



1MG.004 Machinable Technical Ceramics

Summary

Overview

OVERVIEW

APPLICATIONS

BENEFITS

COMPARATIVE TABLE

PRODUCTS

Alumina silicat

Macor®

Alternative to Macor®

Machinable alumina (96 %)

Boron Nitride

Aluminum Nitride - SHAPAL™
Hi M-soft

Alternative to Shapal™ Hi M-
Soft

MACHINING ADVICE

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Final Advanced Materials works on a wide variety of ceramic products, and can supply a selection of machinable ceramics.

Sintered ceramics are used in all technologies where heat resistance, abrasion resistance, chemical resistance, mechanical strength are criteria justifying their use. However, these ceramics involve a specific equipment and know-how in terms of mechanical machining or shaping and their design can be costly.

On the contrary, machinable technical ceramics (MTC) are easily manufactured by means of conventional machine tools. These ceramics can be sawn, drilled, milled, turned with classic tools, available in all general mechanical workshops. They are designed to completely replace sintered ceramics while maintaining an excellent quality.

MTC allow the production of small series parts, as well as validation prototypes. A single ceramic cannot meet all the requirements and all the requests, that is why we have developed over the years, a full range of easily machinable ceramic materials, capable of responding to a maximum of constraints.

Final Advanced Materials has machining facilities and a certified ISO 9001 quality:

- Cylindrical, surface grinding, turning
- Milling
- Drilling
- Ultrasonic machining and drilling
- Plane and cylindrical polishing
- Tapping, threading, grinding
- Ceramic- metal assembly, brazing, plating

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Machinable Technical Ceramics

Final Advanced Materials also machines:

- The quartz, ruby, glass, glass-ceramic, filtration's porous ceramics
- Composites, fiberglass epoxy, silica, carbon, graphite
- Machinable insulator material, calcium silicate, mica, silica-alumina

Applications

- Electronic components
- Very high-temperature electrical insulation
- Foundry crucibles
- High-temperature lubricants
- Electrical components, insulators, etc.
- Medical devices
- Production of prototypes
- Production of brazed components
- Attachment of components for welding
- Electrical parts
- Supports
- Wear parts

Benefits

- Hardness
- High mechanical strength
- Dimensional stability, even at high temperatures
- Resistance to wear and corrosion
- Electrically insulating
- Resistance to chemical products
- High-temperature withstand
- Dielectric and ferro-electric properties

Comparative Table

Property	Ceramic	Metal	Polymer
Hardness	High	Low	Bad
Elastic Modulus	High	Good	Low
Resistance to High Temperature	High	Low	Bad
Thermal Expansion	Low	Good	Good
Malleability	Low	Good	Good
Corrosion Resistance	Good	Low	Low
Erosion Resistance	Good	Low	Low
Electrical Conductivity	Low	Good	Low
Density	Average	High	Low
Thermal Conductivity	Average	Good	Low



Machinable Technical Ceramics

Products

Alumina silicat

Alumina silicate can be used up to 650 °C in its raw shape and 1,300 °C in cooked finish. It can be used to make prototypes, for the brazing, the fixations of parts to be welded, insulators, supports, electrical components, etc.

This ceramic allows to develop parts by cutting, sawing, drilling, milling with plates, cylindrical rods or discs using conventional machines. It appears in a compact form and has attractive electrical and mechanical characteristics. It allows the machining of high precision components without using expensive moulds or prefabricated parts: it is the ideal solution for the manufacturing of prototypes or small series. Metals in fusion, such as zinc, do not wet this ceramic, it is inert in oxidizing and reducing atmospheres and provides an outstanding resistance to thermal shocks. It does not outgas and can be used under vacuum.

Composition	%	Composition	%
SiO ₂	60	Na ₂ O	< 0.2
Al ₂ O ₃	35	P ₂ O ₅	0.15 ignition loss 0.08
TiO ₂	2	MgO	< 0.08
K ₂ O	1	CaO	0.03
Fe ₂ O ₃	0.8	Na ₂ O	< 0.2

Applications:

- Production of prototypes
- Production of brazed components
- Attachment of components for welding
- Electrical components
- Supports
- Wear parts

Technical Data:

Property	Unit	Alumina Silicate, raw	Alumina Silicate, 940 °C	Alumina Silicate, 1,100 °C	Alumina Silicate, 1,300 °C
Item N°		080-0012	080-0021	080-0022	080-0023
Density	g/cm ³	2.9	2.9	-	2.65
Porosity	%	1.5 to 2	0 to 0.5	0 to 0.5	0.05
Water Absorption	%	-	3.7	3.1	0.8
Hardness on Mohs' scale		2.5	-	5.5	7.5
Compressive Strength at 20 °C	MPa	96	110	120	487
Flexural Strength	MPa	23	25	30	50
Max. Operating Temperature	°C	700	940	1,100	1,300



Machinable Technical Ceramics

Property		Unit	Alumina Silicate, raw	Alumina Silicate, 940 °C	Alumina Silicate, 1,100 °C	Alumina Silicate, 1,300 °C
Specific Warmth	at 20 °C	J K ⁻¹ kg ⁻¹	-	950	-	-
	at 1,000 °C		-	1,160	-	-
Thermal Conductivity at 20 °C		W.m ⁻¹ .K ⁻¹	-	-	1.39	2.67
Expansion Coeff. at 20 °C	at 200 °C	%			0.07	
	at 400 °C				0.156	
	at 600 °C		-	-	0.23	-
	at 800 °C		-	-	0.312	-
	at 1,000 °C		-	-	0.399	-
Electrical Resistivity at 20 °C		Ω.m	-	-	5.2x10 ¹¹	5.8x10 ¹¹
Dielectric Constant at 20 °C at 1 MHz			-	-	6.5	5.9
Loss Tangent at 1 kHz		%	-	-	0.2	0.2
Dielectric Strength at 20 °C		kV/mm	8 to 10	-	6 to 7	12 to 17
Corrosion Resistance at 20 °C			good			
Alkali Resistance at 20 °C			good			

Instructions of Implementation of the Ceramic

In its raw state, alumina silicate is machined like wood or brass, with the bandsaw, and for any traditional process: milling, turning, threading, boring, grooving, polishing, it is recommended to use tools in very hard metals, without cooling, and to clean carefully dusts of ceramic.

In the cooked form, note that parts should not exceed 12 mm of thickness if you want to avoid any crack; for higher thicknesses we shall drill holes.

During firing, the ceramic expands, from 1.9 % at 980 °C to 2 % at 1,040 °C. Beyond, variations are negligible, and the precision can reach ± 0:05 mm. We can finish grinding by softening.

To bond this ceramic, we shall prefer the ceramic glue Cotronics® 919.

Firing Procedure

To resist at more than 650 °C, the parts must be prepared in the furnace by sintering. The operation will start in cold oven and the heating levels will not exceed 260 °C per hour. Consider the expansion to obtain the final dimensions (approximately 2 %). These levels will have to go down to 150 °C per hour if the parts have a thickness of more than 12 mm. The maximum temperature will not exceed 1,010 °C to 1,100 °C, and will be held, from 30 minutes for a thickness of 6 mm to 45 minutes for a thickness of 20 mm. The right value can be calculated by extrapolation. We shall cool then gradually until the part will be taken out of the furnace at about 90 °C.



Machinable Technical Ceramics

Special Instructions

Action	Advice
To cut, to drill, to turn, to bore, to thread, to perforate, to straighten, to drill out	Possible with conventional tools. Tools speeds and materials are similar to those used for metals machining. Carbide tools must be carefully sharpened.
Heating	Plan the expansion from 1.8 to 2 % Example: a machined dimension of 9.8 mm will become a final dimension of 10 mm. Diameters also undergo this expansion.
Lubricants & Cooling Liquids	NEVER use neither lubricants, nor cooling liquids.
Cleaning	Clean the machines thoroughly after work: alumina silicate is abrasive in powder form.
Remanufacturing	Possible with water to a very high precision When required by the application: by means of silicon carbide grinding wheels.
In case of failure	Remember to check the causes most frequently observed: - Is the firing temperature badly adjusted? - Is there a miscalculation of the expansion? - Does the created model present sharp corners and «hard» transitions?

Macor®

Macor® is an outstanding engineering material which can quickly be designed into highly complex shapes, using conventional metalworking tools. Opening a wide range of possibilities, Macor® gives the performance of a technical ceramic with the versatility of a high performance polymer, while providing the machinability of a soft metal.

Macor® remains continuously stable at 800 °C, with a maximum peak at 1,000 °C. Its coefficient of thermal expansion readily matches most metals and sealing glasses. As an electric insulator, particularly at high temperatures, it is excellent at high voltages and a broad spectrum of frequencies. Macor® is a white, nonwetting, odourless and non-outgassing material that exhibits zero porosity. It is also radiation resistant. Macor® is of a pure white and can be polished to a high gloss. It can be metallized, welded and bonded to a thick or thin epoxy film. Another main advantage of this unique material is that, even in small quantities, it can be manufactured in an economic way.

Composition	%	Composition	%
SiO ₂	46	K ₂ O	10
MgO	17	B ₂ O ₃	7
Al ₂ O ₃	16	F	4



Machinable Technical Ceramics

Fields	Examples
Ultra-High Vacuum Environments	Insulator, coil support, vacuum feed-throughs
Constant Vacuum Applications	Spacers, headers and windows for microwave tube devices, sample holders in field ion microscopes
Aerospace Industry	retaining rings, mechanical joints on the orbital probes
Nuclear-Related Experiments	Reference piece to measure dimensional change in other materials (Macor® is not dimensionally affected by irradiation)
Welding	Nozzle on the tips of oxyacetylene torches (nonwetting characteristic of Macor®)
Fixtures	electrode support and burner block in several industrial high heat, electrical cutting operations
Medical Equipment	Medical components are integrated by Macor®'s inertness

Technical Data

Property	Unit	Macor®
Item N°		166-0001
Density	g/cm³	2.52
Porosity	%	0
Hardness		Knoop 100 g: 25 MPa
Compressive Strength	MPa	345 to 900
Flexural Strength	MPa	94
Elastic Modulus	GPa	66.9
Max. Peak Temperature	°C	1,000
Max. Operating Temperature	°C	800
Specific Warmth at 20 °C	J/kg.K	795.5
Thermal Conductivity at 20 °C	W.m⁻¹.K⁻¹	1.46
Expansion Coeff. From 20 °C	to 600 °C	11.2
	to 800 °C	12.3
Electrical Resistivity at 20 °C	Ω.m	10 ¹⁵
Dielectric Constant at 20 °C for 1 MHz		6.01
Loss Tangent at 1 kHz		0.004
Dielectric Strength at 20 °C	kV/mm	45
Corrosion Resistance at 20 °C		good
Alkali Resistance at 20 °C		very good

Machining

Extremely machinable, Macor® offers tight tolerances capabilities, allowing complicated shape design (optimal performances up to +/- 0.013 mm for dimensions, < 0.5 µm for finished surface and up to 0.013 µm for polished surface).



Machinable Technical Ceramics

Available Products

Type	Dimensions
Plate	up to 300x300x55 mm
Rod	round section: up to Ø55x300 mm square section: 60x60x300 mm

We also machine your parts according to your drawings.

Machinable alumina (96 %)

Machinable alumina ceramic is ready to use and required no heat treatment. However, Cotronics®960 hardener can be used increase even more the wear resistance of its surface: just apply and fire at 320 °C. Machinable alumina ceramic is usable to 1,650 °C and resists to molten metals, acids, solvents and thermal chocs. It is ideal for applications in electrical, electronic, metallurgical, fixtures and vacuum industries.

Applications:

- Electrical components, insulators
- Prototypes, brazing
- Vacuum and R.F. heating fixtures
- Various supports...

Technical Data:

Property	Unit	Machinable Alumina
Item N°		960
Density	g/cm ³	3.0
Porosity	%	10
Hardness		Mohs 5
Compressive Strength	MPa	414
Flexural Strength	MPa	262
Max. Peak Temperature	°C	1,650
Thermal Conductivity at 20 °C	W.m ⁻¹ .K ⁻¹	4.6
Expansion Coefficient	10 ⁻⁶ /K	7.74
Electrical Resistivity at 20 °C	Ω.m	10 ¹²
Dielectric Constant at 20 °C for 1 MHz		9
Loss Tangent at 1 kHz		0.0016
Dielectric Strength at 20 °C	kV/mm	7.8
Corrosion Resistance at 20 °C		good
Alkali Resistance at 20 °C		good

Machinable Instructions

Machinable alumina is machined with high precision with traditional sharp cutting tools, carbide cutting tools are preferred:



Machinable Technical Ceramics

- Lubrication: Water provides excellent cooling and lubrication. Insufficient lubrication will cause dulling of cutting tools and chipping of the ceramic.
- Cutting: Cut down into work. Use bonded silicon carbide or diamond cut off wheel with speeds of 1,800 to 2,600 rpm. Use a a bandsaw with carbide grit blade at the speed of 23 m/mn, 14 non-lubricated teeth for the outlines.
- Drilling: Use a carbide drills
 - at 2,000 rpm within 6 mm in diameter
 - at 1,000 rpm above 6 mm
 - never exceed 12 mm (1/2").
- Threading: Use a diamond wheel with a tool post grinder or tungsten carbide tools.
- Tapping: Use high speed steel or carbide. Drill size should allow for 70 % thread form.
- Turning: Use carbide tool bits or silicon carbide wheels on post grinder.

Available Products

Type	Dimension
Plate	from 6 mm x 150 mm x 150 mm to 19 mm x 150 mm x 150 mm
Rod	from Ø6 mm x 150 mm to Ø88 mm x 300 m

We machine your parts according to your drawings.

Boron Nitride

Boron nitride is a white solid material in the as produced hot pressed form. Due to the densification method used, the physical properties of the material are different according to the perpendicular and parallel axis to the direction of sintering. Boron nitride is non-toxic. Three standards machinable boron nitride:

- **Final®BN:** Boron nitride with binder
- **Final®BN HP:** High purity boron nitride without binder
- **Final®BN HP2:** Boron nitride highly resistant to mechanical strength

Applications:

- Electric insulator at very high temperatures
- CVD crucibles
- Thermocouple sheath
- Resistor holder
- High temperature lubricant
-

Technical Data:

Property	Unit	Final®BN HP
Item N°		200-0095



Machinable Technical Ceramics

Density		g/cm ³	1.91
Hardness on Knopp's scale		kg/mm ²	16
Compressive Strength	parallel	MPa	17.92
	perpendicular		23.44
Flexural Strength	parallel	MPa	13.96
	perpendicular		21.54
Elasticity Modulus	parallel	GPa	34.1
	perpendicular		75.2
Max. Peak Temperature		°C	850 (2,000 inert)
Specific Warmth at 20 °C		J K ⁻¹ kg ⁻¹	810
Thermal Conductivity at 100 °C	parallel	W.m ⁻¹ .K ⁻¹	79
	perpendicular		130
Dielectric Strength at 20 °C		kV/mm	79

Available Products

We machine your parts according to your drawings.

Aluminum Nitride - SHAPAL™ Hi M-soft

Aluminium nitride (AlN) is a nitride of aluminium and a wide band gap (6.2 eV) semiconductor material. It is an electrical insulating refractory material having very high thermal conductivity (higher than that of copper at 200 °C) and showing high resistance to oxidation and abrasion. It has potential applications for substrate and in power electronics for the manufacture of microwave power transistors.

Aluminium nitride is synthesized by the carbothermal reduction of aluminium oxide or by direct nitridation of aluminium. It is transparent in the visible wavelengths and in the infrared (0,5 to 3µm) and can be used as a window for infrareds and radars.

Applications:

- Various electronic components that require heat dissipation and electrical insulation
- Various components that require high-frequency wave properties, including low dielectric constant and dielectric loss
- Tools and setters that require a low coefficient of thermal expansion.



Machinable Technical Ceramics

Technical Data:

Property	Unit	Aluminum Nitride SHAPAL™ Hi M-soft	Machinable Aluminum Nitride
Item N°		166-0002	055-0031
Density	g/cm ³	2.8	2.9
Porosity	%	0	< 0.1
Hardness on Vickers' scale	MPa	3.8	-
Compressive Strength	MPa	980	1,170
Flexural Strength	MPa	300	300
Elasticity Modulus (Young)	GPa	176	-
Max. Peak Temperature	°C	1,000 (1,900 inert)	1,020 (1,900 vacuum)
Thermal Conductivity at 20 °C	W.m ⁻¹ .K ⁻¹	92	92.6
Expansion Coeff. from 20 °C	to 600 °C	4.8	
	to 800 °C	5.0	
Electrical Resistivity to 20 °C	Ω.m	10 ¹¹	10 ¹⁰
Dielectric Constant at 20 °C with 1 MHz		6.8	7.1
Dielectric Strength at 20 °C	kV/mm	65	40

Available Products

We machine your parts according to your drawings.

Alternative to Shapal™ Hi M-Soft

We also offer a competitive product to Shapal™ M Soft by Tokuyama. This aluminum nitride has equivalent characteristics to Shapal™ M while being economically more interesting.

Type	Dimension
Plate	up to 315x200x60 mm
Rod	up to 58x300 mm
We also machine your parts according to your drawings	

Machining Advice

These ceramics are machined accurately with conventional carbide tools. The following procedures will be monitored and verified frequently, as well as we will use and verify frequently very sharp tools: these materials are very hard and abrasive, they damage rapidly the tools edges. It is imperative to work slowly without vibration nor hurry.

Lubrication: water is an excellent lubricant/ coolant. Maintain a continuous flow on the tool and the workpiece, to avoid splinters. For even more precision, use the recommended products.



Machinable Technical Ceramics

Sawing: with circular diamond or silicon carbide saws, speeds from 2,000 to 2,500 rpm, top-down.

Trimming or Filing: with ribbons covered continuously with carbide powder, speed 30 m/mn maximum.

Drilling: with carbide drills, Carbolloy 883 type. Slow down speeds announced for HSS drills. Never drill in a single continuous operation, suspend and restart the drill progress. Use a hammer drill, re-sharpen every 3 to 4 holes.

Boring:

- Speed: 2.2 to 3.8 m/mn
- Tool load: 0:051 mm/tooth
- Depth: 4 to 5 mm

Threading: use a diamond tool with chips recovery or use a small tool in tungsten carbide.

Tapping: High speed steel tools such as those in carbide are suitable. Prepare front holes at 70 % of the final diameter. Lubricate with kerosene.

Turning: with small carbide tools, or silicon carbide grinding wheels with chips recovery (Carbolloy 883)

- Cutting speed: 2.7 to 4.5 m/mn
- Advance: 0.051 to 0.08 mm/turn
- Depth: 4 to 6 mm

Grinding: with carbide discs sealed with epoxy, at recommended speeds. Use soft discs and of well distributed grains; for important jobs, finish with hard discs and of fine grains. Lubricate with a 1 % oil solution. Polish with white lead on a wedge or a soft rag.

Metalizing: For thick films, use metal inks (silver, gold and silver, platinum). For thin films, work by sputtering.

Physical variables included in this documentation are provided by way of indication only and do not, under any circumstances, constitute a contractual undertaking. Please contact our technical service if you require any additional information.

Property	Unit	Al ₂ SiO ₅ raw	Al ₂ SiO ₅ 940 °C	Al ₂ SiO ₅ 1,100 °C	Al ₂ SiO ₅ 1,300 °C	Macor®	
Item N°		080-0012	080-0021	080-0022	080-0023	166-0001	
Physical Characteristics							
Density	g/cm ³	2.9	2.9	-	2.65	2.52	
Porosity	%	1.5 to 2	0 to 0.5	0 to 0.5	0.05	0	
Water Absorption	%	-	3.7	3.1	0.8	-	
Mechanical Characteristics							
Hardness		Mohs: 2.5	-	Mohs: 5.5	Mohs: 7.5	Knoop 100 g: 25 MPa	
Compressive Strength at 20 °C	MPa	96	110	120	487	345 to 900	
Flexural Strength	MPa	23	25	30	50	94	
Elasticity Modulus	GPa	-	-	-	-	66.9	
Thermal Characteristics							
Max. Peak Temperature	°C	-	-	-	-	1,000	
Max. Operating Temperature	°C	700	940	1,100	1,300	800	
Specific Warmth at 20 °C	J K ⁻¹ kg ⁻¹	-	950	-	-	795.5	
Thermal Conductivity at 20 °C	W.m ⁻¹ .K ⁻¹	-	-	1.39	2.67	1.46	
Expansion Coef.	20 – 600 °C	%	-	-	0.23	-	11.2
	20 – 800 °C		-	-	0.312	-	12.3
	20 – 1.000 °C		-	-	0.399	-	-
Electrical Characteristics							
Electrical Resistivity at 20 °C	Ω.m	-	-	5.2x10 ¹¹	5.8x10 ¹¹	10 ¹⁵	
Dielectric Constant at 20 °C for 1 MHz		-	-	6.5	5.9	6.01	
Loss Tangent at 1 kHz		-	-	0.2	0.2	0.004	
Dielectric Strength at 20 °C	kV/mm	8 to 10	-	6 to 7	12 to 17	45	
Chemical Characteristics							
Corrosion Resistance at 20 °C		good	good	good	good	good	
Alkali Resistance at 20 °C		good	good	good	good	very good	

Property	Unit	Machinable Al ₂ O ₃	Final®BN HP	AIN SHAPAL™ Hi M-soft	Machinable AIN
Item N°		960	200-0095	166-0002	055-0031
Physical Characteristics					
Density	g/cm ³	3.0	1.91	2.8	2.9
Porosity	%	10	-	0	< 0.1
Water Absorption	%	-	-	-	-
Mechanical Characteristics					
Hardness		Mohs 5	Knopp : 4 kg/mm ²	Vickers pour 300 g: 3.8 MPa	-
Compressive Strength at 20 °C	MPa	414	17.92 et 23.44 ⊥	980	1,170
Flexural Strength	MPa	262	13.96 et 21.54 ⊥	300	300
Elasticity Modulus	GPa	-	34.1 et 75.2 ⊥	Young: 1,800	-
Thermal Characteristics					
Max. Peak Temperature	°C	1,650	850 (2,000 inert)	1,000	-
Max. Operating Temperature	°C	-	-	-	1,020 (1,900 vacuum)
Specific Warmth at 20 °C	J K ⁻¹ kg ⁻¹	-	810	-	-
Thermal Conductivity at 20 °C	W.m ⁻¹ .K ⁻¹	4.6	79 et 130 ⊥	92	92.6
Expansion Coef.	20 - 600 °C	%	-	4.8	-
	20 - 800 °C		-	5.0	-
Electric Characteristics					
Electrical Resistivity at 20 °C	Ω.m	10 ¹²	-	10 ¹¹	10 ¹⁰
Dielectric Constant at 20 °C with 1 MHz		9	-	6.8	7.1
Loss Tangent at 1 kHz		0.0016	-	-	-
Dielectric Strength at 20 °C	kV/mm	7.8	79	65	40
Chemical Characteristics					
Corrosion Resistance at 20 °C		good	-	-	-
Alkali Resistance at 20 °C		good	-	-	-