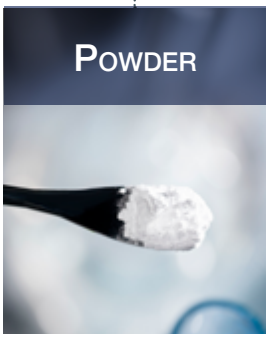
Baikowski®

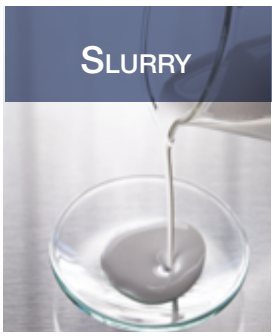
Solution partner for

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.

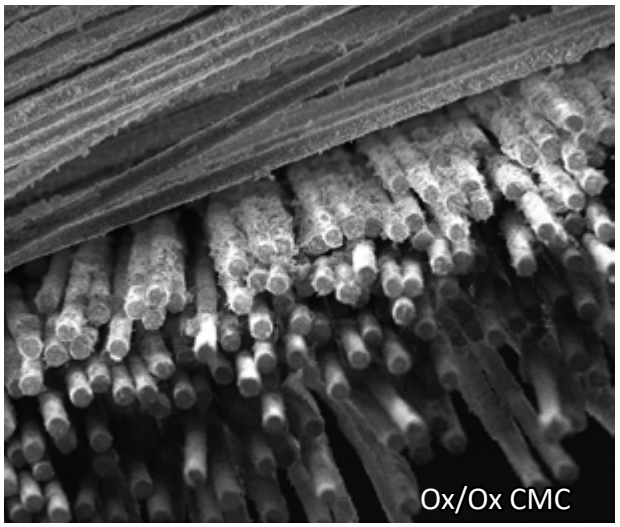
What is an outstanding matrix & how is a slurry formulated for an Ox/Ox CMC of high quality?

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·


Ox/Ox CMC

	CMC TYPE			
	Carbon/ Carbon	Carbon/SiC	SiC/SiC	Ox/Ox
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 oxidizing atmosphere	Protection is necessary if oxidizing atmosphere		Oxidizing atmosphere allowed
Creep resistance	++++	+++	+++	+ (alumina) ++ (mullite)
Maximum operating temperature (°C)	2000 - 2100	1350 -2100	1100 - 1600	900 - 1300

> 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

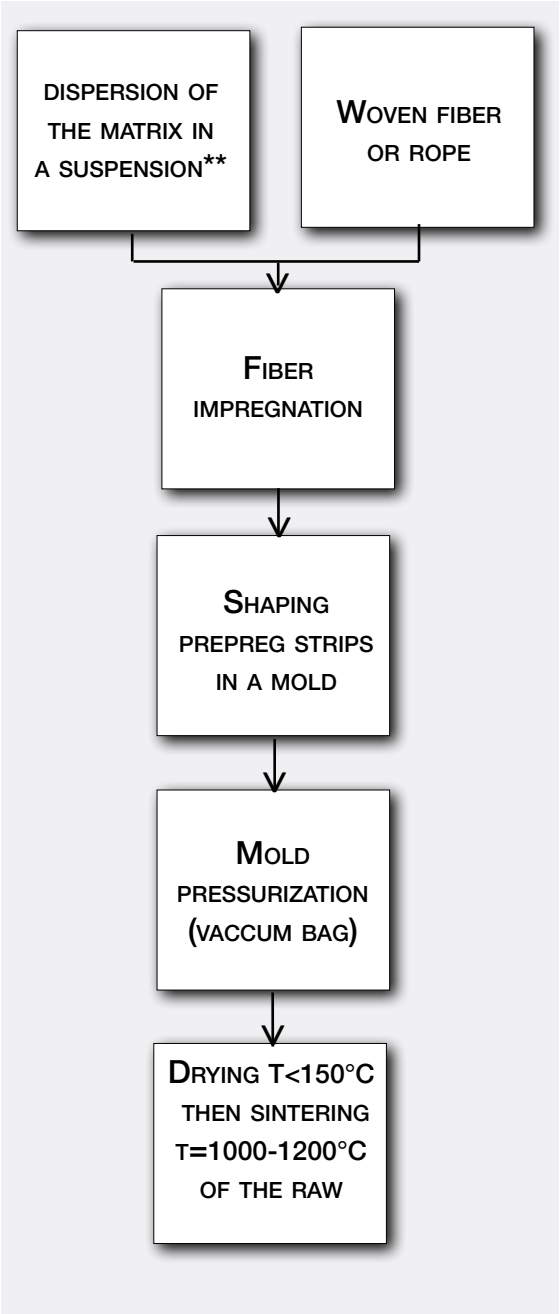
- Hybrid tubes for high-pressure steam transport
- Components for stationary gas turbines
- Heat shields
- Missile head
- Reactor components (gas mixers, exhaust cones, reactor jackets, blades, etc.)
- Burner
- Furnace door
- Metal treatment racks
- Gas valves
- Thermal protection screens

3. Manufacturing methods

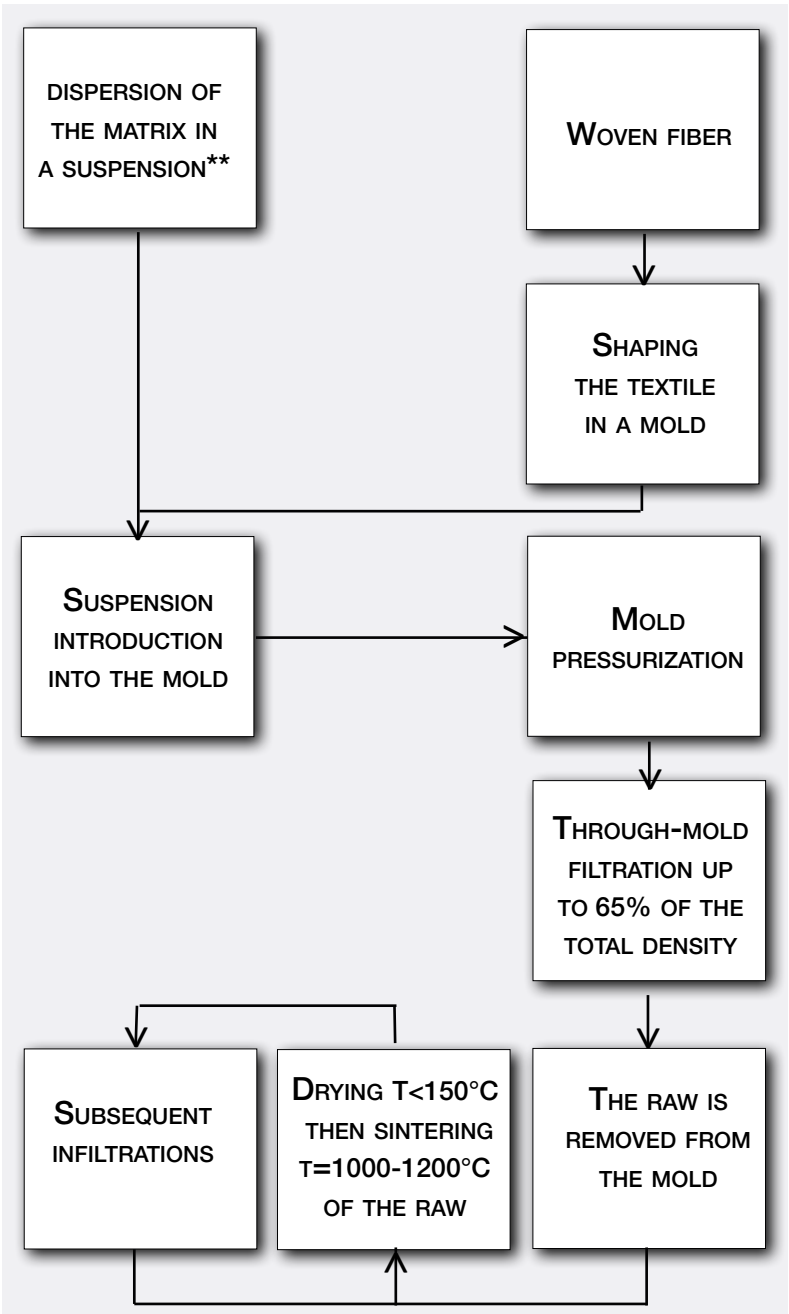
> Among the different manufacturing methods, **pre-impregnation** and **pressure infiltration** are the most widespread. They are both used and based on slurries that should meet the process needs (rheology, filler ratio, etc.).**

> 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.

Pre-impregnation



Pressure infiltration



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®, 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, electro-steric 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

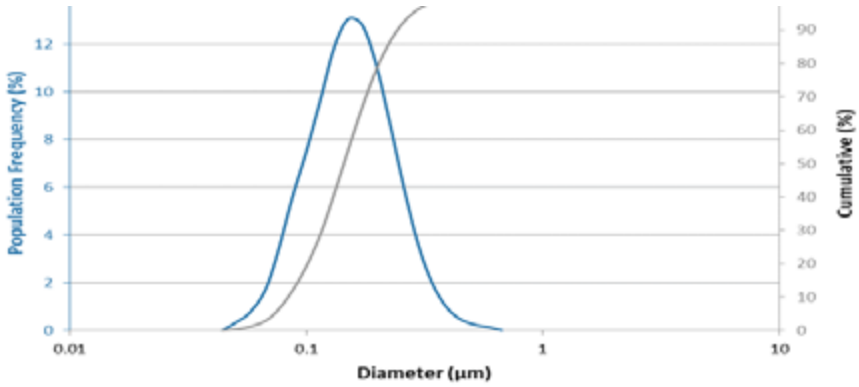
- < 1µm particle size
- Controlled viscosity
- Slurry stability (in compliance with additives, especially binders /pH/aging)
- Lowest possible densification temperature
- Controlled porosity for good mechanical performances

5. Baikowski® main CMC slurry & powder offering

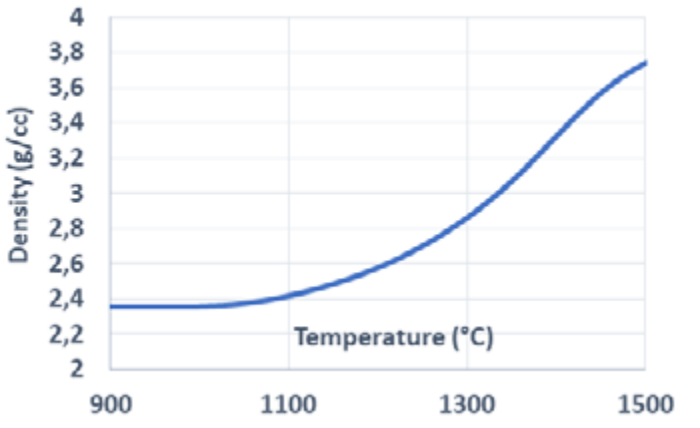
> SM8 (Al_2O_3)

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

- 100% alpha
- High Purity Alumina (4N)
- Controlled particle size distribution $d_{50} \approx 0.12\mu m$
- Specific Surface $\approx 10 m^2/g$



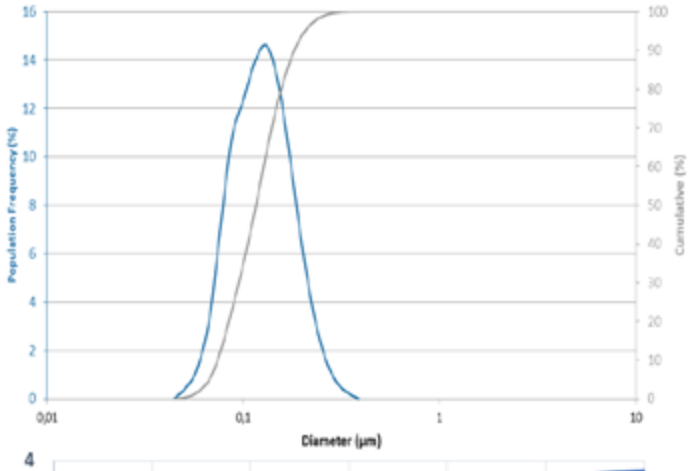
- Good green density (60%) with fine particles
- 80% densification achieved at 1400°C
- 90% densification achieved at 1450°C
- 97% at 1550°C



> BA15-PSS (Al_2O_3 slurry)

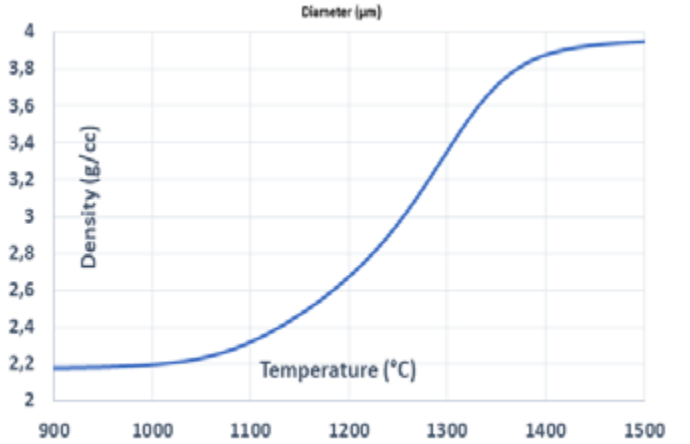
BA15-PSS offer all the advantages of a ready-to-use slurry, plus a good control of the particle size distribution and high sintering reactivity.

- 100% alpha
- High chemical purity (4N)
- Controlled particle size distribution $d_{50} \approx$ 0.11µm
- SSA ≈ 17m²/g
- Solid loading: 50 wt%
- Low viscosity: 0.13 Pa.s at 10 s^{-1}



Our BA15-PSS allows excellent fiber impregnation

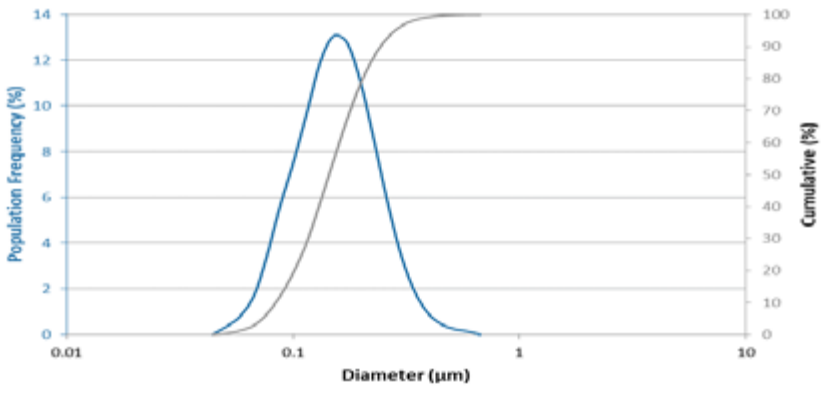
- 80% densification at 1300°C
- 97% at 1400°C



> Mullite ($3Al_2O_3$-$2SiO_2$)

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

- 100% mullite
- High chemical purity
- Controlled particle size distribution $d_{50} < 0.2$µm
- Specific surface ≈ 35m²/g
- Slurry or spray-dried availability



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6. Custom CMC solutions

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

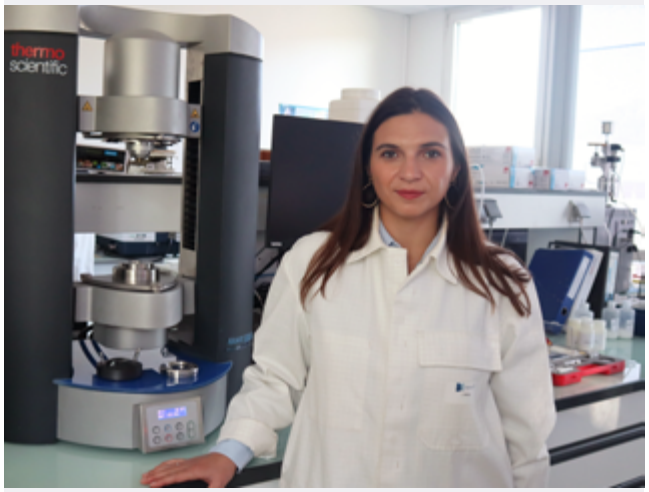
- High purity
- Sintering additives
- Nano particles
- Mixed oxides (e.g. alumina/zirconia for additional mechanical properties)

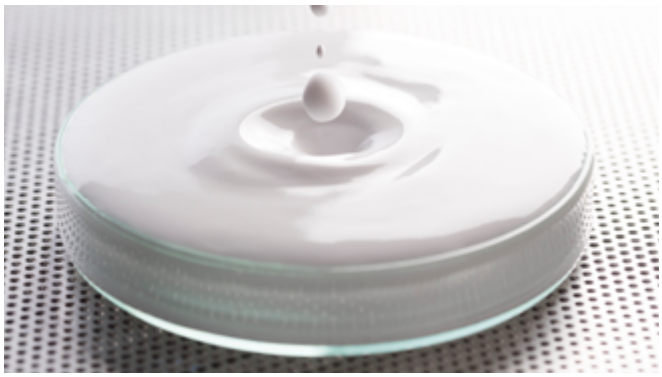
> Product **customization** examples:

- 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

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





> Discover all our solutions for CMC applications

7. Scientific publications

> Enhancing thermal stability of oxide ceramic matrix composites via matrix doping / February 2022
Renato S.M. Almeida, H. Farhandi, K. Tushtev, K. Rezwan
Baikowski® product: **BA15**

> See more scientific publications

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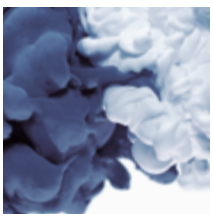

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