Introduction

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

- Alumina
- Zirconia
- Magnesia
- Boron Nitride
- Silicon Nitride
- Silicon Carbide
- ...

**FINAL Advanced Materials** manufactures ceramic parts with precision. From the blanks obtained by molding 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: sensors, medical technology, equipment and mechanical engineering, microsystems technology, chemical and processes engineering.

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.

**Do not hesitate to contact us for more information, for the design and machining of your parts.**

For any question, please contact: info@final-materials.com
1 – CLASSIFICATION

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

- Silicate ceramics
- Non-oxide ceramics
- Oxide ceramics

**Silicate ceramics**: as the oldest group amongst all the 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 zircon are used to achieve special properties such as higher strength. During sintering a large proportion (> 20%) of glass phase material, with silicon dioxide (SiO2) as the major component, is formed in addition to the crystalline phases. 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)**:
  
  Identification according to DIN EN 60 672

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**Non-oxide ceramics**: include ceramic materials based on compounds of boron, carbon, nitrogen and silicon. (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, results in a very high elastic modulus, and provides high strength and hardness combined with excellent resistance to corrosion and wear.

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**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. At very high sintering temperatures a uniform microstructure is created which is responsible for the improved properties.

- **Aluminium Oxide (C 700)**

- **Other Oxides (C 800)**

2 – IMPLEMENTATION

A perfect control of the entire process of implementation ensures the microstructure of the material. 3 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 1 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 diskss samples.

For any question, please contact: info@final-materials.com
We also have the possibility to produce coloured sintered ceramic parts. During pressing, we mix coloured oxides to the ceramic powder.

For example:
- Black Zirconium oxide ZrO2 for watches
- Grey, red or blue Aluminium oxide Al2O3 for jewelry

**a) 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, unsintered mass 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 mechanical stresses. The choice of a suitable forming process is usually determined by economic factors (efficient manufacturing).

We can offer you two different pressing types: Isostatic or uniaxial.

**b) Firing**: 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 goal of ceramic technology is the manufacture of a mechanically strong body able to withstand the widely differing requirements and conditions of the application. There is only a small degree of bonding between the particles of the green body. The ceramic bonding, and the very high strength associated with it, is obtained only by sintering at high temperatures. Firing allows sintering (with or without a liquid phase) to take place, and this is what actually creates the ceramic material. The sintering rate is dependent on purity, grain size, compaction and the sintering atmosphere.

Through reactions that occur during sintering, a strengthening and densification of the ceramic takes place, resulting in a reduction in porosity. This process results in a volume reduction; this is called sintering shrinkage. The amount of shrinkage for the various ceramic materials is widely different. The shrinkage coefficient defined by the quality of powder used allows to calculate the dimensions of the part once sintered.

**c) Machining**: The green body is machined with a conventional tooling, the fragility of the material requires special attention. Machining cost is rather low.

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

For any question, please contact: info@final-materials.com
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

**d) Assembly**

**Brazing**: the ceramic parts are metallised, this metallisation allows brazing up to temperatures of 1200°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 which is a significant expansion differential between the different materials, 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, we shall study the appropriate assembly with you.

**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, in order to resist better to the contraction or elongation stresses induced. Whatever your problem of ceramic adhesion, do not hesitate to contact us.

**Mechanical assembly**: We have a long experience of this type of assembly, we can offer you different techniques:
- Screwing
- Seaming

**3 – DESIGN OF CERAMIC PARTS**

The use of typical metallic and polymeric materials (steel, cast-iron, aluminium alloys, nickel-based alloys, etc.) for machine and tool construction, automotive construction and process engineering is deeply ingrained in most design engineers: the different characteristics and constraints are known. When a technical problem has to be solved, the designer must create a number of technical elements; if ceramic materials are to be used, he must pay particular attention to the need for the design to be appropriate for the material. Ductile materials react to small area/local overloads, compensating for them through elastic extension in accordance with Kooke’s law, with some plastic deformation in reserve. This does not apply to materials
that are hard and therefore brittle - and also not flaw-tolerant. There are therefore considerable differences between the local loading capacity of parts made of ductile (metallic) materials and of brittle/hard (ceramic) materials. 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
- Make the forming process and sintering processes easier
- Split complex forms into several simpler pieces
- Avoid over-specifying surface properties and unnecessarily close tolerances

**Avoiding stress concentrations**
- Minimise notch stresses
- Apply forces over large areas
- Avoid sudden changes in cross-sectional area
- Avoid corners and sharp edges

**Minimise tensile stresses**
- Specify cross-sections appropriate to the expected loading
- Convert tensile stress into compressive stress through appropriate construction
- Include compressive pre-stressing
- Arrange for forces to be applied in a manner suitable for ceramics

**Avoid material accumulations**
- Pay attention to keeping wall thickness as uniform as possible
- Separate the nodes in the design
- Avoid sudden changes in cross-section
- Design for good densification

**Minimise final finishing**
- Specify the shape of the green body and the green body machining, leaving only very little working allowance for final finishing
- Prefer green machining to final finishing
- Allow only small and limited machined surfaces
- Only specify requirements that are absolutely necessary
- Define non-machined roundings and chamfers

**Pay attention to manufacturing-specific details**
- Ease removal from the mould
- Avoid undercuts
- Choose the most favorable forming process for the green body
- Avoid thin walls and bridges
- Aim to keep the component proportions suitable for manufacturing
- Create clear seating and fastening facilities for subsequent machining
- Pay attention to special requirements of the individual manufacturing steps such as: wet and dry pressing, extrusion, sintering and glazing

**Keep Shapes Simple**

- Avoid steps and offsets if possible
- Avoid oval parts
- Give preference to modular construction

**Avoid Stress Concentrations**

- Avoid sudden changes in cross-sectional area
- Minimise notch-like structures
- Avoid corners and sharp edges, round inner edges and cutouts

**Avoid Material Accumulations**

- Aim for even wall thickness in extrusions
- Separate the nodes
- Avoid thick ends on mouldings

For any question, please contact: info@final-materials.com
# 4 – CHARACTERISTICS TABLES

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<tr>
<th>MATERIALS</th>
<th>Alumina</th>
<th>Zirconia</th>
<th>Silicon carbide</th>
<th>Boron nitride</th>
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**Characteristics table**

**Density (g/cm³)**
- Alumina: 3,9
- Zirconia: 6
- Silicon carbide: 5,6
- Boron nitride: > 3,1
- Aluminim nitride: 2,2
- Silicon nitride: 3,3
- Aluminum titanate: 3,18 à 3,4
- 3,35

**Open Porosity (%)**
- Alumina: 0
- Zirconia: 0
- Silicon carbide: 0
- Boron nitride: 0
- Aluminim nitride: 0
- Silicon nitride: 12,5
- Aluminum titanate: 0

**Colour**
- Alumina: ivory
- Zirconia: white
- Silicon carbide: yellow
- Boron nitride: black
- Aluminim nitride: white
- Silicon nitride: grey
- Aluminum titanate: grey
- 12,5: ivory

**Mechanical characteristics 20 °C**

**Hardness Vickers HV10 (N/mm²)**
- Alumina: > 17 000
- Zirconia: > 12 000
- Silicon carbide: > 10 000
- Boron nitride: > 25 000
- Aluminim nitride: -
- Silicon nitride: > 10 500
- Aluminum titanate: 15 200
- 3,3: -

**Compression strength (N/mm²)**
- Alumina: 2 500
- Zirconia: > 1800
- Silicon carbide: > 1800
- Boron nitride: > 2 500
- Aluminim nitride: 142
- Silicon nitride: > 2000
- Aluminum titanate: 3 000
- 3,3: -

**Flexural strength (N/mm²)**
- Alumina: > 370
- Zirconia: > 600
- Silicon carbide: > 600
- Boron nitride: > 400
- Aluminim nitride: 45
- Silicon nitride: > 350
- Aluminum titanate: 769
- 3,3: 25

**Elasticity modulus (GPa)**
- Alumina: > 380
- Zirconia: > 200
- Silicon carbide: > 200
- Boron nitride: 400
- Aluminim nitride: -
- Silicon nitride: > 320
- Aluminum titanate: 290
- 3,3: 17

**Toughness (MPa.m1/2)**
- Alumina: 4
- Zirconia: 7
- Silicon carbide: 8
- Boron nitride: 3,5
- Aluminim nitride: > 3
- Silicon nitride: 7,5
- Aluminum titanate: -

**Weibull Modulus**
- Alumina: 15
- Zirconia: 20
- Silicon carbide: 16
- Boron nitride: 10
- Aluminim nitride: -
- Silicon nitride: 25
- Aluminum titanate: -

**Thermal characteristics**

**Max. operating temperature (°C)**
- Alumina: 1700
- Zirconia: 1000
- Silicon carbide: 1000
- Boron nitride: 1900 (1600 on air)
- Aluminim nitride: 1400 (850 on air)
- Silicon nitride: 1000
- Aluminum titanate: 1400
- 1500

**Specific heat 20°C (J/kgK)**
- Alumina: 900
- Zirconia: 400
- Silicon carbide: 400
- Boron nitride: 670
- Aluminim nitride: -
- Silicon nitride: -
- Aluminum titanate: 700

**Thermal conductivity 100°C (W/mK)**
- Alumina: 30
- Zirconia: 2,5
- Silicon carbide: 3
- Boron nitride: 125
- Aluminim nitride: 47
- Silicon nitride: 180
- Aluminum titanate: 25
- 3,3: 1,4

**Coeff of thermal expansion 20 à 1000°C (10-6 /K-1)**
- Alumina: 8,5
- Zirconia: 11
- Silicon carbide: 11
- Boron nitride: 4,5
- Aluminim nitride: 5,85
- Silicon nitride: 4,6
- Aluminum titanate: 3,2
- 3,3: < 1

**Electrical characteristics**

**Specific resistivity 20°C (Ω.m)**
- Alumina: 10⁻¹²
- Zirconia: > 10⁻⁷
- Silicon carbide: > 10⁻⁷
- Boron nitride: 10⁻⁷ à 10⁻⁵
- Aluminim nitride: 3,10⁻¹²
- Silicon nitride: > 10⁻¹⁰
- Aluminum titanate: 10⁻¹²
- 3,3: 50.10⁻⁶

**Specific resistivity 600°C (Ω.m)**
- Alumina: 10⁻⁷
- Zirconia: > 10⁻⁷
- Silicon carbide: > 10⁻⁷
- Boron nitride: -
- Aluminim nitride: -
- Silicon nitride: -
- Aluminum titanate: -

**Dielectric strength (kV/mm)**
- Alumina: 17
- Zirconia: -
- Silicon carbide: -
- Boron nitride: 19,6
- Aluminim nitride: 15
- Silicon nitride: -
- Aluminum titanate: -

For any question, please contact: info@final-materials.com