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MACOR 01

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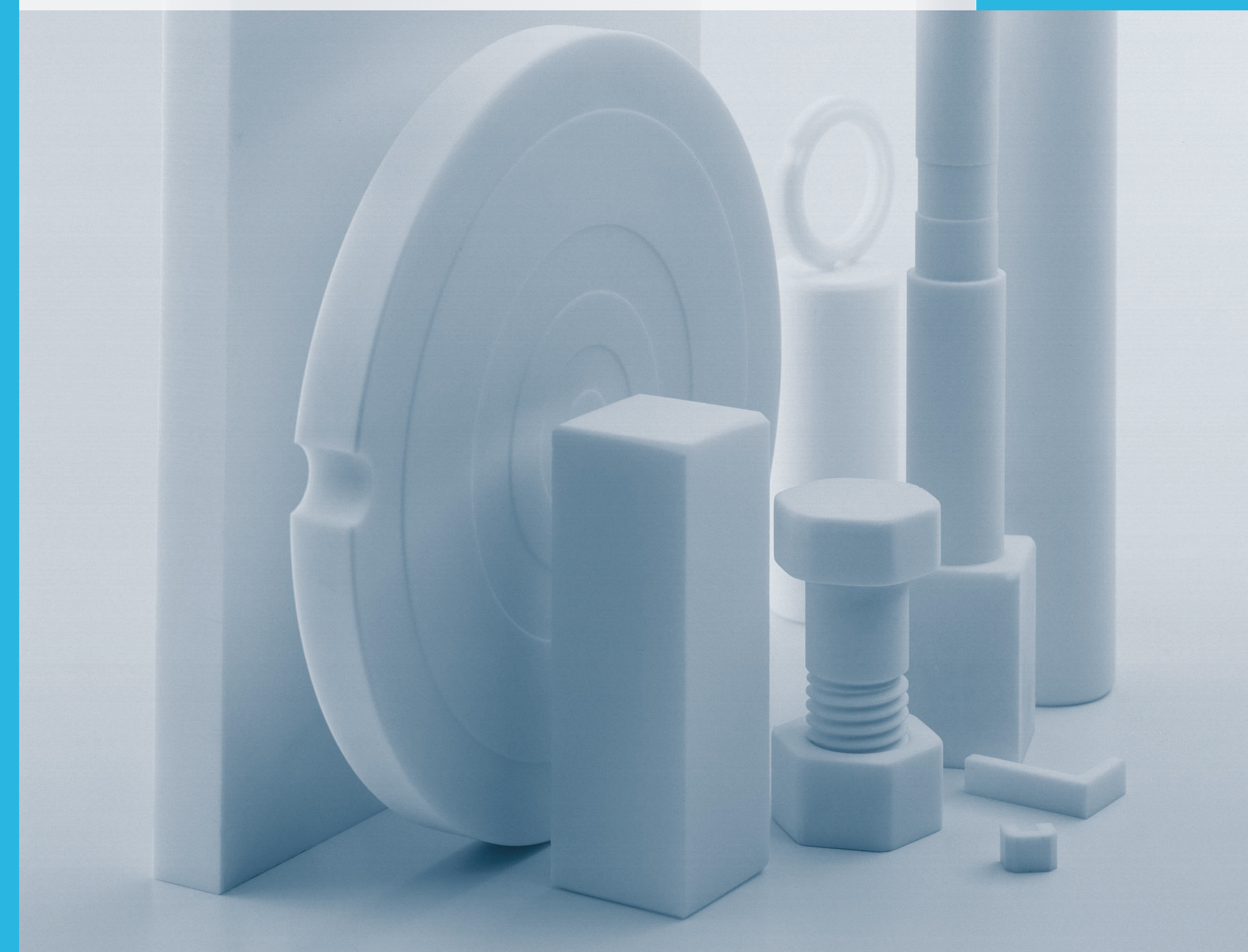
MACOR®

CORNING
Discovering Beyond Imagination

Lighting &
Materials



MACOR®
Machinable Glass Ceramic

- is MACHINABLE with ordinary metal working tools
- allows FAST TURNAROUND, no post firing required
- holds TIGHT TOLERANCES, up to .0005”
- withstands HIGH TEMPERATURE, up to 1000°C (no load)
- is CLEAN, no outgasing and zero porosity

With MACOR® Machinable Glass Ceramic (MGC), fabrication is fast because it can be machined into complicated shapes and precision parts with ordinary metal working tools, quickly and inexpensively, and it requires no post firing after machining. That means no frustrating delays, no expensive hardware, no post fabrication shrinkage, and no costly diamond tools to meet specifications.

Properties

MACOR® Machinable Glass Ceramic has a continuous use temperature of 800ºC and a peak temperature of 1000ºC. Its coefficient of thermal expansion readily matches most metals and sealing glasses. It is nonwetting, exhibits zero porosity, and unlike ductile materials, won’t deform. It is an excellent insulator at high voltages, various frequencies, and high temperatures. When properly baked out, it won’t outgas in vacuum environments.

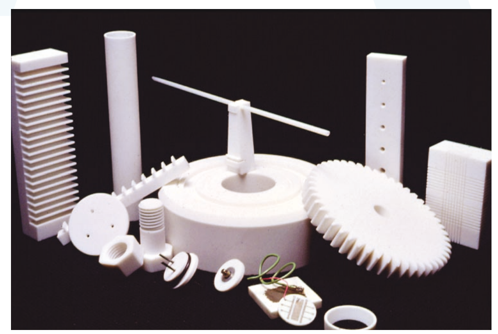
Machining

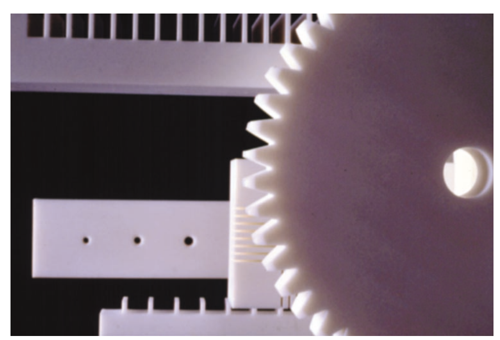
Machining tolerances are surprisingly tight, up to .0005". It can be machined to a surface finish of less than 20µin. and polished to a smoothness of 0.5µin.-AA. Configurations are limited only by available equipment and the experience of the machinist.

Sealing, Joining and Metalizing

MACOR MGC can also be joined or sealed - both to itself and to other materials - in a number of ways: metalized parts can be soldered together and brazing has proven an effective method of joining the material to various metals; epoxy produces a strong joint, and sealing glass creates a vacuum tight seal. Even a straight-forward mechanical joint is possible.

It can be thick film metalized using metal inks, or thin film metalized by sputtering.





Applications

Ultra-High Vacuum Environments

MACOR® Machinable Glass Ceramic is used as an insulator or coil support and for vacuum feed-throughs. In these applications, the conductive materials are supported by the MACOR MGC part and a compatible sealing glass is used to produce a vacuum-tight, hermetic seal.

Constant Vacuum Applications

MACOR MGC parts are found in spacers, headers and windows for microwave tube devices and as sample holders in field ion microscopes.

Aerospace Industry

Over 200 distinctly shaped MACOR MGC parts can be found on America’s reusable Space Shuttle Orbiter. Retaining rings of MACOR MGC are used at all hinge points, windows and doors.

Also, large pieces of MACOR glass ceramic are used in a NASA spaceborne gamma radiation detector. For this application, frame corners are joined by a combination of machined (butt-lap) mechanical joints and a sealing glass.

Nuclear-Related Experiments

Since MACOR MGC is not dimensionally affected by irradiation, small cubes of the material are machined to a tolerance of one micron and used as a reference piece to measure dimensional change in other materials.

Welding Nozzles

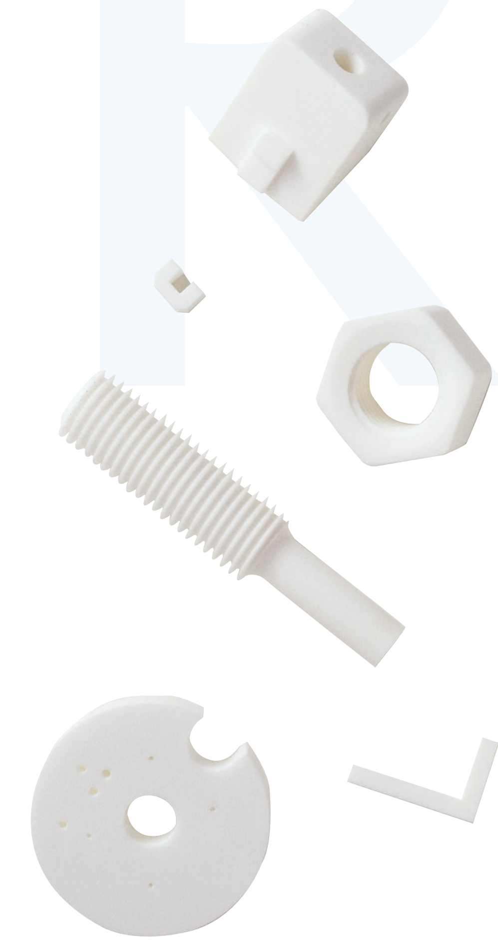
Welding equipment manufacturers are using MACOR MGC as a nozzle on the tips of oxyacetylene torches. The material’s nonwetting characteristic means molten particles won’t adhere to and decrease the effectiveness of the nozzle.

Fixtures

MACOR MGC is used as an electrode support and burner block in several industrial high heat, electrical cutting operations due to its low thermal conductivity and excellent electrical properties.

Medical Equipment

Producers of medical components are intrigued by MACOR MGC’s inertness, precise machinability and dimensional stability.



The Point is this:

When you need the performance of a technical ceramic (high use temperature, electrical resistivity, zero porosity) and your application demands the ready fabrication of a complicated shape (quickly, precisely, privately), look at MACOR MGC. It will lower costs and substantially reduce the time between design and actual use.

Properties

I. Thermal

	SI/Metric	English
Coefficient of Expansion		
-200 - 25°C	$74x10^{-7}$/°C	$41x10^{-7}$/°F
25 - 300°C	$93x10^{-7}$/°C	$52x10^{-7}$/°F
25 - 600°C	$114x10^{-7}$/°C	$63x10^{-7}$/°F
25 - 800°C	$126x10^{-7}$/°C	$70x10^{-7}$/°F
Specific Heat, 25°C	.79 KJ/kg°C	0.19 Btu/lb°F
Thermal Conductivity, 25°C	1.46 W/m°C	10.16 $\frac{\text{Btu in}}{\text{hr ft}^2\,°\text{F}}$
Thermal Diffusivity, 25°C	$7.3x10^{-7}m^2/s$	$0.028\ ft^2/hr$
Continuous Operating Temperature	800°C	1472°F
Maximum No Load Temperature	1000°C	1832°F

II. Mechanical

	SI/Metric	English
Density	$2.52\ g/cm^3$	$157\ lbs/ft^3$
Porosity	0%	0%
Young's Modulus, 25°C (Modulus of Elasticity)	66.9 GPa	$9.7x10^6$psi
Poisson's Ratio	0.29	0.29
Shear Modulus, 25°C	25.5GPa	$3.7x10^6$psi
Hardness, Knopp, 100g	250	250
Rockwell A	48	48
Modulus of Rupture, 25°C (Flexural Strength)	94 MPa (minimum specified average value)	13,600 psi
Compressive strength	345 MPa	50,000 psi
Fracture Toughness	$1.53\ MPa\ m^{0.5}$	$1,390\ psi\ in^{0.5}$

III. Electrical

		SI/Metric	English
Dielectric Constant, 25°C			
	1 KHz	6.03	6.03
	8.5 GHz	5.67	5.67
Loss Tangent,	25°C		
	1 KHz	$4.7x10^{-3}$	$4.7x10^{-3}$
	8.5 GHz	$7.1x10^{-3}$	$7.1x10^{-3}$
Dielectric Strength (AC) avg. (at 12 mil thickness and 25°C)		9.4 KV/mm	785 V/mil
Dielectric Strength (DC) avg. (at 12 mil thickness and 25°C)		62.4 KV/mm	5206 V/mil
DC Volume Resistivity, 25°C		$>10^{16}$ ohm-cm	$>10^{16}$ ohm-cm

IV. Chemical

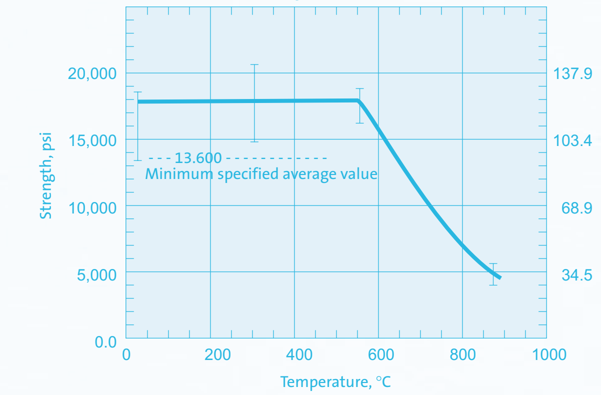
	Tests			Results
Solution	pH	Time	Temp.	Weight Loss (mg/cm^2) Gravimetric
5% HCL (Hydrochloric Acid)	0.1	24 hrs.	95°C	~ 100
0.002 N HNO_3 (Nitric Acid)	2.8	24 hrs.	95°C	~ 0.6
0.1 N $NaHCO_3$ (Sodium Bicarbonate)	8.4	24 hrs.	95°C	~ 0.3
0.02 N Na_2CO_3 (Sodium Carbonate)	10.9	6 hrs.	95°C	~ 0.1
5% NaOH (Sodium Hydroxide)	13.2	6 hrs.	95°C	~ 10
Resistance to water over time				
H_2O	7.6	1 day*	95°C	0.01
		3 days*	95°C	0.07
		7 days*	95°C	9.4
		3 days**	95°C	0.06
		6 days**	95°C	0.11

*Water not freshened daily
**Water freshened daily

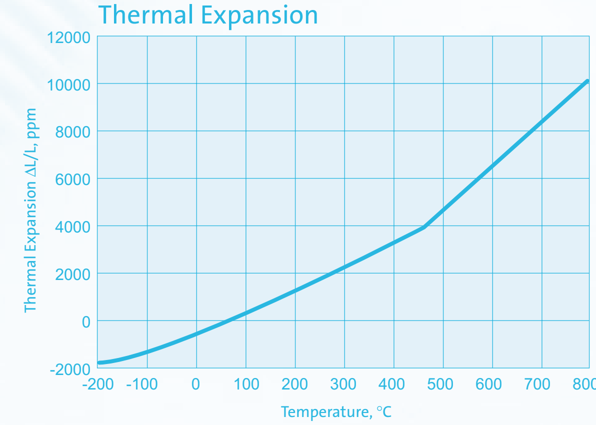
Technical Data

The general characteristics of this material described below were derived from laboratory tests performed by Corning from time to time on sample quantities. Actual characteristics of production lots may vary.

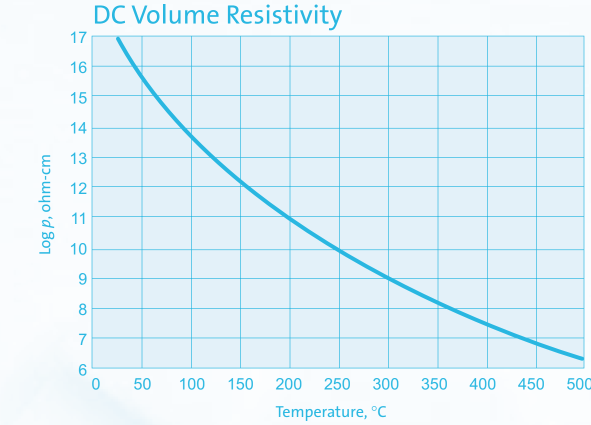
Modulus of Rupture



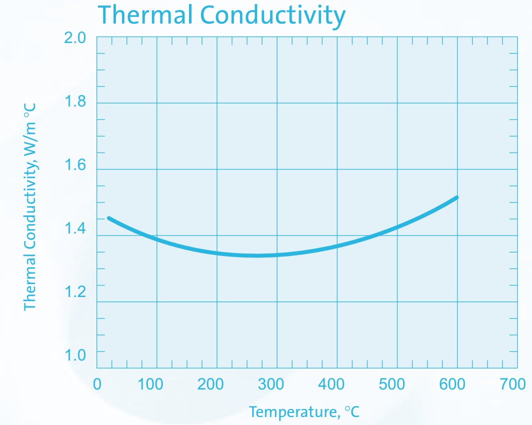
Thermal Expansion



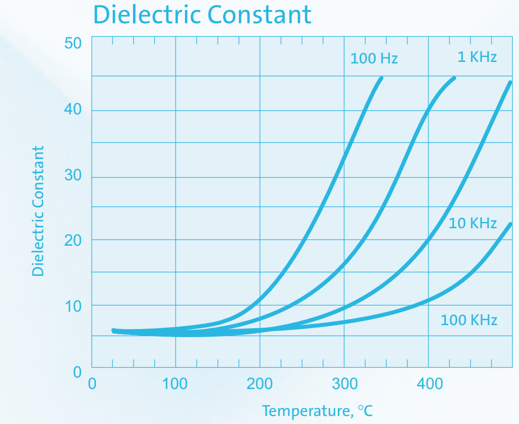
DC Volume Resistivity



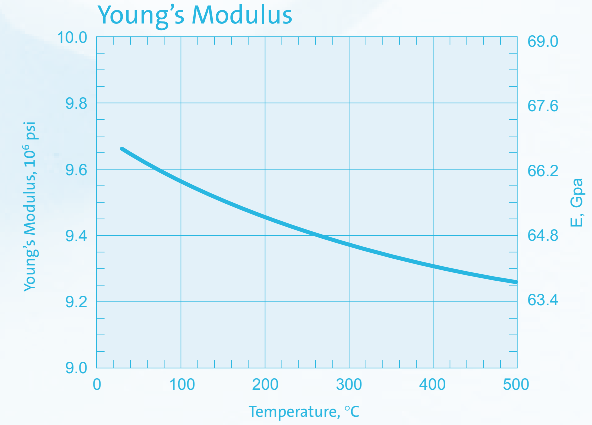
Thermal Conductivity



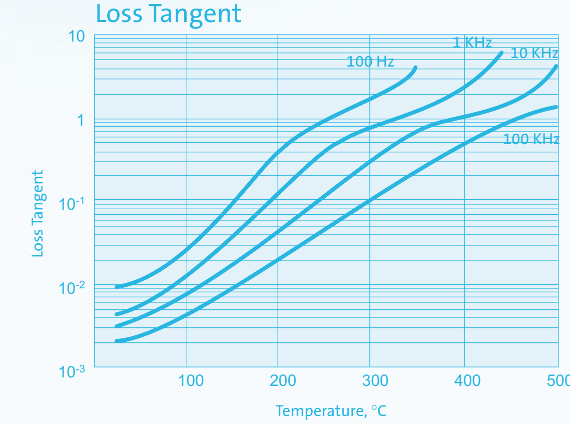
Dielectric Constant



Young's Modulus



Loss Tangent



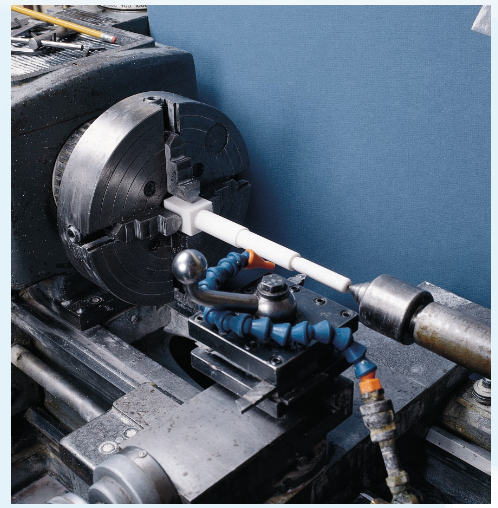
Machining

Key factors for successful machining are proper machining speeds and coolant.

MACOR Machinable Glass Ceramic can be machined with high speed steel tools, but carbide tools are recommended for longer wear.

Achieve the best results by using a water-soluble coolant, such as Cimstar 40 - Pink, especially formulated for cutting and grinding glass or ceramics.

No post firing is required after machining.



Grinding

Diamond, silicon-carbide or aluminum-oxide grinding wheels can be used.

Polishing

Start with loose 400-grit silicon carbide on a steel wheel. For the final polish, use cerium oxide or alumina on a polishing pad for glass or ceramics. A 0.5µin.-AA finish can be achieved.

Sawing

Use a carbide grit blade at a band speed of 100 fpm. An alternative is a silicon carbide or diamond cut-off wheel.

Turning

Cutting speed	30-50 sfm
Feed rate	.002-.005 ipr
Depth of cut	.150-.250 in.

Milling

Cutting speed	20-35 sfm
Chip load	.002 ipt
Depth of cut	.150-.200 in.

Drilling

Drill size	Spindle Speed	Feed Rate
1/4 in.	300 rpm	.005 ipr
1/2	250	.007
3/4	200	.010
1	100	.012
2	50	.015

Allow at least .050" of extra material on the back side for breakout. This excess can be removed after drilling.

Tapping

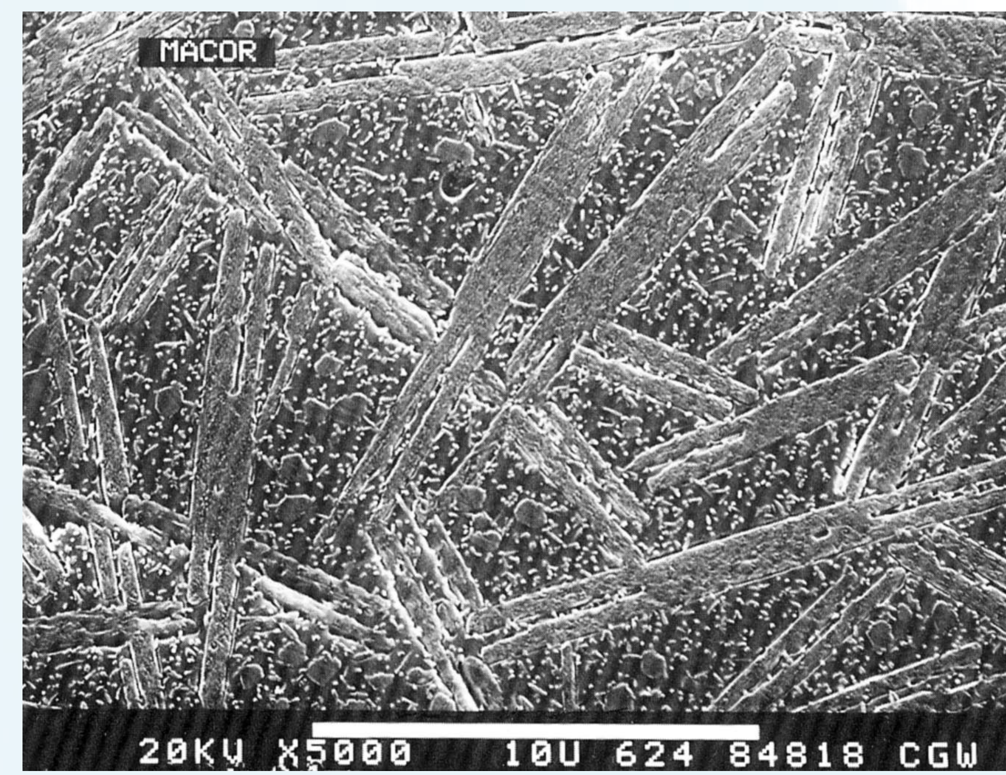
Make clearance holes one size larger than those recommended for metals. Chamfer both ends of the hole to reduce chipping. Run the tap in one direction only. (Turning the tap back and forth can cause chipping.) Continuously flush with water or coolant to clear chips and dust from the tap.

Composition

MACOR Machinable Glass Ceramic is a white, odorless, porcelain-like (in appearance) material composed of approximately 55% fluorophlogopite mica and 45% borosilicate glass. It has no known toxic effects; however, the dust created in machining can be an irritant. This irritation can be avoided by good housekeeping and appropriate machining techniques. The material contains the following compounds:

	Approximate Weight %
Silicon - SiO_2	46%
Magnesium - MgO	17%
Aluminum - Al_2O_3	16%
Potassium - K_2O	10%
Boron - B_2O_3	7%
Fluorine - F	4%

Randomly oriented mica flakes in the microstructure of MACOR MGC are the key to its machinability.



Microstructure of MACOR MGC 5000X magnification.