	< .0001	--
				9.8	9.6	9.6	--
	Volume Resistivity, 25°C	D 257	ohms-cm	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>
	Volume Resistivity, 300° C	D 1829	ohms-cm	1 x 10 <sup>12</sup>	3 x 10 <sup>12</sup>	3 x 10 <sup>12</sup>	1 x 10 <sup>13</sup>
	Volume Resistivity, 500° C	D 1829	ohms-cm	5 x 10 <sup>10</sup>	6 x 10 <sup>10</sup>	6 x 10 <sup>10</sup>	5 x 10 <sup>12</sup>
	Volume Resistivity, 700° C	D 1829	ohms-cm	2 x 10 <sup>9</sup>	6 x 10 <sup>9</sup>	6 x 10 <sup>9</sup>	1 x 10 <sup>12</sup>
Volume Resistivity, 1000° C	D 1829	ohms-cm	--	--	--	--	

# Materials Property Chart

			Zirconia Toughened Alumina			
			ZTA-02 US Patent 8679995	ZTA-14	ZTA-20	
	Property	ASTM Method	Units			
General	Crystal Size (Average)	Thin Section	Microns	< 2	6	3
	Color	--	--	Off White	White	White
	Gas Permeability	--	atms-cc/sec	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>
	Water Absorption	C 20-97	%	0	0	0
Mechanical	Density	C 20-97	g/cc	3.96	4.17	4.30
	Hardness	Vickers 500 gm	GPa (kg/mm <sup>2</sup> )	14 (1440)	14.5 (1478)	14.4 (1470)
	Hardness	--	R45N	81	82	82
	Fracture Toughness	Notched Beam	MPam <sup>1/2</sup>	5	6	6
	Flexural Strength (MOR) (3 point) @ RT°	F417-87	MPa (psi x 10 <sup>3</sup> )	448 (65)	586 (85)	621 (90)
	Tensile Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	259 (38)	344 (50)	350 (51)
	Compressive Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	2413 (350)	2758 (400)	2758 (400)
	Elastic Modulus	C848	GPa (psi x 10 <sup>6</sup> )	358 (52)	338 (49)	338 (49)
	Poisson's Ratio	C848	--	0.23	0.23	0.23
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10 <sup>-6</sup> /C	6.7	6.0	6.0
	C.T.E. 25 - 300° C	C 372-96	x 10 <sup>-6</sup> /C	8.1	7.0	7.0
	C.T.E. 25 - 600° C	C 372-96	x 10 <sup>-6</sup> /C	8.3	7.1	7.1
	Thermal Conductivity @ RT°	C 408	W/m K	27	24	24
	Max Use Temp (non-loading) (at high strength)	--	Fahrenheit (°F)	2732	2730	2730
		--	Celsius (°C)	1500	1500	1500
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	230	250	250
	Dielectric Constant @ 1 MHz	D 150-98	--	10.5	12.5	12.5
	Dielectric Constant @ Gigahertz	D 2520-95	--	--	--	12.4
				--	--	9.4
	Dielectric Loss @ 1 MHz	D 150-98	--	0.0003	0.0006	0.0006
	Dielectric Loss @ Gigahertz	D 2520-95	--	--	0.0005	0.0005
				--	9.4	9.4
	Volume Resistivity, 25°C	D 257	ohms-cm	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>
	Volume Resistivity, 300° C	D 1829	ohms-cm	3 x 10 <sup>12</sup>	1 x 10 <sup>10</sup>	1 x 10 <sup>10</sup>
	Volume Resistivity, 500° C	D 1829	ohms-cm	6 x 10 <sup>10</sup>	2 x 10 <sup>9</sup>	2 x 10 <sup>9</sup>
	Volume Resistivity, 700° C	D 1829	ohms-cm	6 x 10 <sup>9</sup>	2 x 10 <sup>8</sup>	4 x 10 <sup>8</sup>
Volume Resistivity, 1000° C	D 1829	ohms-cm	--	--	--	

# Materials Property Chart

				Zirconia				
				MSZ (Magnesia Stabilized) MSZ-200	MSZ (Magnesia Stabilized) MSZ-300	YTZP 2000 (Yttria Stabilized)	YTZP 4000 (Yttria Stabilized)	CSZ (Cerium Stabilized)
		Property	ASTM Method	Units				
General	Crystal Size (Average)	Thin Section	Microns	30	30	1	1	3
	Color	--	--	Ivory	Yellow	Ivory	Ivory	Yellow
	Gas Permeability	--	atms-cc/sec	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>
	Water Absorption	C 20-97	%	0	0	0	0	0
Mechanical	Density	C 20-97	g/cc	5.72	5.72	6.02	6.07	6.20
	Hardness	Vickers 500 gm	GPa (kg/mm <sup>2</sup> )	11.7 (1200)	11.7 (1200)	12.5 (1250)	12.5 (1250)	11.7 (1200)
	Hardness	--	R45N	78	78	80	80	78
	Fracture Toughness	Notched Beam	MPam <sup>1/2</sup>	12	12	10	10	12
	Flexural Strength (MOR) (3 point) @ RT°	F417-87	MPa (psi x 10 <sup>3</sup> )	620 (90)	586 (85)	951 (138)	1380 (200)	551 (80)
	Tensile Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	310 (45)	310 (45)	550 (80)	690 (100)	337 (49)
	Compressive Strength @ RT°	--	MPa (psi x 10 <sup>3</sup> )	1862 (270)	1862 (270)	2485 (360)	2485 (360)	2000 (290)
	Elastic Modulus	C848	GPa (psi x 10 <sup>6</sup> )	206 (29.8)	206 (29.8)	210 (30)	210 (30)	200 (29)
	Poisson's Ratio	C848	--	0.28	0.28	0.30	0.30	0.25
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10 <sup>-6</sup> /C	8.9	8.9	6.9	6.9	6.9
	C.T.E. 25 - 300° C	C 372-96	x 10 <sup>-6</sup> /C	9.7	9.7	8.1	8.1	8.1
	C.T.E. 25 - 600° C	C 372-96	x 10 <sup>-6</sup> /C	10.0	10.0	10.5	10.5	10.5
	Thermal Conductivity @ RT°	C 408	W/m K	3	3	2.2	2.2	3.5
	Max Use Temp (non-loading) (at high strength)	--	Fahrenheit (°F)	2200	2200	932	932	1000
		--	Celsius (°C)	1200	1200	500	500	537
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	300	300	240	240	250
	Dielectric Constant @ 1 MHz	D 150-98	--	22.7	22.7	30.0	30.0	30.0
	Dielectric Constant @ Gigahertz	D 2520-95	--	29.2	29.2	--	--	--
				6.2	6.2	--	--	--
	Dielectric Loss @ 1 MHz	D 150-98	--	0.0016	0.0016	0.0010	0.0010	0.0010
	Dielectric Loss @ Gigahertz	D 2520-95	--	0.0018	0.0018	--	--	--
				6.2	6.2	--	--	--
	Volume Resistivity, 25°C	D 257	ohms-cm	> 1 x 10 <sup>13</sup>	> 1 x 10 <sup>13</sup>	> 1 x 10 <sup>13</sup>	> 1 x 10 <sup>13</sup>	> 1 x 10 <sup>13</sup>
	Volume Resistivity, 300° C	D 1829	ohms-cm	5 x 10 <sup>7</sup>	5 x 10 <sup>7</sup>	1 x 10 <sup>10</sup>	1 x 10 <sup>10</sup>	1 x 10 <sup>10</sup>
	Volume Resistivity, 500° C	D 1829	ohms-cm	1 x 10 <sup>7</sup>	1 x 10 <sup>7</sup>	1 x 10 <sup>6</sup>	1 x 10 <sup>6</sup>	1 x 10 <sup>6</sup>
	Volume Resistivity, 700° C	D 1829	ohms-cm	2 x 10 <sup>6</sup>	2 x 10 <sup>6</sup>	5 x 10 <sup>3</sup>	5 x 10 <sup>3</sup>	5 x 10 <sup>3</sup>
Volume Resistivity, 1000° C	D 1829	ohms-cm	--	--	--	--	--	

# Materials Property Chart

			Nitride		Carbide	
			Aluminum Nitride (AlN)	Silicon Nitride (Si <sub>3</sub> N <sub>4</sub> )	Silicon Carbide (SiC) Alpha	
	Property	ASTM Method	Units			
General	Crystal Size (Average)	Thin Section	Microns	< 6	4	< 7
	Color	--	--	Gray	Black	Black
	Gas Permeability	--	atms-cc/sec	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>	gas tight <10 <sup>-10</sup>
	Water Absorption	C 20-97	%	0	0	0
Mechanical	Density	C 20-97	g/cc	3.20	3.25	3.15
	Hardness	Vickers 500 gm	GPa (kg/mm <sup>2</sup> )	11.2 (1142)	15 (1529)	26 (2650)
	Hardness	--	R45N	79	83	> 90
	Fracture Toughness	Notched Beam	MPam <sup>1/2</sup>	3	6	4
	Flexural Strength (MOR) (3 point) @ RT	F417-87	MPa (psi x 10 <sup>3</sup> )	241 (35)	900 (130)	483 (70)
	Tensile Strength @ RT	--	MPa (psi x 10 <sup>3</sup> )	139 (20)	537 (78)	241 (35)
	Compressive Strength @ RT	--	MPa (psi x 10 <sup>3</sup> )	2100 (304)	2500 (362)	3306 (480)
	Elastic Modulus	C848	GPa (psi x 10 <sup>6</sup> )	310 (45)	300 (44)	448 (65)
	Poisson's Ratio	C848	--	0.24	0.28	0.17
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10 <sup>-6</sup> /C	--	--	3.7
	C.T.E. 25 - 300° C	C 372-96	x 10 <sup>-6</sup> /C	4.3	--	--
	C.T.E. 25 - 600° C	C 372-96	x 10 <sup>-6</sup> /C	5.0	2.9	4.0
	Thermal Conductivity @ RT	C 408	W/m K	160	29	150
	Max Use Temp	--	Fahrenheit (°F)	2912	2552	2912
		--	Celsius (°C)	1600	1400	1600
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	355	300	--
	Dielectric Constant @ 1 MHz	D 150-98	--	8.6	9.2	10.2
	Dielectric Constant @ Gigahertz	D 2520-95	--	--	--	--
	Dielectric Loss @ 1 MHz	D 150-98	--	0.0026	--	--
	Dielectric Loss @ Gigahertz	D 2520-95	--	--	--	--
	Volume Resistivity, 25° C	D 257	ohms-cm	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>5</sup>
	Volume Resistivity, 300° C	D 1829	ohms-cm	--	--	1 x 10 <sup>4</sup>
	Volume Resistivity, 500° C	D 1829	ohms-cm	--	--	1 x 10 <sup>3</sup>
	Volume Resistivity, 700° C	D 1829	ohms-cm	--	--	--
	Volume Resistivity, 1000° C	D 1829	ohms-cm	--	--	--

# Materials Property Chart

				Silicates					
		Property	ASTM Method	Units	Steatite L-4	Steatite L-5	Cordierite	Mullite	Lava Grade A Fired
General	Crystal Size (Average)	Thin Section	Microns	7	7	--	7	--	
	Color	--	--	Tan	Gray-Green	Orange-Tan	Gray-Tan	Gray-Tan	
	Gas Permeability	--	atms-cc/sec	--	--	Porous	--	Porous	
	Water Absorption	C 20-97	%	0	0	10	0	3	
Mechanical	Density	C 20-97	g/cc	2.65	2.75	2.00	3.00	2.30	
	Hardness	Vickers 500 gm	GPa (kg/mm <sup>2</sup> )	4.9 (500)	4.9 (500)	5.8 (590)	10 (1000)	4.4 (450)	
	Hardness	--	R45N	57	57	50	78	42	
	Fracture Toughness	Notched Beam	MPam <sup>1/2</sup>	--	--	--	3	--	
	Flexural Strength (MOR) (3 point) @ RT	F417-87	MPa (psi x 10 <sup>3</sup> )	117 (17)	138 (20)	66 (9.5)	206 (30)	69 (10)	
	Tensile Strength @ RT	--	MPa (psi x 10 <sup>3</sup> )	103 (15)	103 (15)	19 (2.7)	138 (20)	21 (3)	
	Compressive Strength @ RT	--	MPa (psi x 10 <sup>3</sup> )	551 (80)	586 (85)	165 (24)	1034 (150)	172 (25)	
	Elastic Modulus	C848	GPa (psi x 10 <sup>6</sup> )	103 (15)	103 (15)	103 (15)	179 (26)	--	
	Poisson's Ratio	C848	--	0.24	0.24	0.31	0.24	--	
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10 <sup>-6</sup> /C	7.3	8.5	2.1	3.6	2.9	
	C.T.E. 25 - 300° C	C 372-96	x 10 <sup>-6</sup> /C	7.4	8.6	2.5	4.1	3.3	
	C.T.E. 25 - 600° C	C 372-96	x 10 <sup>-6</sup> /C	7.5	8.6	3.0	4.8	3.6	
	Thermal Conductivity @ RT	C 408	W/m K	3	3	3	4	2	
	Max Use Temp	--	Fahrenheit (°F)	2350	2350	2350	3100	2000	
	--	Celsius (°C)	1290	1290	1290	1700	1100		
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	260	270	120	250	100	
	Dielectric Constant @ 1 MHz	D 150-98	--	5.6	5.7	5.5	6.7	5.3	
	Dielectric Constant @ Gigahertz	D 2520-95	--	5.6	5.8	--	6.7	--	
	Dielectric Loss @ 1 MHz	D 150-98	--	0.003	0.0014	--	0.003	--	
	Dielectric Loss @ Gigahertz	D 2520-95	--	0.005	0.0017	--	0.003	--	
	Volume Resistivity, 25°C	D 257	ohms-cm	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	> 1 x 10 <sup>14</sup>	--	
	Volume Resistivity, 300° C	D 1829	ohms-cm	2 x 10 <sup>10</sup>	1 x 10 <sup>11</sup>	--	4 x 10 <sup>10</sup>	--	
	Volume Resistivity, 500° C	D 1829	ohms-cm	1 x 10 <sup>9</sup>	4 x 10 <sup>10</sup>	--	1 x 10 <sup>9</sup>	--	
	Volume Resistivity, 700° C	D 1829	ohms-cm	2 x 10 <sup>8</sup>	1 x 10 <sup>9</sup>	--	--	--	
	Volume Resistivity, 1000° C	D 1829	ohms-cm	--	--	--	--	--	