

A case study of performance degradation in
insulating panels:

Comparison between Blanket Aerogel and Mineral Wool Panels

Corso di Laurea Magistrale – Ingegneria dei Materiali

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Aim of the Project

A comparison between Aerogel Blanket and Mineral Wool Panel from the aspect of the thermal deterioration.

- How does aging affects the thermal insulating properties?

Thermal Analysis

- TG – DTA Analysis;
- Analysis on Heating Microscope;
- Thermal analysis in the Laboratory Furnace:
 - Analysis of the morphology on SEM;
 - Micro Chemical Analysis EDS.

Mineralogical analysis:

- XRD Analysis;

Analysis of Fire Reaction:

- Test of fire resistance with a cone calorimeter.



Panel Features

Rock Wool Panel



	Thickness	Composition
Matrix	60 mm	<ul style="list-style-type: none"> ▪ Mineral fibers 98 % <ul style="list-style-type: none"> ▪ Basalt 85 % ▪ Limestone 6 % ▪ Calcium Oxides 9 % ▪ Polyurethane Binder 2%
Coating	1 mm	<ul style="list-style-type: none"> ▪ Cellulosic fibers 60 % ▪ Mineral fibers 30 % ▪ Gel 10 %

Aerogel Blanket: Aeropan®



	Thickness	Composition
Matrix	9 mm	<ul style="list-style-type: none"> ▪ Glass fiber 65 % ▪ Silica Aerogel 35 %
Coating	1 mm	<ul style="list-style-type: none"> ▪ Polypropylene reinforced with glass fiber

Physical and Hygroscopic Properties

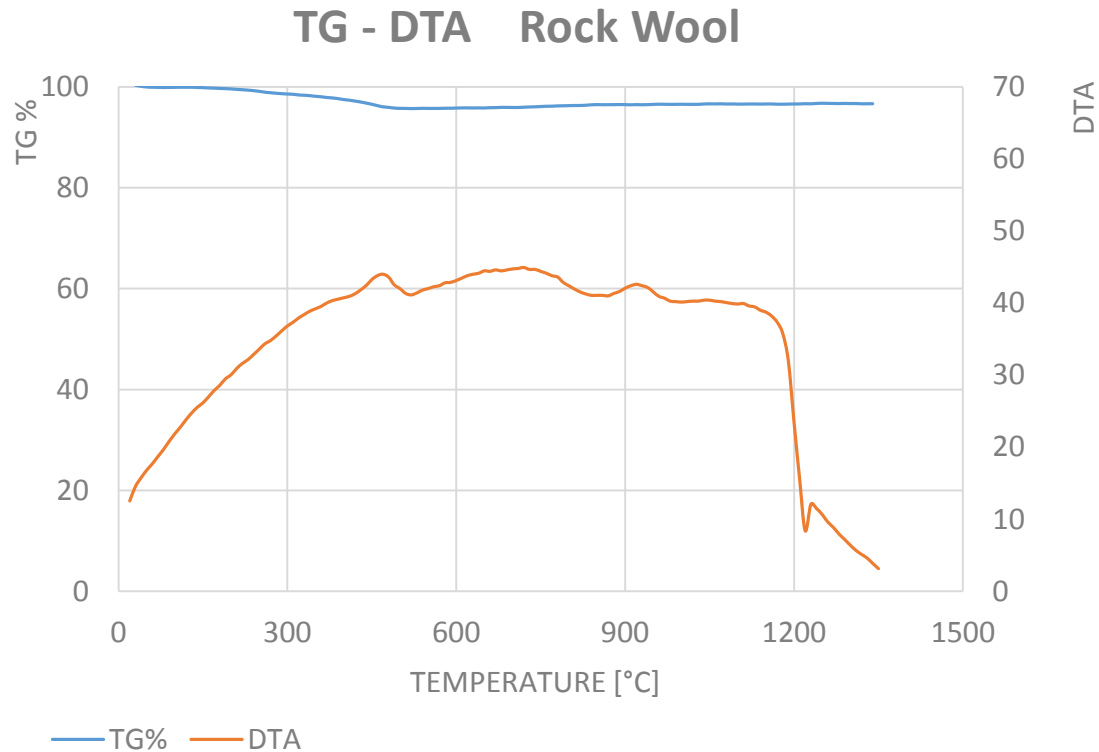
Rock Wool Panel

		U.M.	VALUE	DESCRIPTION
Thickness (UNI EN 823)		(mm)	60 ± 5 %	-
Nominal Density (UNI EN 1602)		ρ (Kg/m ³)	170 ± 10%	mean value
Nominal fiber diameter		(μm)	3 - 7	-
Resistance factor to water vapor diffusion (UNI EN 12086)	μ Matrix	-	1	23°C
	μ Coating	-	1.000	
Thermal Conductivity (UNI EN 12667)		λ (W/mK)	0,038	Value determined at a temperature of 10°C
Specific Heat (EN 12524)		Cp (J/KgK)	1.030	Value determined at a temperature of 40°C

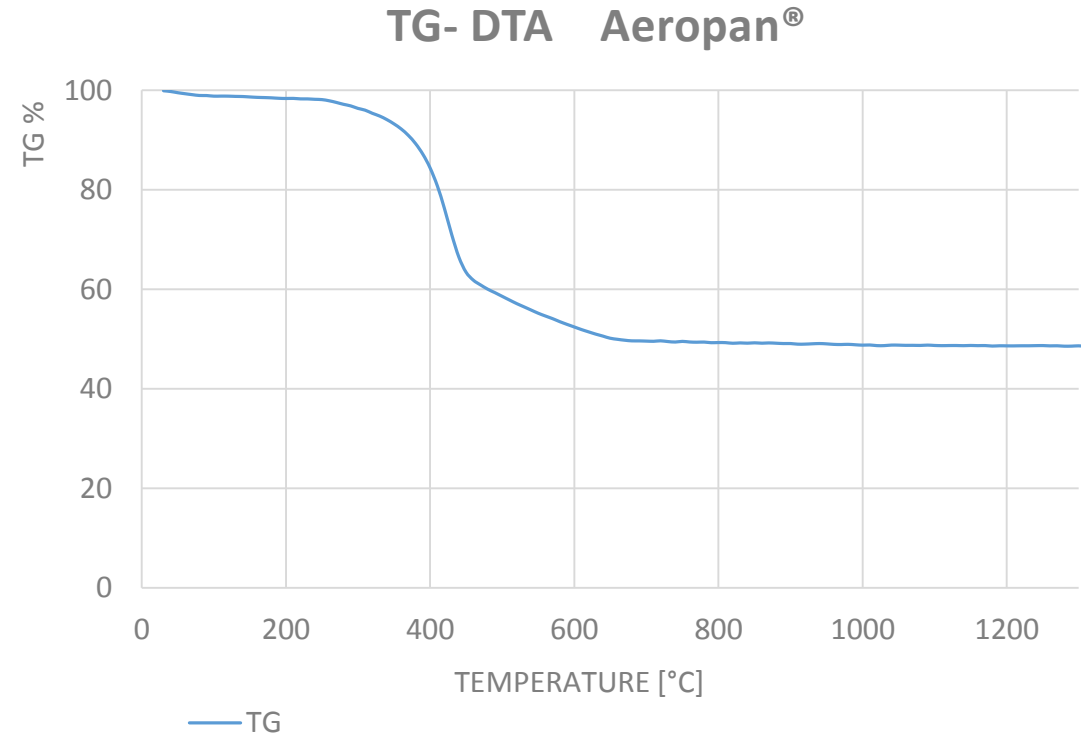
Aerogel Blanket: Aeropan®

		U.M.	VALUE	DESCRIPTION
Thickness (UNI EN 823)		(mm)	10 ± 5 %	-
Nominal Density (UNI EN 12667)		ρ (Kg/m ³)	150 ± 10%	mean value
Nominal fiber diameter	Glass fiber	(μm)	6 – 9	-
	PP	(μm)	8 - 12	-
Resistance factor to water vapor diffusion (UNI EN 12086)		μ	5	23°C
Thermal Conductivity (UNI EN 12667)		λ (W/mK)	0,013	Value determined at a temperature of 10°C
Specific Heat (EN 12524)		Cp (J/KgK)	1000	Value determined at a temperature of 40° C

Differential Thermal Analysis (DTA) and Thermo Gravimetric (TG)



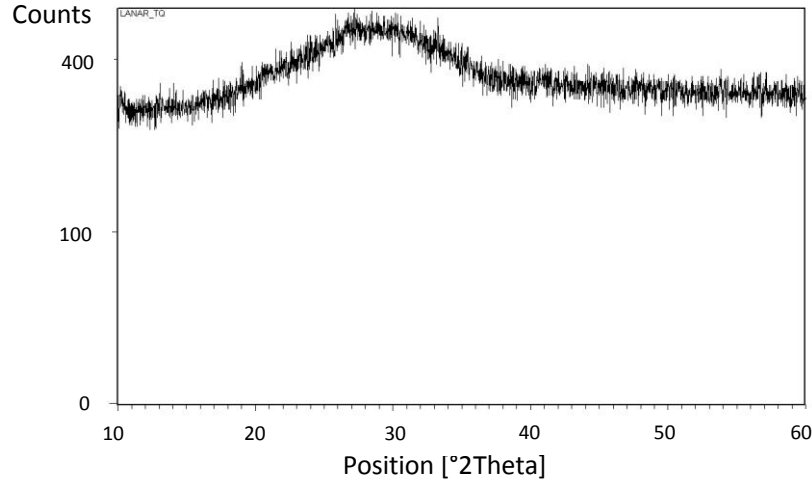
- ❑ **0 - 500 ° C:** Weight loss of 5% → Loss of the polyurethane binder.
- ❑ **DTA:** Endothermic peak at ~ 1200 ° C → Melting a crystalline phase contained in the basalt.



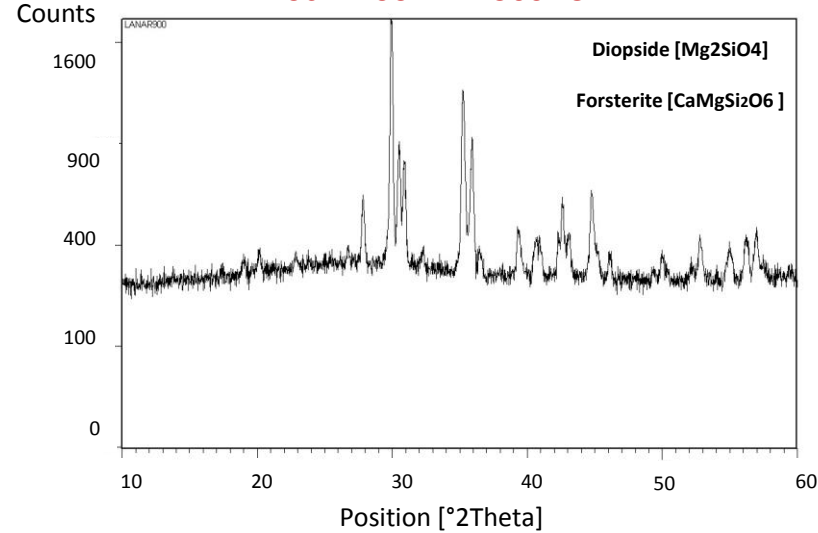
- ❑ **0 – 700 °C:** Weight loss of ~ 50% → Loss of the organic-component PP contained in finishing;

XRD Analysis

Rock Wool Room Temperature



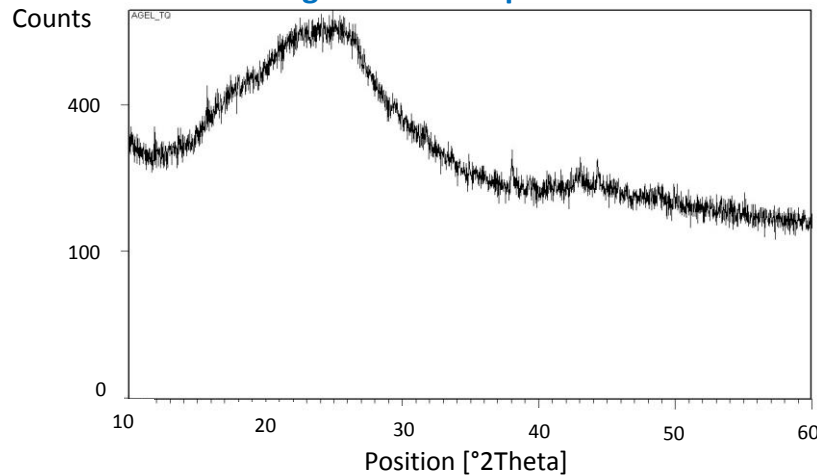
Rock Wool T = 900 °C



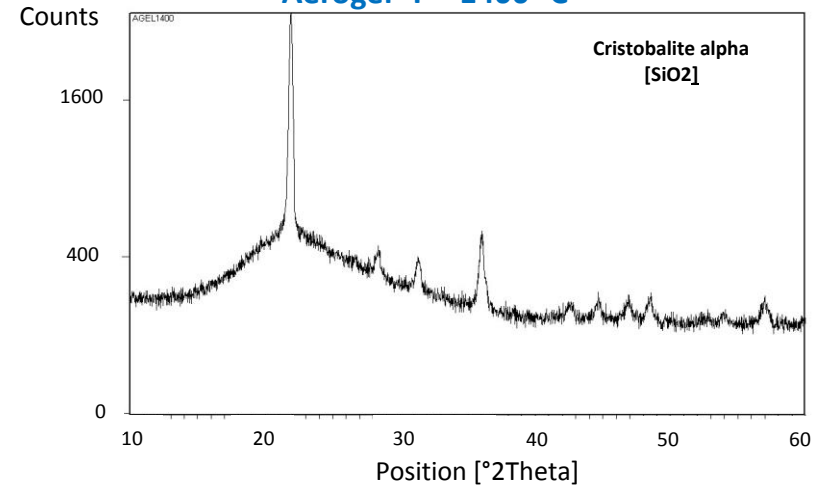
Rock Wool:

- ❑ **RT:** The sample is completely amorphous;
- ❑ **T = 900 °C :** The sample crystallized by the formation of Diopside and Forsterite.

Aerogel Room Temperature



Aerogel T = 1400 °C

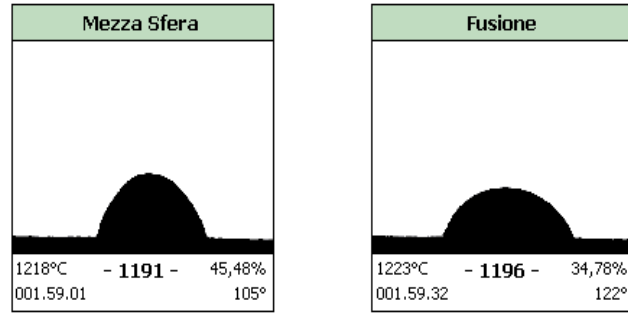
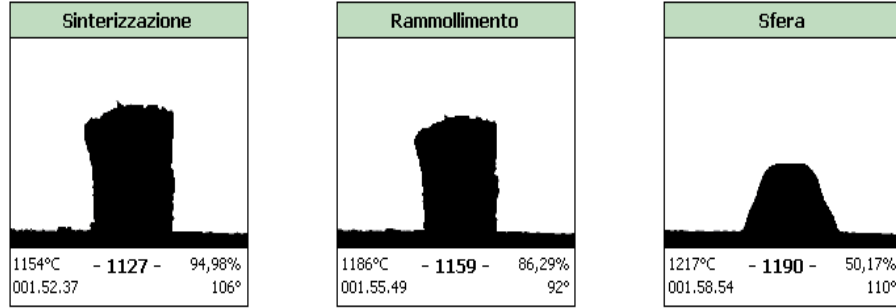


Aerogel:

- ❑ **RT:** The sample is completely amorphous;
- ❑ **T = 1400 °C :** Devitrification of the silica by means of the formation of Cristobalite alpha.

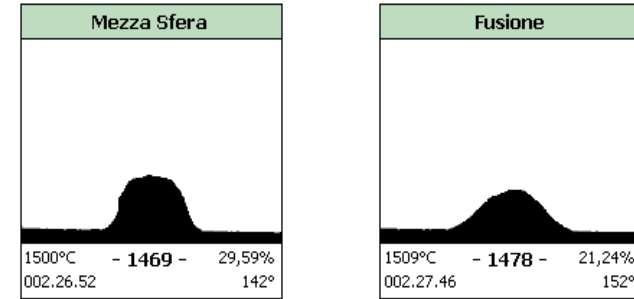
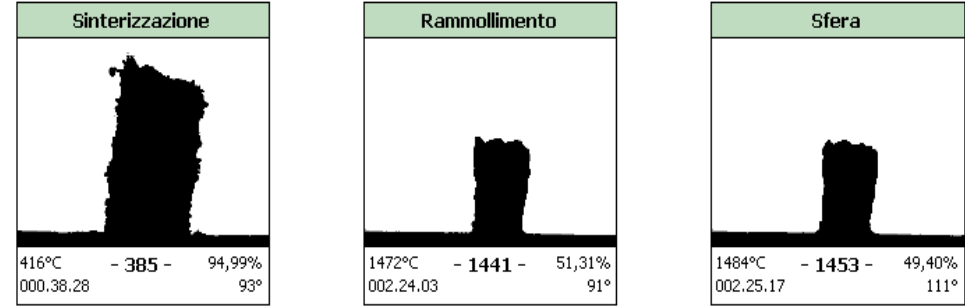
Analysis to the Heating Microscope

Rock Wool Panel



Characteristics temperature : Rock Wool	
	Temperature
Sintering	1154 °C
Softening	1186 °C
Sphere	1217 °C
Half-Sphere	1218 °C
Melting	1223 °C

Aerogel Blanket: Aeropan®



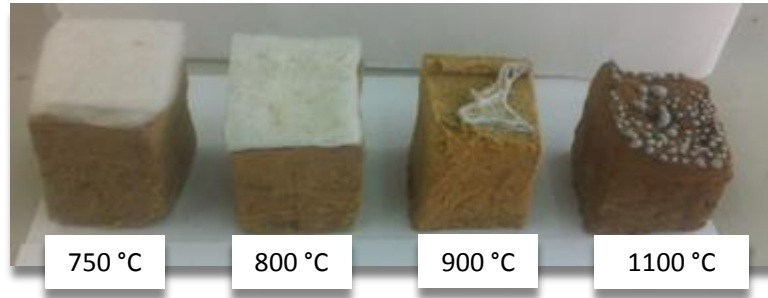
Characteristics temperature : Aeropan®	
	Temperature
Sintering	416 °C
Softening	1472 °C
Sphere	1484 °C
Half-Sphere	1500 °C
Melting	1509 °C

Thermal analysis with Laboratory Furnace

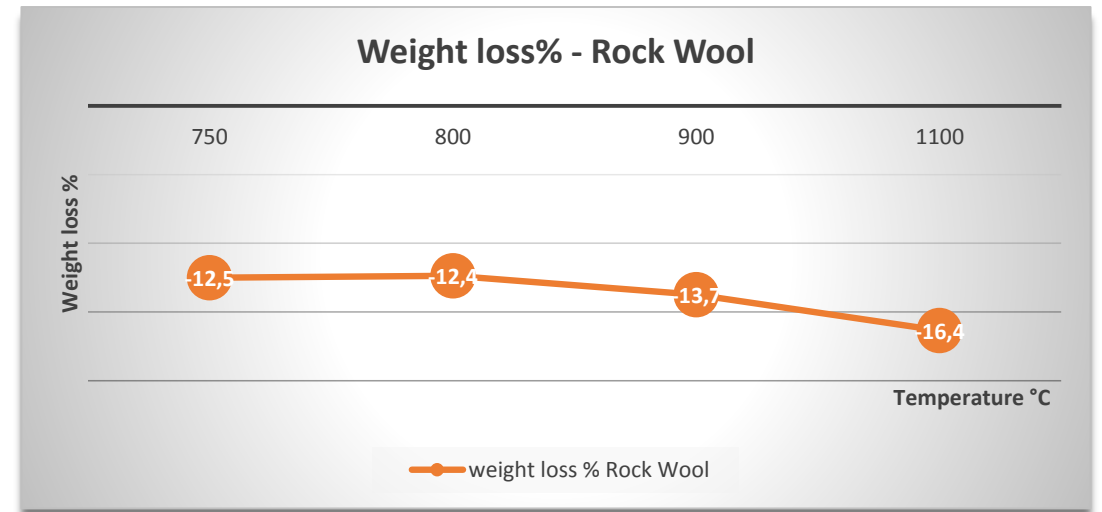
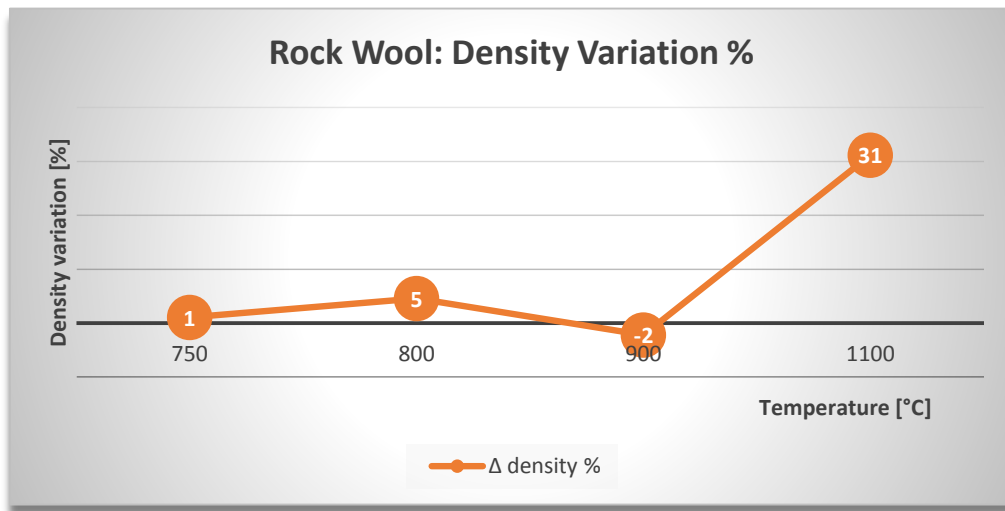
Rock Wool
Room Temperature



Rock Wool after Heat Treatment



- ❑ **750 °C:** Weight loss of about 13%, consistent with the loss of polyurethane binder between the fibers.
- ❑ **900 °C:** Complete degradation of the organic binder contained in the upper reinforcement.
- ❑ **1100 °C:** Maximum withdrawal of the sample and sintering of the upper reinforcement.



Thermal analysis with Laboratory Furnace

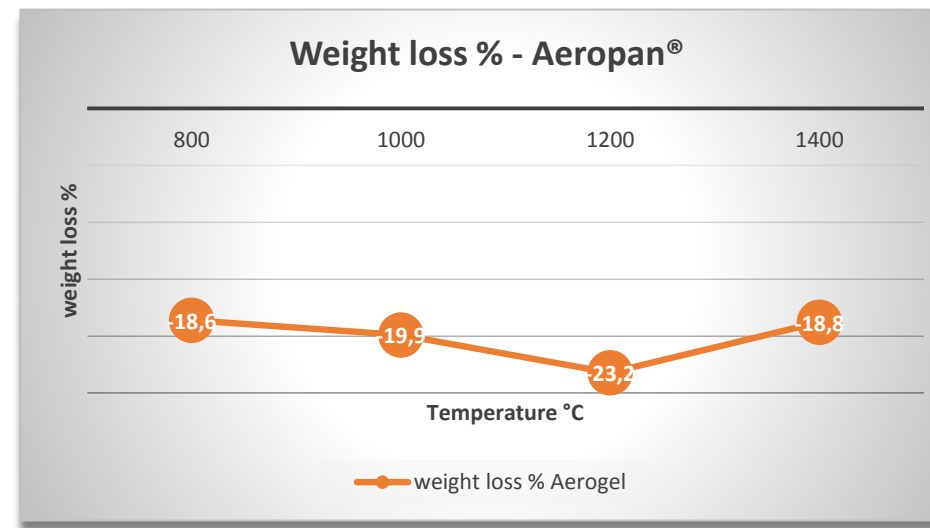
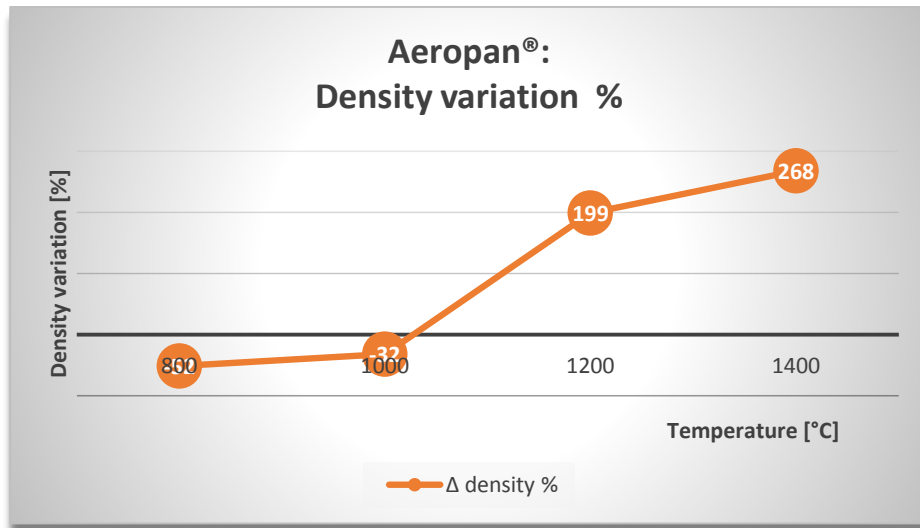
Aeropan®
Room Temperature



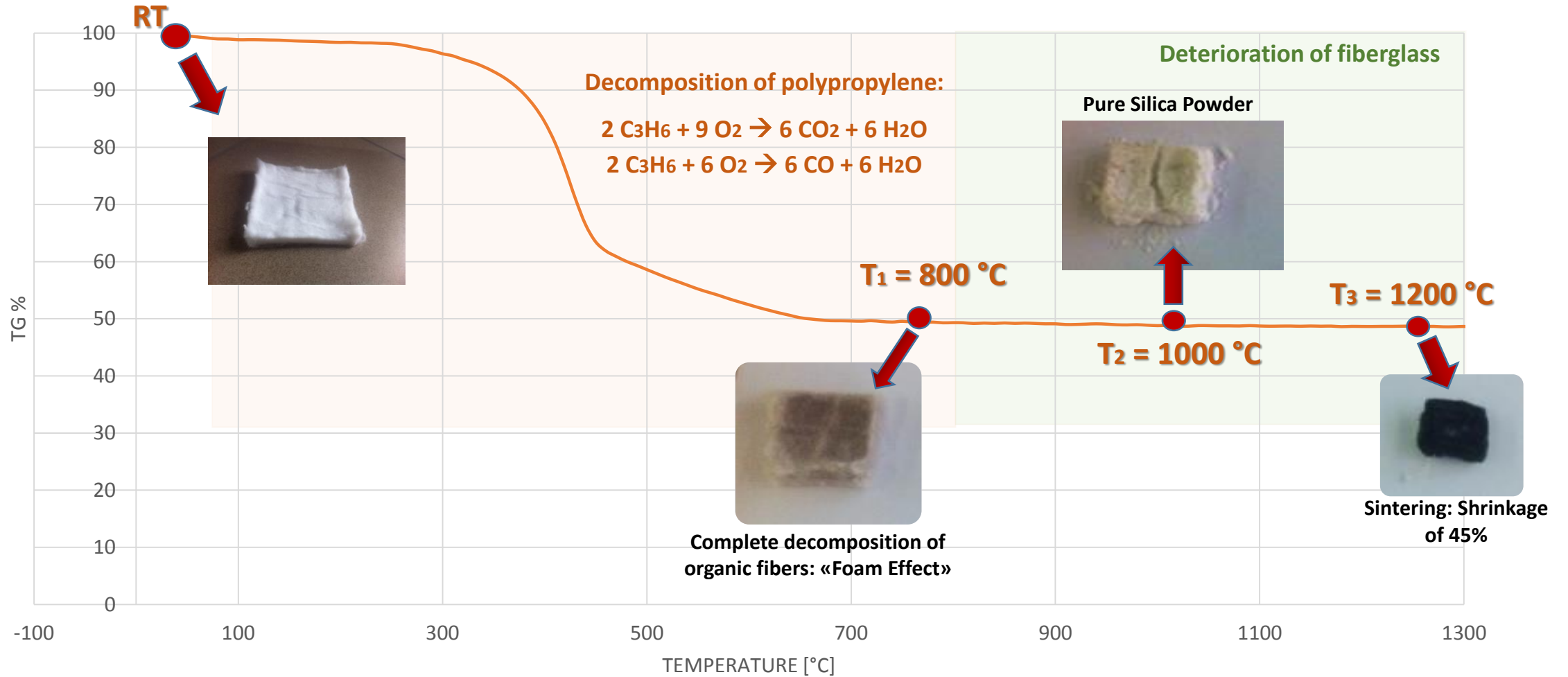
Aeropan® after Heat Treatment



- ❑ **T < 850 °C:** Reduction of density due to the increase of the thickness (+ 80% at 800 °C). The organic substances (fibers PP), have acted as a blowing doing swell the sample: **“Foam Effect”**.
- ❑ **1000 °C:** Deterioration of glass fiber, which has passed its characteristic temperature softening (~ 850°C).
- ❑ **1200 °C:** The sample has been sintering: average shrinkage of about 45%.
- ❑ **1400 °C:** The sample reaches a maximum shrinkage of 50%.

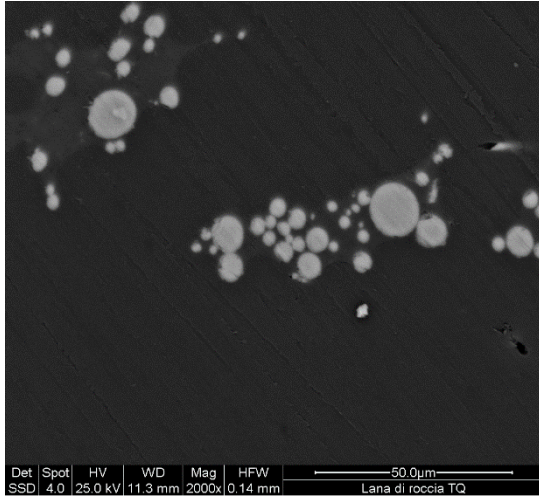


Thermal Aging - Aeropan®

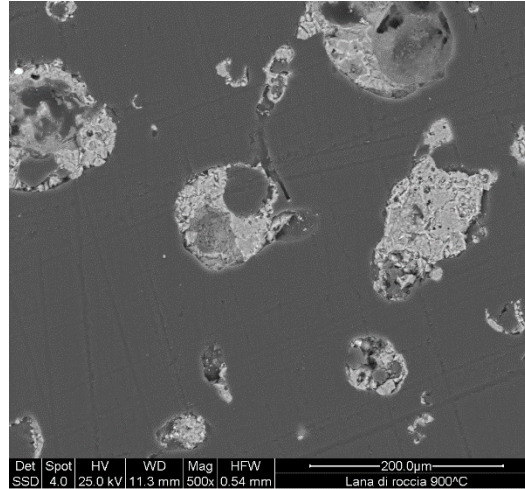


Thermal and Morphological Analysis: ESEM

Rock Wool: RT



Rock Wool T = 900 °C



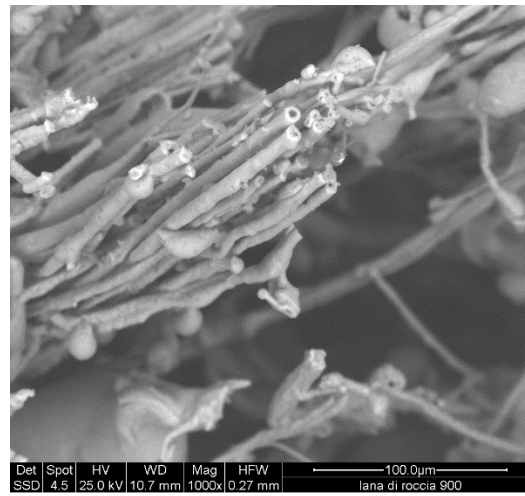
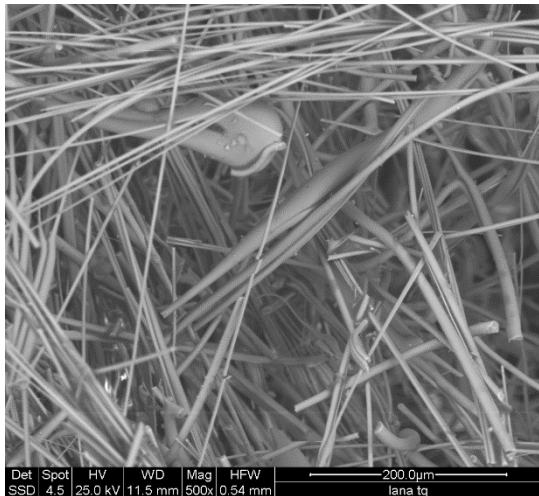
Before Treatment:

- Basalt fibers have a diameter almost perfectly spherical in size from 2 to 13 μm.
- The fibers are randomly arranged and spaced from each other.



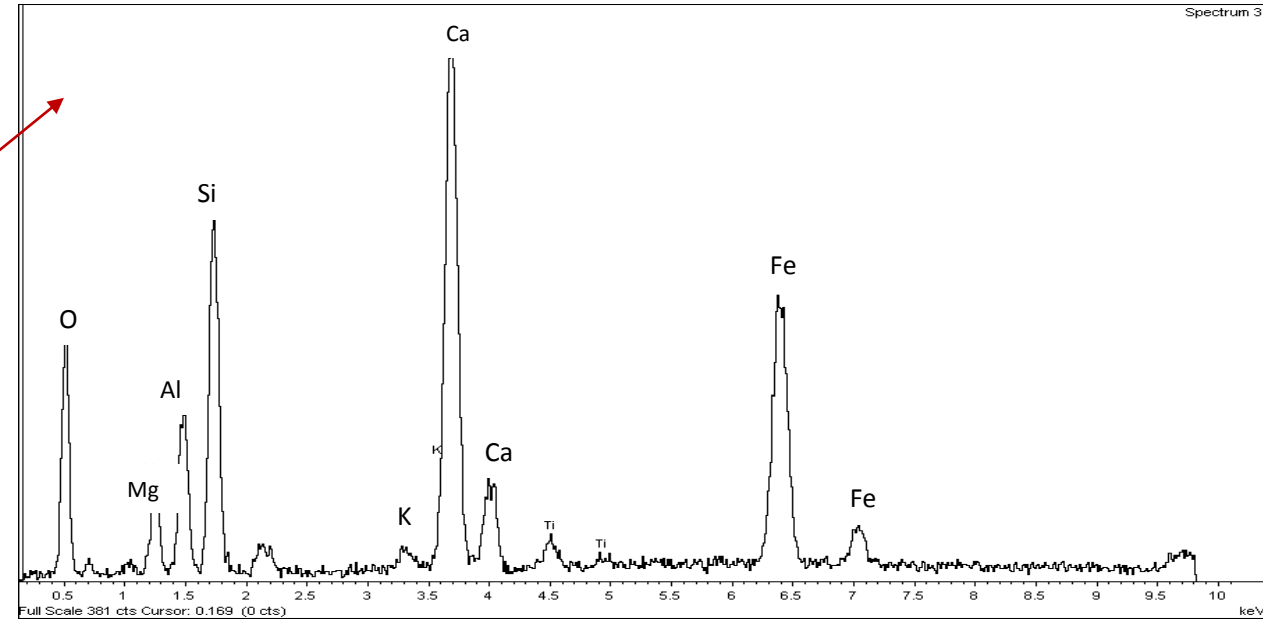
After Treatment:

- Basalt fibers lose their spherical shape due to the formation of crystals on the surface.
- The fibers agglomerate with each other to form fiber bundles: going to start sintering.
- The fibers have a cavity inside: a direct consequence of the formation of crystals.

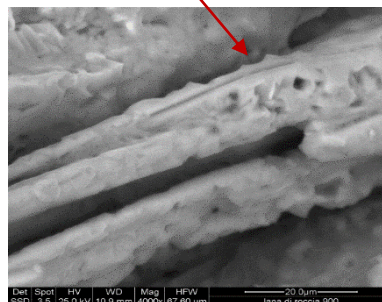
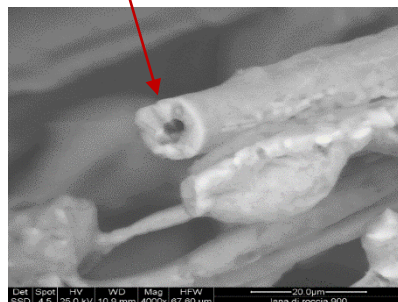


Microanalysis EDS

Rock Wool T = 900 °C

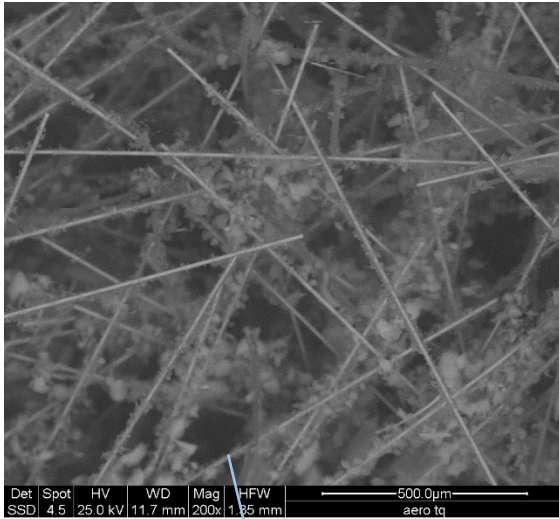


	Si	Ca	Al	K	Mg	Na	Total
Spectrum 1	44.41	24.88	16.31	0.83	12.94	0.62	100.00
Spectrum 2	42.22	20.74	19.90	0.80	14.13	2.21	100.00
Spectrum 3	34.16	41.55	13.79	0.96	8.53	1.02	100.00
Spectrum 4	42.53	30.17	16.60	2.30	5.95	2.45	100.00
Spectrum 5	44.40	20.39	14.60	0.64	19.55	0.43	100.00
Spectrum 6	38.76	31.88	14.59	1.12	12.73	0.91	100.00
Mean	41.08	28.27	15.96	1.11	12.31	1.27	100.00
Std. Dev.	3.97	8.04	2.21	0.61	4.71	0.85	-

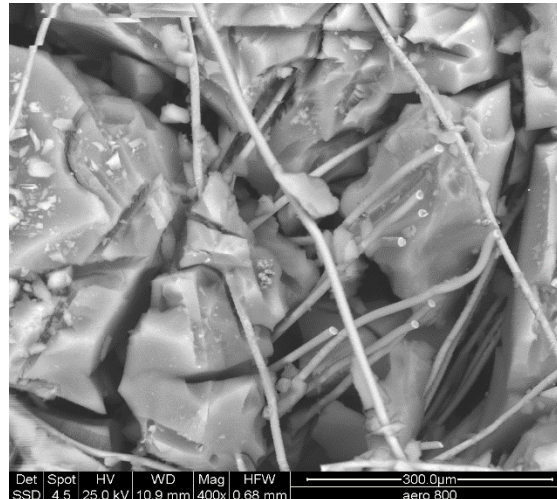
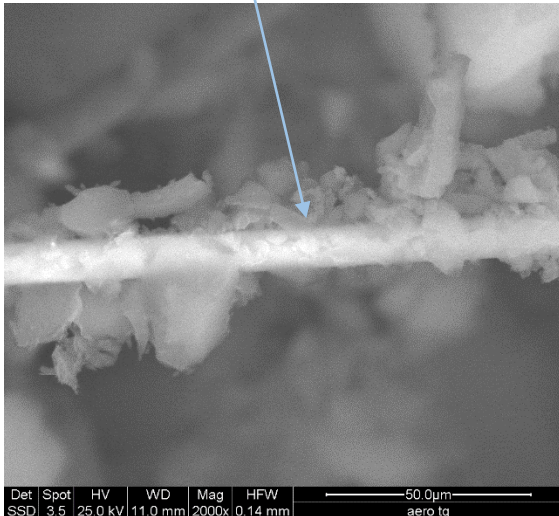
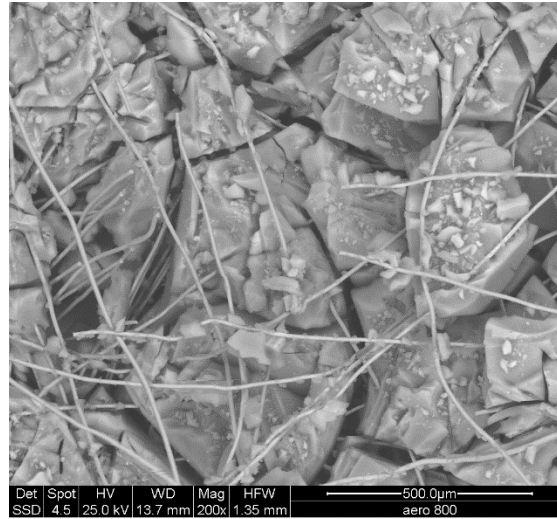


Thermal and Morphological Analysis: ESEM

Blanket Aerogel: RT



Blanket Aerogel: T = 800 °C



Before Treatment:

- Glass fibers have a constant diameter of 15 µm, instead the length exceeds the diameter of an order of magnitude.
- Glass fibers are completely saturated in aerogel nanoparticle.

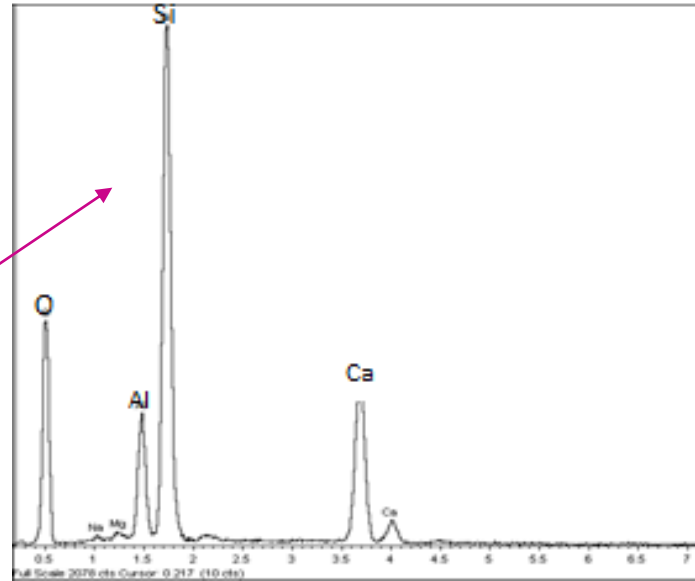
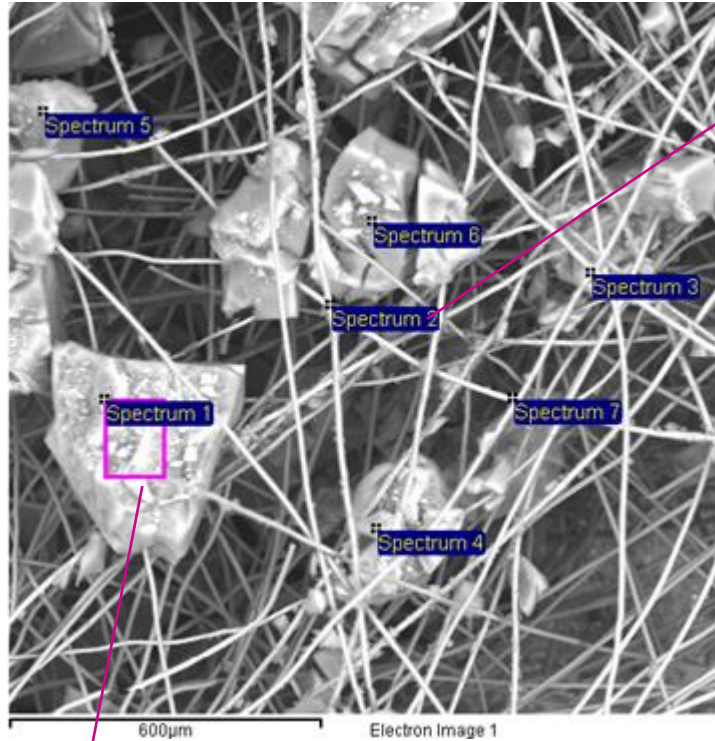


After Treatment:

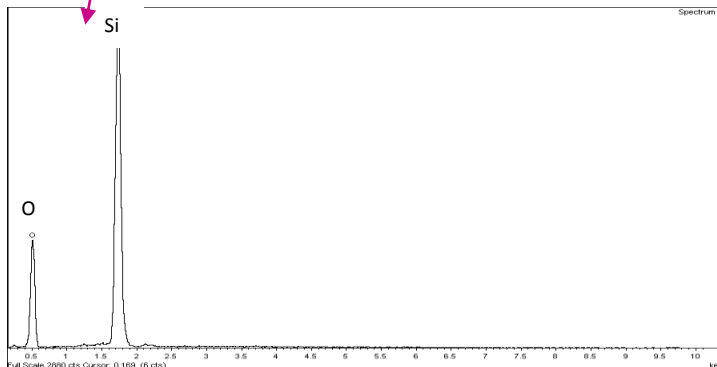
- Glass fibers begin to deteriorate (softening temperature $T \sim 850 \text{ }^\circ\text{C}$).
- Fibers are almost completely cleaned from aerogel: silica aerogel, sinters in compact clusters.

Microanalysis EDS

Blanket Aerogel T = 800 °C



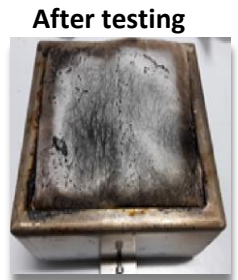
- Glass fibers are constituted by **Si**, **Ca** and **Al**: therefore there are no network modifiers which can inhibit the physical and mechanical properties of the fibers.
- Purity of the aerogel particles: the spectra shows the presence of pure silica (SiO_2).



Test fire reaction with Cone Calorimeter

Test by means of directives **ISO 5660-1**: heat flux of 25 kW/m^2 corresponding to a temperature of the cone: $T \sim 600 \text{ }^\circ\text{C}$.

Rock Wool



Parameters	Average
Initial mass (gr)	61,0
t_{ignition} (s)	19
t_{flameout} (s)	263
THR (MJ/m^2)	23
Mass Lost (g/m^2)	766
Mass Lost Rate (g/m^2)	1,3
PHRR (KW/m^2)	169
t_{pHRR} (s)	35
$\Delta m_{1200\text{s}}$ (gr)	12
$\Delta m_{1200\text{s}}$ (%)	- 19,6 %

- Flameout time of about 260 s;
- Total heat release THR maintains a value of around 23 MJ/m^2 ;
- The maximum rate of release of heat is after 35 s with a pHRR of about 169 KW/m^2 .
- The weight loss after 20 min is about 20% of the total.

Aeropan®



Parameters	Average
Initial mass (gr)	16,0
t_{ignition} (s)	11,0
t_{flameout} (s)	62
THR (MJ/m^2)	3,6
Mass Lost (g/m^2)	141,6
Mass Lost Rate (g/m^2)	0,43
PHRR (KW/m^2)	44,77
t_{pHRR} (s)	20
$\Delta m_{1200\text{s}}$ (gr)	2,2
$\Delta m_{1200\text{s}}$ (%)	- 13,8 %

- Flameout time of about 60 s;
- Total Heat Release THR is 3.6 MJ/m^2 .
- The maximum rate of release of heat is after 20 s with a pHRR of about 45 KW/m^2 .
- The weight loss after 20 min is about 14% of the total.
- The development of smoke is very low, almost imperceptible.

Conclusions

- From the thermal analysis performed on two samples, it is clear that in terms of performance of thermal insulation, the aerogel blanket of not only does not undergo deterioration, but to contrary increases its insulating capacity, thanks to the combustion reaction of the PP that, releasing CO₂, determines the bulge of the sample.
- Both materials have a good dimensional stability up to ~ 200 ° C, to below which are not manifested shrinkage or significant loss of consistency.
- For $T > 200$ ° C, blanket Aerogel undergoes a weight loss greater than the rock wool in the same range. However, the only matrix of aerogel blanket presents a weight loss more limited.
- In terms of fire resistance, blanket aerogel is the most powerful, thanks to the absence of a real production of flames and fumes, and drip.

Future Developments

➤ **Thermal Hygrometer Analysis through Climatic Chamber:**

- Simulation of aging due to temperature and humidity and evaluation of dimensional stability;

➤ **Chemical and Morphological ESEM Analysis in Variable Temperature:**

- Analysis of the evolution of the thermal deterioration;

➤ **Analysis by attack of UV radiation:**

- Evaluation of chemical degradation after extended exposure.

Acknowledgements

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