AREMCO

MACHINABLE CERAMICS
Technical Bulletin A1-S1

502-600

502-800

502-1100-FF

502-1100-UF

502-1600

MACHINABLE CERAMICS

Material Properties	502-600	502-800	502-1100-UF	502-1100-FF	502-1400-BF	502-1600[1]
Composition-Purity	Glass Ceramic	Macor Glass Ceramic	Alumino-Silicate Un-Fired	Alumino-Silicate Full-Fired	Alumina, 96% Bisque-Fired	Boron Nitride, 99%
Thermal Properties						
Max Use Temperature						
Oxidizing, °F, (°C)	1100 (593)	1472 (800)	1000 (537)	2100 (1150)	2600 (1427)	1650 (900)
Vacuum, °F, (°C)	1100 (593)	1472 (800)	1000 (537)	2100 (1150)	2600 (1427)	3270 (1800)
Inert, °F, (°C)	1100 (593)	1472 (800)	1000 (537)	2100 (1150)	2600 (1427)	3990 (2200)
Coefficient Thermal Expansion, in/in/°F x 10^{-6} (°C)	5.8 (10.5)	7.0 (12.6)	2.5 (4.5)	2.9 (5.2)	3.5 (6.3)	0.2 (0.3)
Thermal Conductivity, W/m-K	1.3	1.5	1.6	1.3	4.3	50
Mechanical Properties						
Compressive Strength, psi (Mpa)	32,000 (221)	50,000 (345)	12,000 (83)	25,000 (172)	9,000 (62)	12,300 (85)
Flexural Strength, psi (Mpa)	11,000 (72.9)	13,600 (94)	4,000 (28)	10,000 (69)	4,000 (28)	5,075 (35)
Hardness, Rockwell A	47	48	39	45	42	19
Electrical Properties						
Volume Resistivity, ohm-cm	1×10^{12}	1×10^{17}	1×10^{14}	1×10^{14}	1×10^{14}	$> 1 \times 10^{14}$
Dielectric Strength, volts/mil	380	785	80	100	80	865
Dielectric Loss, 1 MHz	0.012	~0.005	0.06	0.053	0.003	< 0.0002
Dielectric Constant, 1 MHz	6.8	~6.0	5.8	5.3	5.5	4
Physical Properties						
Density, g/cc	2.80	2.52	2.60	2.30	3.00	2.00
Water Absorption, %	0.0	0.0	2.5	2.3	25	—

*Measurements taken at 25 °C. Additional data at elevated temperatures may be available upon request.

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MACHINING GUIDELINES

Fixturing
Hold parts carefully to prevent chipping or cracking. Place soft paper sheet in between ceramic and gripping jaws as needed. Support plates for drilling or milling operations using a soft backup block and mounting adhesive such as Aremco's Crystalbond 509 or 590 (refer to Technical Bulletin A9). Support cylinders using an internal metal sleeve. Do not use pointed screws to hold parts.

Lubricant
A low concentrate water-soluble lubricant is recommended for 502-600 and 502-800. Dry machining is recommended for 502-1100-UF, 502-1400-BF, 502-1600-99 because these ceramics have high open porosity and absorb water readily.

Cutting
Use sharp cutting tools only as ceramics are abrasive and dull cutters may cause localized heating that leads to chipping. Carbide tools (Titanium coated or Tungsten) and/or bonded diamond wheels are preferred but high-speed tools can be used for short runs. Cut downwards into the work, never up from the bottom. Maintain speeds from 2000–2500 rpm and advance the cut by feel.

Drilling
Solid carbide drills, preferably with micro-grain carbide, will give best results. Do not drill thru in order to avoid chipping. For best results, work from one side, then rotate piece and work from the other side. Otherwise, allow for 1⁄16″ of extra material on drill break-thru side to allow for grinding cleanup. For large quantities, accurate two-sided hardened bushed drill jigs will provide accurate results. The drill should be advanced slowly by ¼″ per turn.

Drill Size	Spindle Speed*	Feed Rate
¼″	300–2000 rpm	.003–.005
½″	250–1200 rpm	.004–.007
¾″	200–700 rpm	.005–.010
1″	100–300 rpm	.006–.012

*The higher end of the speed range is recommended for most products except 502-800 Macor.

Grinding
Use silicon carbide resin-bonded wheels for surface grinding at speeds recommended by the wheel manufacturer. Use a soft, coarse-grained wheel for heavy grinding. Use 1% soluble oil solution to extend life of grinding wheels. Use a 35-grit Blanchard-Besley type grinder for rough heavy grind; use a 60–80-grit wheel for surface grinders.

Milling
Micro-grain Carbide end mills are recommended.

Drill Size	Spindle Speed
¼″	< 1000 rpm
½″	< 800 rpm
¾″	< 600 rpm
1″	< 400 rpm

Depth of Cut .050–.070″ per cut
Feed Rate 3″ per minute

Slotting
Slotting may be accomplished using a metal-bonded diamond or silicon carbide wheel on a surface grinder for slots up to 0.050″. Alternatively, a carbide end-mill can be used making small cuts up to 0.025″ with plenty of lubricant.

Tapping
Use sharp tungsten carbide tool bits. For internal threads, make clearance holes slightly larger than standard tap drill recommendations. Chamfer both sides of hole prior to threading to minimize chipping. Run the tap in one direction only as turning the tap back and forth can cause chipping. Continuously flush with air, water or coolant to clear chips and dust from the tap.

Cleaning
When coolant is used, bake out parts at 200–250 °F for 1–2 hours to remove residual moisture. Remove any discoloration caused by the lubricant by clean firing up to 1000 °F.

502-1100-UF Unfired—Machining & Firing Notes
Typical tolerances after firing are ± 1% or ± 0.005″ whichever is greater. Tighter tolerances can be achieved by wet grinding after firing. Machine all dimensions 1–2% undersize to allow for expansion during firing. All dimensions including centered and off-centered internal holes will increase by this percentage after firing. Maximum recommended cross-sectional thickness is 3⁄8″. Hollow cut or drill holes thru the unfired ceramic to maintain a 3⁄8″ maximum cross-section. When it is necessary to exceed 3⁄8″, do not exceed 5⁄8″ and the rate of firing should be slowed.

Bake at 200 °F for two hours to remove moisture and increase temperature at a rate of 200 °F per hour maximum (slower for thicker sections) to 1100 °F. Soak at 1100 °F for six hours, then increase temperature at a rate of 200 °F per hour to 2050 °F and soak for 30 minutes for each ¼″ of cross-section (eg. soak a ½″ thick part for one hour). Turn off furnace and allow cooling to below 150 °F before removing parts.

502-1400-BF Bisque-Fired—Firing Notes
This product has been bisque-fired to 2475 °F, but additional firing to 3075–3125 °F can be performed to achieve high density, hardness and mechanical strength. Allow for 15–18% shrinkage using the following firing schedule. Raise temperature 500 °F per hour to 2000 °F and 200 °F per hour to 3125 °F. Soak for 12 hours then cool to room temperature before removing parts.

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