1MG.002
Sintered Technical Ceramic

Summary

Overview

Our wide range of sintered technical ceramics will allow you to select the most suitable material for your application:

- Alumina (Al_2O_3)
- Zirconia (ZrO_2)
- Aluminium Nitride AlN
- Boron Nitride (BN)
- Silicon Nitride (Si_3N_4)
- Silicon Carbide (SiC)

Final Advanced Materials manufactures ceramic parts with precision. From the blanks obtained by moulding or extrusion, we get these shaped parts by diamond machining for dense ceramics.

We provide the definition and machining of prototypes, as well as the individual production in small and large series. We design and machine the ceramic components adapted to specific customer applications.

We only work with calibrated and qualified ceramics of high purity. The ceramic parts that we transform, reproduce without modification, the physical characteristics of the blanks before machining, without any variation or mechanical depreciation.

The intrinsic properties to ceramics, i.e. hardness, abrasion resistance, compressive strength, resistance to high temperatures, to thermal shocks, high dielectric strength, all these qualities are preserved and reproduced on the finished parts.

The summary tables of this catalog will be of great help to define the best selection.

Applications

- Production of customized components
- Flame tubes
- Heat exchangers
- Firing trays
- Protection of electrical circuits
- Substrates
- Medical prostheses
- Sealing gaskets
- Ceramic machining tools
- Wire guides
- Mechanical components

Benefits

- Hardness
- High mechanical resistance
- Dimensional stability, even at high temperatures
- Resistance to wear and corrosion
- Electrically insulating
- Resistance to chemical products
- High-temperature withstand

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

Classification

The sintered ceramics are subdivided into groups according to their mineralogical or chemical composition. Final Advanced Materials can reference three main groups:

- **Silicate Ceramics**
- **Non-Oxide Ceramics**
- **Oxide Ceramics**

Ceramics in the following tables are identified according to DIN EN 60 672.

Silicate Ceramics

Silicate ceramics represent the largest proportion of fine ceramic products. The major components of these polyphase materials are clay and kaolin, feldspar and soapstone as silicate sources. Additionally such components as alumina and zirconium are used to achieve higher mechanical properties. Due to the relatively low sintering temperatures, the good understanding of how to control the process, and the ready availability of the natural raw materials, silicate ceramics are much cheaper than the oxide or non-oxide ceramics.

Aluminium Silicates	**C100**
Quartz Porcelain, plastic processing	C110
Quartz Porcelain, pressed	C111
Cristobalite Porcelain, plastic processing	C112
Alumina Porcelain	C120
Alumina Porcelain, highly resistant	C130
Lithium Porcelain	C140
Magnesium Silicates	**C200**
Steatite low tension	C210
Steatite standard	C221
Steatite, low loss tangent	C230
Forsterite, porous	C240
Forsterite, dense	C250
Alkaline Earth – Aluminium Silicates & Zirconium Porcelain	**C400**
Cordierite, dense	C410
Celsian, dense	C420
Calcium-based, dense	C430
Zirconium-based, dense	C440
Porous Aluminium Silicates & Magnesium Silicates	**C500**
Alumino-Silicate based	C510
Magnesium-Alumino-Silicate based	C511
Cordierite based	C520
Mullite with a small percentage of alkali	C600
Mullite with 50 to 65 % Al_2O_3	C610
Mullite with 65 t 80 % Al_2O_3	C620

Non-oxide ceramics

Non-oxide ceramics include ceramic materials based on compounds of boron, carbon, nitrogen and silicon. However, products made of amorphous graphite do not belong to this category. These ceramics usually contain a high proportion of covalent compounds. This allows their use at very high temperatures and results in a very high elastic modulus.

Carbides	**C300**
Silicon Carbide	SiC
Boron Carbide	B_4C
Nitrides	**C900**
Aluminium Nitride	C910
Boron Nitride	C920
Silicon Nitride, dense	C935
Titan Nitride	C920

Oxide ceramics

Oxide ceramics are defined as all materials that are principally composed of a single phase and a single component (> 90 %) metal oxide. These materials have little or no glass phase. The raw materials are synthetic products with a high purity.

Titanates & other ceramic with high permittivity	**C300**
Titan dioxide base	C310
Titan and magnesium base	C320
Titan dioxide and other oxides	C330
Calcium and titan oxides	C340
Ferroelectric perovskite base	C350
Ceramics with a high alumina percentage	**C700**
> 80 to 86 % alumina	C780
> 86 to 95 % alumina	C786
> 95 to 99 % alumina	C795
> 99 % alumina	C799
Other oxides	**C800**
Beryllium oxide, dense	C810
Magnesium oxide, porous	C820
Partially stabilized	PSZ*
Fully stabilized	FSZ*
Quadratic polycrystalline	TZP*
Silica glass	SiO_2*
Spinel (MgO, Al_2O_3)	Spinel**
Mullite (Al_2O_3, SiO_2)	Mullite**
Titan oxides (TiO_2)	TiO_2*

*identification according to DIN ENV 14 242 **common name

If you wish to know more about the technical caracteristic of these ceranics, please refer to the table at the end of this catalog.

Implementation

A perfect control of the entire process of implementation ensures the microstructure of the material. Three elements are essential to obtain a sintered ceramic part with optimal characteristics:

- Powder
- Pressing
- Sintering

According to the criteria of your request, we adapt the various stages of implementation:

- For the **prototypes**, we will press one block with our standard tooling. There are no tooling costs, nevertheless there is a machining phase before sintering rather long but inexpensive (depending on the geometry of your part). Re-machining with a diamond tool depending on the severity of the required tolerances.

- For the **series**, we will provide an equipment allowing to obtain the part the closest possible to its final geometry to reduce a maximum the cost of materials and the expenses of manufacturing. A re-machining with a diamond tool is always necessary in case of too restrictive dimensional tolerances.

For **the validation of a material** (chemical composition, particle size, thermal and mechanical characterization, …) we can offer you the realization of disks samples.

We also have the possibility to produce **coloured sintered ceramic parts**. During pressing, we mix coloured oxides to the ceramic powder.

For example:
- Black Zirconiumoxide ZrO_2 for watches
- Grey, red or blue Aluminiumoxide Al_2O_3 for jewelery

The manufacturing steps are as follows:

1. Pressing

At first, it is necessary to select a calibrated powder, of high quality, with a controlled and constant shrinkage. The powder particles are compacted to form a coherent shape with sufficient strength for subsequent handling. If necessary, this shaped, unsinteredmass of powder (known as a green body) can be machined economically before firing, since corresponding steps are much more expensive after sintering.

When applying the various forming processes, care must be taken to avoid significant density gradients and textures in the green body, since these can be amplified during sintering, leading to distortions and internal mecanical stresses. The choice of a suitable forming process is usually determined by economic factors (efficient manufacturing). There are two different pressing types : Isostatic or uniaxial.

2. Sintering

As a rule, green bodies made by a forming process like casting, plastic forming and pressing, contain, in addition to the ceramic powder mixture (including the permanent additives), moisture and often organic deflocculants, plasticisers, binders and other additives. All these volatile components at high temperature are removed from the green body at the beginning of sintering. The shrinkage coefficient defined by the quality of powder used allows to calculate the dimensions of the part once sintered.

3. Machining

Once sintered, the part can only be machined with a diamond tooling or by ultrasound. This operation is much longer, difficult and expensive.

Our ways of machining:

- Surface, cylindrical grinding, turning
- Milling
- Drilling
- Machining and ultrasonic drilling
- Plane and cylindrical polishing
- Tapping, threading, lapping

We also machine:

- quartz, ruby, glass, glass-ceramic, porous ceramics of filtration
- composites, glass filled resins, silica, carbon
- machinable insulation materials, calcium silicate, mica, aluminosilicate

4. Assembly

Brazing: the ceramic parts are metallised and this metallisation allows brazing up to temperatures of 1,200 °C in air or under vacuum. Braze alloys suited to materials to be assembled ensure sufficient mechanical strength to ceramic-metal fixtures. The main disadvantage of this type of assembly is to deal with a significant expansion differential between the different materials. It is partially controlled with construction principles which permit the consideration of it, or, which allow to reduce the effects of it. Every application is unique and specific.

Adhesion: Adhesion on metal ceramic parts implies to know exactly the maximal temperature to stand for, to evaluate the chemical constraints of the environment, the mechanical stress and the electrical capacity expected from this assembly. One of the most important factors is the thermal expansion coefficient of the elements in contact.

In the specific case where adhesion between two materials of different nature (i.e. different dilatabilities) must be realised, it is necessary to try to approach these parameters with the glue used, to better resist to the contraction or elongation stresses induced.

Mechanical assembly: Two techniques of assembly are available, screwing and seaming (for assembly between metal and ceramic).

Design

The use of typical metallic and polymeric materials is deeply ingrained in most design engineers and the different characteristics andconstraints are known. On the contrary, the design of ceramic parts is less known and more specifc. A ceramic part cannot be designed in the same ways than a mellaic part. Its design must adapt to the specificities of ceramics characteristics: ductile materials react to small area/local overloads, compensating for them through elastic extension, with some plastic deformation in reserve.

This therefore also calls for different design rules:

Aim for simple forms and dimensioning that is suitable for manufacturing

- Adapt the design to suit the forming process of the green body.
- Split complex forms into several simpler pieces.
- Avoid over-specifying surface properties and unnecessarily close tolerances.

Avoiding stress concentrations

- Apply forces over large areas.
- Avoid corners and sharp edges.

Minimise tensile stresses

- Convert tensile stress into compressive stress through appropriate construction.
- Include compressive pre-stressing.

Avoid material accumulations

- Design for good densification.
- Avoid sudden changes in cross-section.

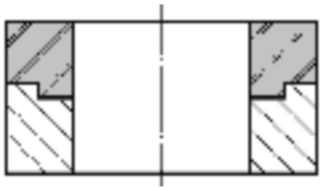
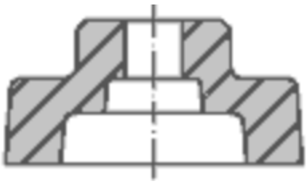
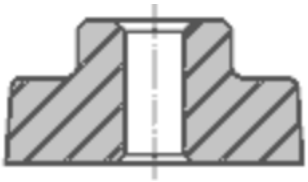
Minimise final finishing

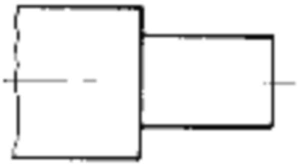
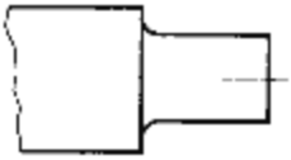
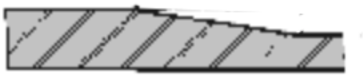
- Prefer green machining to final finishing.
- Alllow only small and limited machined surfaces.
- Define non-machined roundings and chamfers.

Pay attention to manufacturing-specific details

- Ease removal from the mould.
- Avoid thin walls.
- Pay attention to special requirements of the individual manufacturing steps such as: wet and dry pressing, extrusion, sintering and glazing.

Design Examples :

Aim for simple forms	
Unfavourable	**Favourable**
	
	

Avoiding stress concentrations	
Unfavourable	**Favourable**
	
	
	

Products

Final Advanced Materials supplies technical ceramic products of various types. Although these materials share similar properties (hardness, non-porosity, rigidity, dimensional stability, etc.), they differ in certain respects, particularly in terms of corrosion resistance.

Alumina Al_2O_3

Aluminium oxide is a technical ceramic oxide of primary importance, as it is suitable for a wide variety of applications. It is characterized by a high degree of hardness and thermal stability. It also shows exceptionally good resistance to high temperatures and abrasion.

Zirconia ZrO_2

Zirconium oxide is employed to an increasing extent, on the grounds of its useful characteristics: high rupture strength, comparable thermal expansion to cast iron, exceptionally high flexural and tensile strength, high resistance to wear and abrasion, and low thermal conductivity. Moreover, this material is a conductor of oxygen ions, and possesses excellent tribological properties.

Silicon Carbide SiC

Silicon carbide products are characterized by properties which are pronounced to a varying degree, depending upon the type of carbide used (dense or porous). These products generally show very high strength, even at high temperatures, and are distinguished by their hardness and their resistance to wear, corrosion, oxidation, and thermal impacts. They also feature a very low coefficient of thermal expansion, very high thermal conductivity and good tribological properties. In addition, they are electrical semiconductors.

Boron Nitride BN

Boron nitride can be easily machined to virtually any shape. In inert and reducing atmospheres, boron nitride is resistant to temperatures in excess of 2,000 °C. It shows low thermal expansion, although its dielectric strength is high. Moreover, it is not wetted by the majority of molten metals and slags, and can therefore be used as a receptacle for the majority of molten metals.

Aluminium Nitride AlN

Aluminium nitride shows remarkably high thermal conductivity, together with good electrical insulating properties, making this material a useful resource for electrical engineering projects. In addition, this material can be metal-plated by conventional processes, in preparation for brazing or welding.

Silicon Nitride Si_3N_4

Silicon nitride is a particularly important ceramic of its type, as it features a unique combination of properties. It is extremely hard, highly resistant to thermal impacts, chemical products and wear, even at high temperatures, and features a low coefficient of thermal expansion, in combination with average thermal conductivity.

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.

FINAL
+ADVANCED MATERIALS

DATA SHEET 1MG.002

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Comparative Table

	Unit	Al_2O_3	ZrO_2		SiC	BN	AlN	Si_3N_4
Item N°		055-0010	055-0020	055-0021	103-0010	200-0090	055-0030	103-0020
Composition		Al_2O_3 99.7 %	ZrO_2-Y_2O_3	ZrO_2-MgO	SSiC	BN HD2	AlN	Si_3N_4
DIN ISO Identification		C799	C800	C800	-	-	C910	C935
Physical Characteristics								
Density	**g/cm^3**	3.9	6	5.6	> 3.1	>=1.9	3.3	3.18 to 3.40
Open Porosity	**%**	0	0	0	0	0	0	0
Colour		off white	white	yellow	black	white	grey	grey
Mechanical Characteristics at 20 °C								
Hardness on Vickers' scale HV10	**MPa**	> 17,000	> 12,000	> 10,000	> 25,000	-	> 10,500	15,200
Compressive Strength	**MPa**	2,500	> 1,800	> 1,800	> 2,500	-	-	3,000
Flexural Strength	**MPa**	> 370	> 600	> 600	> 400	14 ∥ 30 ⊥	> 350	769
Elastic Modulus	**Gpa**	> 380	> 200	> 200	400	-	> 320	290
Toughness	**$MPa.m^{1/2}$**	4	7	8	3.5	-	-	7.5
Weibull Modulus		15	20	16	10	-	-	25
Thermal Characteristics								
Max. Operating Temperature	**°C**	1,700	1,000	1,000	1,600 1,900*	850 2,000*	1,000	1,400
Specific Warmth at 20 °C	**$J\ K^{-1}\ kg^{-1}$**	900	400	400	670	-	-	700
Thermal Conductivity at 100 °C	**$W.m^{-1}.K^{-1}$**	30	2.5	3	125	21	170 to 180	25
Expansion coefficient from 20 to 1,000 °C	**$10^{-6}/K^{-1}$**	8.5	11	11	4.5	5.5 ∥ 1 ⊥	4.6	3.2
Electrical Characteristics								
Electrical resistivity at 20 °C	**Ω.m**	10^{12}	> 10^7	> 10^7	10^3	> 10^{13}	-	10^{12}
Electrical resistivity at 600 °C		10^6	> 10^3	> 10^3	-	-	-	-
Dielectric Strength	**kV/mm**	17	-	-	-	> 70	15	-

*inert atmosphere