





# Solution partner for **FINE MINERALS**

# ADVANCED MATERIALS FOR OXIDE CMCs

4N Alumina & mullite solutions



Ceramic Matric Composites (CMCs) combine refractoriness of ceramics and pseudo-plasticity of composite.

Among composites, Ox/Ox CMCs have corrosion, thermal and mechanical resistances adapted to the constraints and requirements of the energy, aerospace, and defense sectors.

Indeed, their contribution to **material performance and structural lightening** has led to a significant reduction in **energy consumption**. As an indication, the proportion of CMCs has increased from 10% to 50% between an A320 and an A380 airplane.

- **1-** The different types of composites
- 2- Ox/Ox CMC application fields
- **3** Manufacturing methods
- **4** How to formulate a slurry for high quality CMCs?
- **5** Baikowski® main CMC slurry & powder offering
- 6- Custom CMC solutions
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#### What is an outstanding matrix & how is a slurry formulated for an Ox/Ox CMC of high quality?

### **1** The different types of composites

- > Composites are made of a **matrix and fibers.**
- Among the different matrices available, there are:Polymer matrices
- Metal matrices like aluminum, nickel or titanium,

• Ceramic matrices made of **carbon**, **silicon carbide**, **alumina**, **mullite**, **ZTA or zirconia**, as described in the table below.

> The choice of matrix and fibers depends on the environment, operating temperatures, and characteristics required.





	СМС ТҮРЕ			
	Carbon/	Carbon/SiC	SiC/SiC	Ox/Ox
	Carbon			
Fiber	Carbon	Carbon	Sic	Alumina, Mullite
				Quartz
Fiber traction resistance (GPa)	4-7	4	2,7	3 (Al2O3)
				2 (Mullite)
				1,5 (Quartz)
Fiber cost (€/kg)	20-50	20-50	1000 - 20000	600 - 800
Density (g.cm-3)	1,4 - 1,7	1,8 - 2,8	2,3 -2,9	2,1 - 2,8
Environment	Not for use in	Protection is necessary if		Oxidizing
	oxidizing	oxidizing atmosphere		atmosphere
	atmosphere			allowed
Creep resistance	++++	+++	+++	+ (alumina)
				++ (mullite)
Maximum operating	2000 - 2100	1350 -2100	1100 - 1600	900 - 1300
temperature (°C)				

> In general, **CMCs are chemically stable, with excellent structural, and thermal properties.** Ox/Ox CMCs offer in particular the advantage of not being sensitive to oxidation. They also have good mechanical properties for maximum operating temperatures between 900 and 1300°C.

Among the various application benefits that can be mentioned, these composites have widely contributed to reduce the weight and improve the Specific Fuel Consumption of the exhaust sections of airplane engines.

# 2. Ox/Ox CMC application fields



- Hybrid tubes for high-pressure steam transport
- Components for stationary gas turbines
- Heat shields
- Missile head

• Reactor components (gas mixers, exhaust cones, reactor jackets, blades, etc.)





- Burner
- Furnace door
- Metal treatment racks
- Gas valves
- Thermal protection screens



## 3.Manufacturing methods

> Among the different manufacturing methods, **pre-impregnation** and **pressure infiltration** are the most widespread. They are both used and based on slurries that should meet the process needs (rheology, filler ratio, etc.).\*\*

> In order to not damage the fiber, the CMC thermal treatment can not be done at the **sintering temperatures** usually required for ceramics manufacturing. Therefore, the consolidation and the cohesive strength of the matrix must be sufficient below 1000/1200°C.





## 4. How to formulate a slurry for high quality CMCs?

> The first success criteria is the **slurry stability** that implies low interacting particles. At Baikowski<sup>®</sup>, we perform zeta potential measurements to develop our slurries.

> This slurry stability is achieved by adding a **dispersant** that depends on whether the objective is ionic, electrosteric or steric stabilization.

> To guarantee this stability over time, rheological analyses are carried out on a regular basis. These viscosity controls enable us to characterize our slurry aging and to offer ready-to-use products with very **good processability.** 

#### KEY PARAMETERS

- < 1µm particle size
- Controlled viscosity
- Slurry stability (in compliance with additives, especially binders /pH/aging)
- Lowest possible densification temperature
- Controlled porosity for good mechanical performances

## 5.Baikowski® main CMC slurry & powder offering

#### > SM8 (Al<sub>2</sub>O<sub>3</sub>)

SM8 alumina benefits for CMC applications are a monodisperse particle size distribution and good raw density





#### > BA15-PSS (Al2O3 slurry)

BA15-PSS offer all the advantages of a ready-to-use slurry, plus a good control of the particle size distribution and high sintering reactivity.

- 100% alpha
- High chemical purity (4N)
- Controlled particle size distribution  $d_{50}\approx 0.11 \mu m$
- SSA  $\approx 17 \text{m}^2/\text{g}$
- Solid loading: 50 wt%
- Low viscosity: 0.13 Pa.s at 10 s<sup>-1</sup>

Our BA15-PSS allows excellent fiber impregnation

- 80% densification at 1300°C
- 97% at 1400°C



#### > Mullite (3Al<sub>2</sub>O<sub>3</sub>-2SiO<sub>2</sub>)

Developed to offer enhanced compatibility with mullite fibers, our extremely pure mullite is small-sized to enable good densification.

- 100% mullite
- High chemical purity
- $\bullet$  Controlled particle size distribution d50 < 0.2  $\mu m$
- Specific surface  $\approx 35 \text{ m}^2/\text{g}$
- Slurry or spray-dried availability





#### > SLAz (Al<sub>2</sub>O<sub>3</sub> & Nano-zirconia doping)

Ready-to-use slurries of high purity fine alpha alumina with customized nano-zirconia ratio

> SLAz are tailor made slurries of our SLA high purity fine alpha alumina (d50=120 nm) and zilight<sup>®</sup> nano-zirconia (d50=5 nm):

- Customized ratio of nano-zirconia homogeneously reparted into fine alpha alumina matrix
- Customized solid loading

\*\*For specific uses, Baikowski® can provide ready-to-disperse powders



> Discover all our solutions for CMC applications

## > The SLAz slurries are stable on a large range of pH : from 4 to 10



> Low viscous slurries ( $\eta$ < 0.3 Pa.s) and small impact of the nano-ZrO<sub>2</sub> on the viscosity for slurry's processability.



## 6.Custom CMC solutions

> Adjustment of **doping and chemical composition** can be done such as:

- High purity
- Sintering additives
- Nano particles
- Mixed oxides (e.g. alumina/zirconia for additional mechanical properties)

#### > Product **customization** examples:

- Control of particle size distribution and SSA
- Binder-free spray-dried powders (for a better processability of submicronic powders)
- Concentrated slurries (solid loading up to 65wt%)
- Functionalized powders for organic solvent uses



#### **PRODUCT DESIGN**

> <u>Contact us</u> and we will develop together the product that meets all your specific needs and requirements.







## 7. Scientific publications

Enhancing thermal stability of oxide ceramic matrix composites via matrix doping / September 2024 Renato S.M. Almeida, H. Farhandi, K. Tushtev, K. Rezwan Baikowski<sup>®</sup> product: **BA15** 

> See more <u>scientific publications</u>





## Your solution partner for fine minerals



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