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Glass recycling: a challenge for the future

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Decarbonizing our industry: an imperative

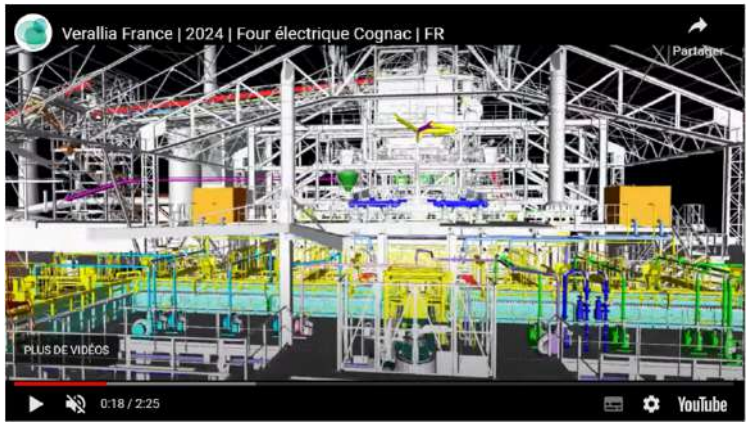
- **2050: Net Zero Emissions objective**
  - ✓ GIEC and COP work
  - ✓ Societal and customer expectations
  - ✓ Regulatory framework

- **20% of greenhouse gas emissions come from glass raw materials**

- **Recycling is a major lever for decarbonization**
  - ✓ Reduction in emissions linked to raw materials
  - ✓ Reduced energy requirements

New furnace technology

- **Electric: Verallia (Cognac) 2024**
  - **furnace 100% electric (60% less CO2 emission)**



https://youtu.be/R2pP_GXz90E

- **Hybrid: Saverglass (Le Havre) 2027**
  - **furnace 80% electric (**https://www.gazettenormandie.fr/article/le-havre-accueillera-le-premier-four-bas-carbone-de-saverglass)

- **Alternative: use of hydrogen (2% in 2050)**

Recycle to decarbonize

❑ Reduce COx, NOx, SOx emissions

- ✓ Decrease the use of fossil fuels: modify furnace technology
- ✓ Recycling glass for use as cullet in glass-making: lowering synthesis temperatures, limited the decarbonation due to the precursor's reaction

❑ Types of glass

- ✓ Containers glasses
- ✓ Float glass
- ✓ Automotive glass
- ✓ Glass wool
- ✓ *Pharmaceutical glass*
- ✓ *Solar panels*
- ✓ *Wind turbine blades*
- ✓ *Glass-ceramic*

❑ Ways of recycling

- ✓ **Close-loop**: re-use glass as cullet
- ✓ **Open-loop**: use glass waste for a new function (e.g. in the manufacturing of concrete, foam-glass, etc.)

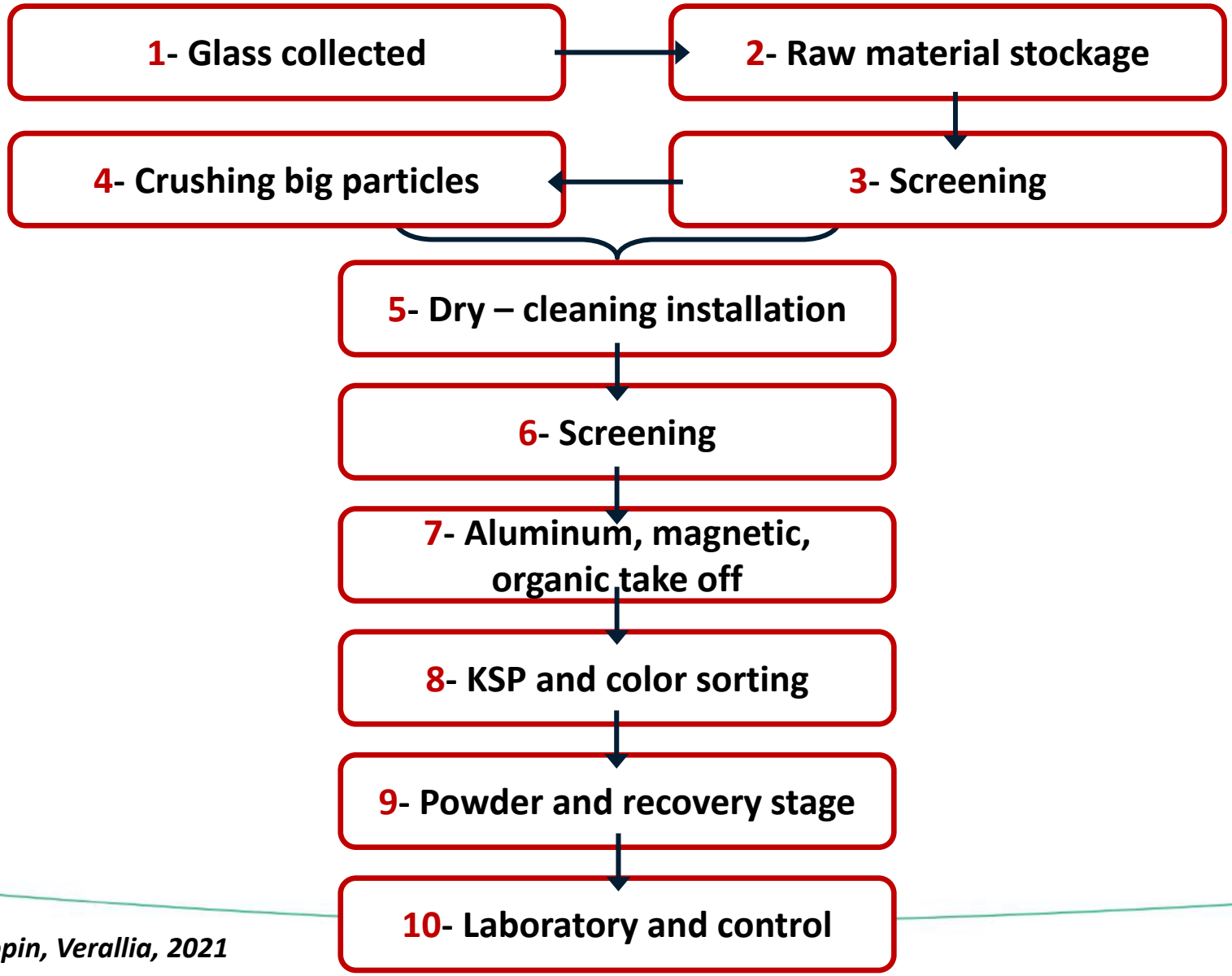
Containers glass

- A well-established historical approach (since 1974)
- High performance based on a local organization and efficient treatment centers processing: KSP (Keramiek, Steen and Procelein); Magnetic and non-magnetic metals; Lead glass
- Cullet: primary raw materials for glassmakers (65% to 90% in 2030)

Glass collected → **Raw material stockage** → **Cullet product**

See talk G. Chazelle, Verallia, USTV 2024

Containers glass: key for each installation



From C. Chopin, Verallia, 2021

Float glass

- **Float glass building: circuit in the process of being set up (REP)**
- **Deposit = 200 kt/year; Low collection rate << 10%; Quality and quantity issues**

End-of-life float glass from dismantlement ⟷ **Closed loop only float glass to make float glass recycling**

Careful removal and storage to preserve the integrity of the glazing

Transport and dismantlement of joinery

Charging of cullet / Production of low-carbon glass

From G. Galal, Saint-Gobain, 2021

Automotive glass

Automotive waste glass resource:

Way 1: after-sales deposit

Way 2: end-of-life vehicles deposit

After-sales deposit (30 kt/year): glass recovery device well in place even if the storage of windshields is sometimes difficult due to the volume

End-of-life vehicles deposit (30 kt/year): difficult to set up. Easier to crush the entire vehicle than to dismantle it upstream

From N. Brec, TRACAUTO, 2021

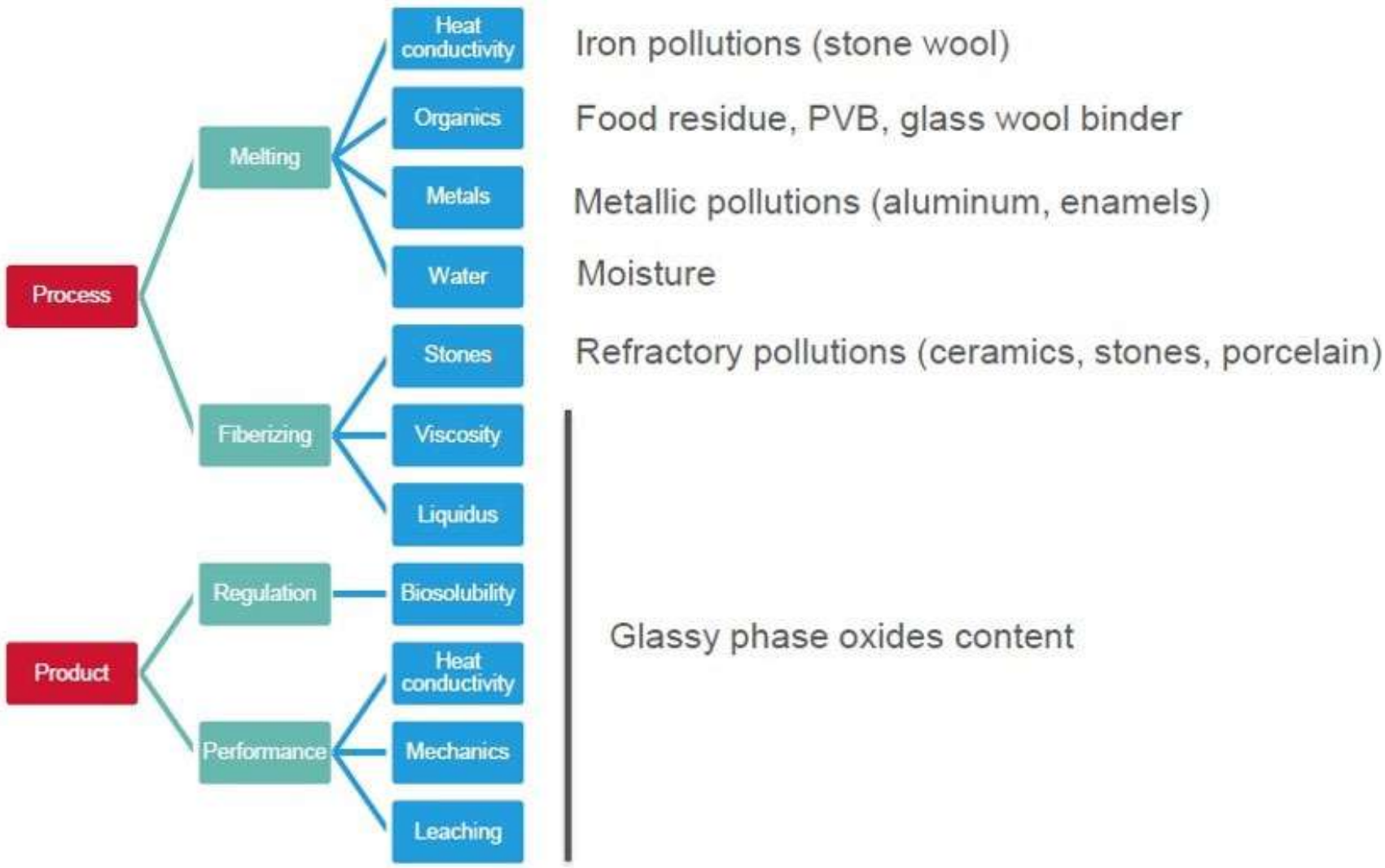
Glass wool

Glass recycling in glass wool production

→ A major technical challenge influencing the way to produce
→ Well established for container and float glass sources
→ On track for post-consumer glass wool
→ Strong technical efforts needed for decarbonization

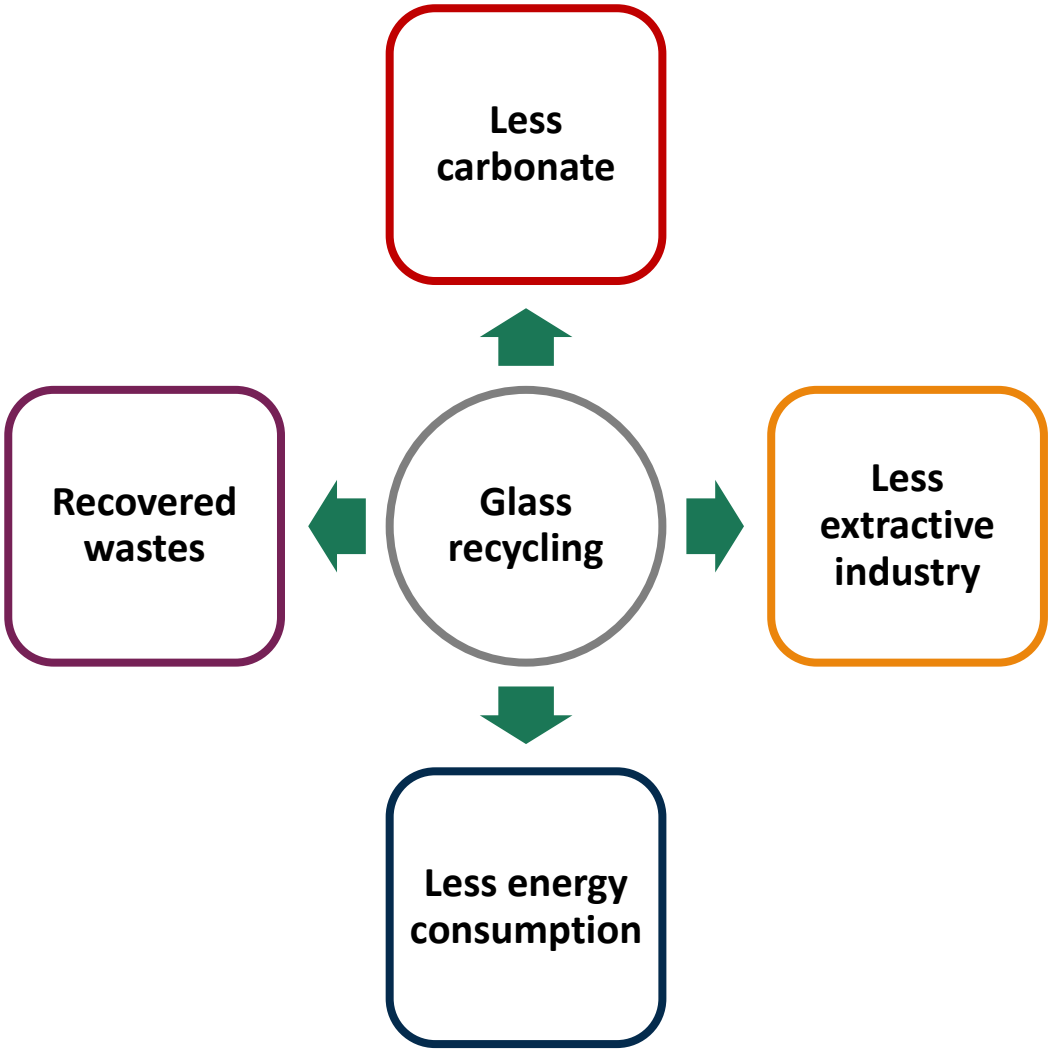
From G. Barba Rossa, Saint-Gobain, 2021

Glass wool: recycling challenge



From G. Barba Rossa, Saint-Gobain, 2021

In conclusion



From waste glasses to foam glass: a case of study

Waste glass resources

Window glass

Televisions - Cathode ray tube

Container glass

Lamp glass

Glass foam synthesis

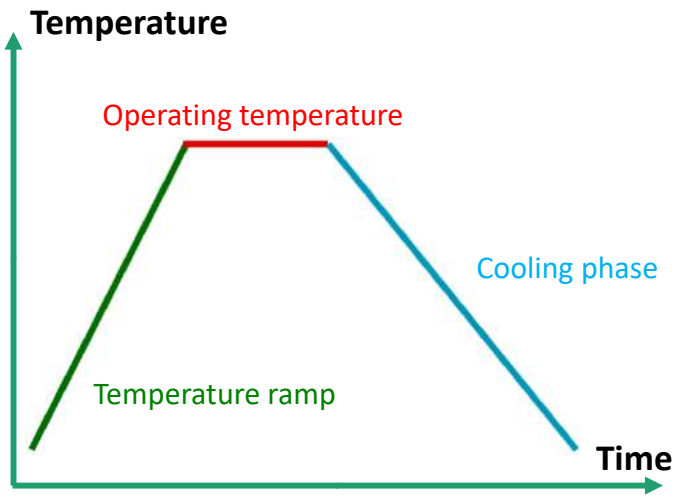
- **Elaboration**

Glass waste + **Foaming agent** —Heat treatment→ **Formation of gas bubbles (CO_2 or N_2)** —Expansion→ **Glass foam**

- **Glass waste**
  - **CRT**: Cathode Ray Tube glass
  - **SLS**: Soda-Lime Silicate glass

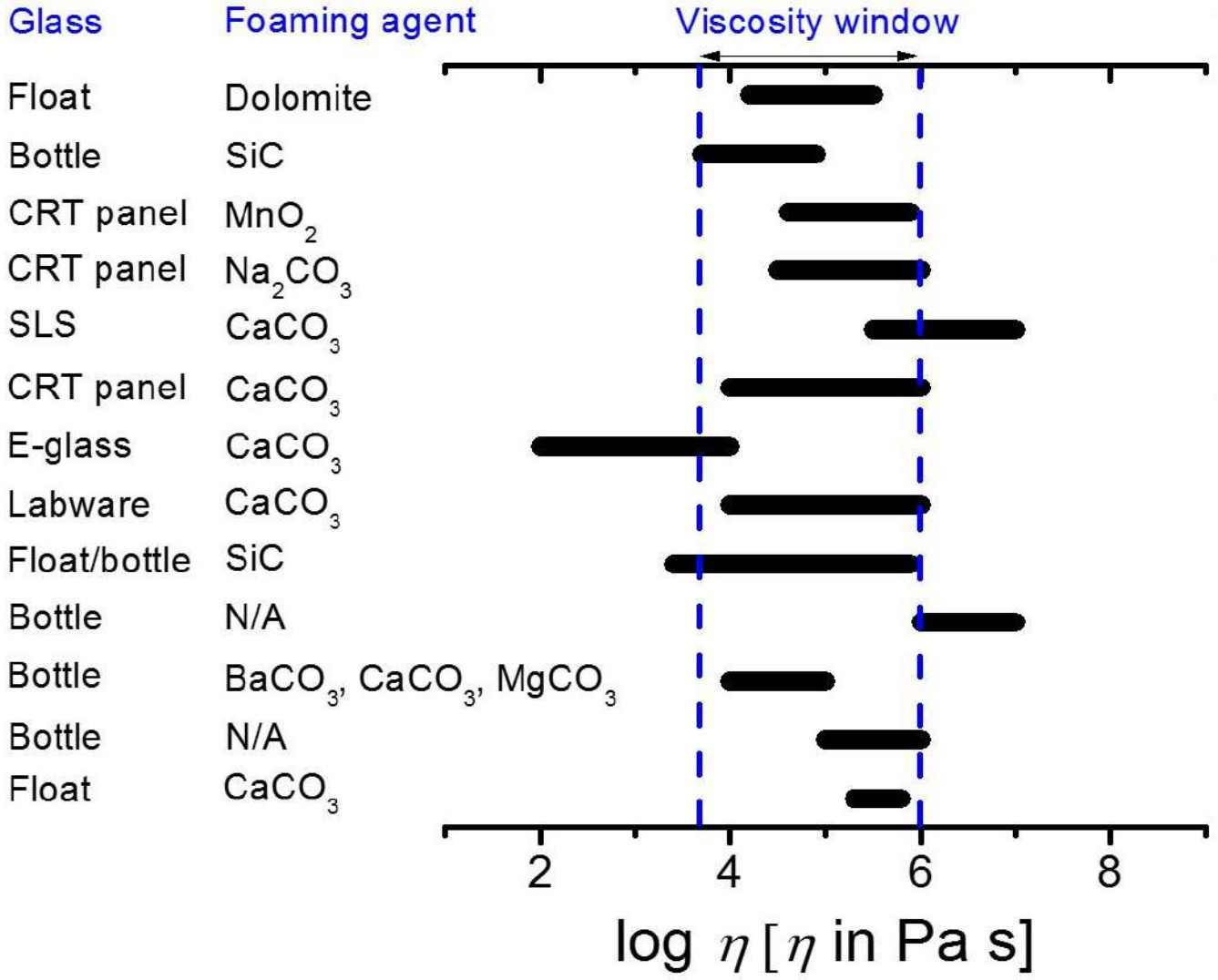
- **Foaming agent**

e.g. **MnO_2, $CaCO_3$, SiC, AlN**



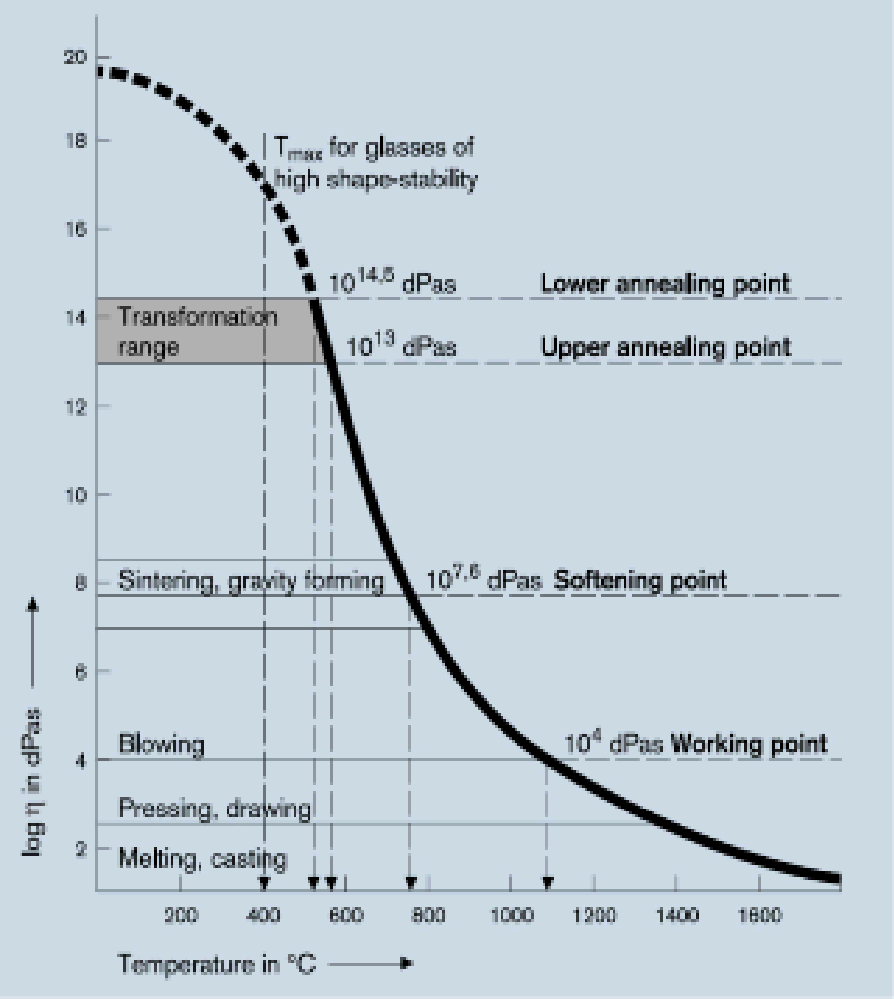
Furnace temperature vs. time

Viscous window



From Petersen et al, JNCS, 2017

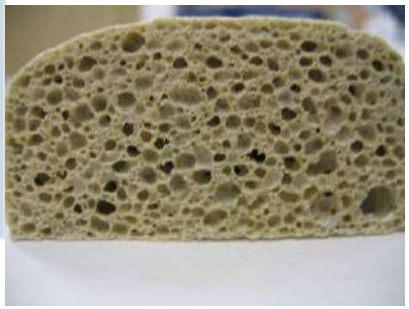
Viscous window



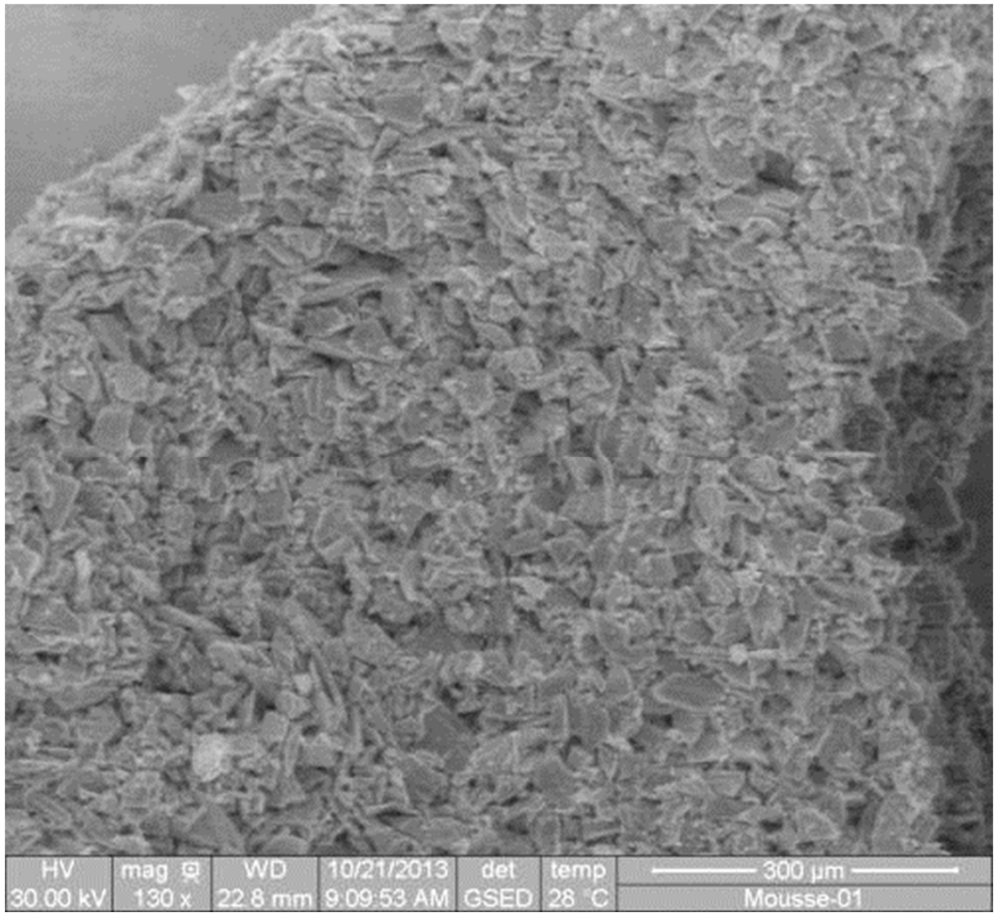
viscosity curve

Gas bubbles prisoners of the viscous melt

→ Expanded glass



In situ foaming observation by HT-ESEM vs. time @ 750°C



Collaboration: Renaud Podor, ICSM

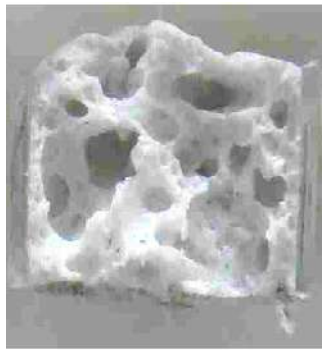
Influence of synthesis parameters

CRT + $CaCO_3$

@ 750°C

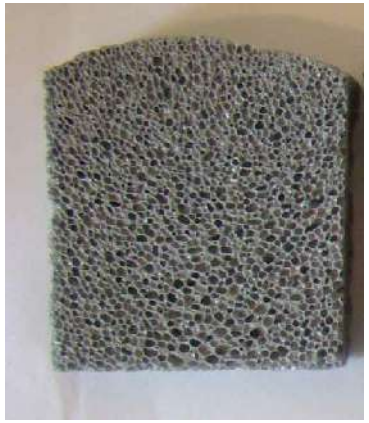
@ 800°C

@ 850°C



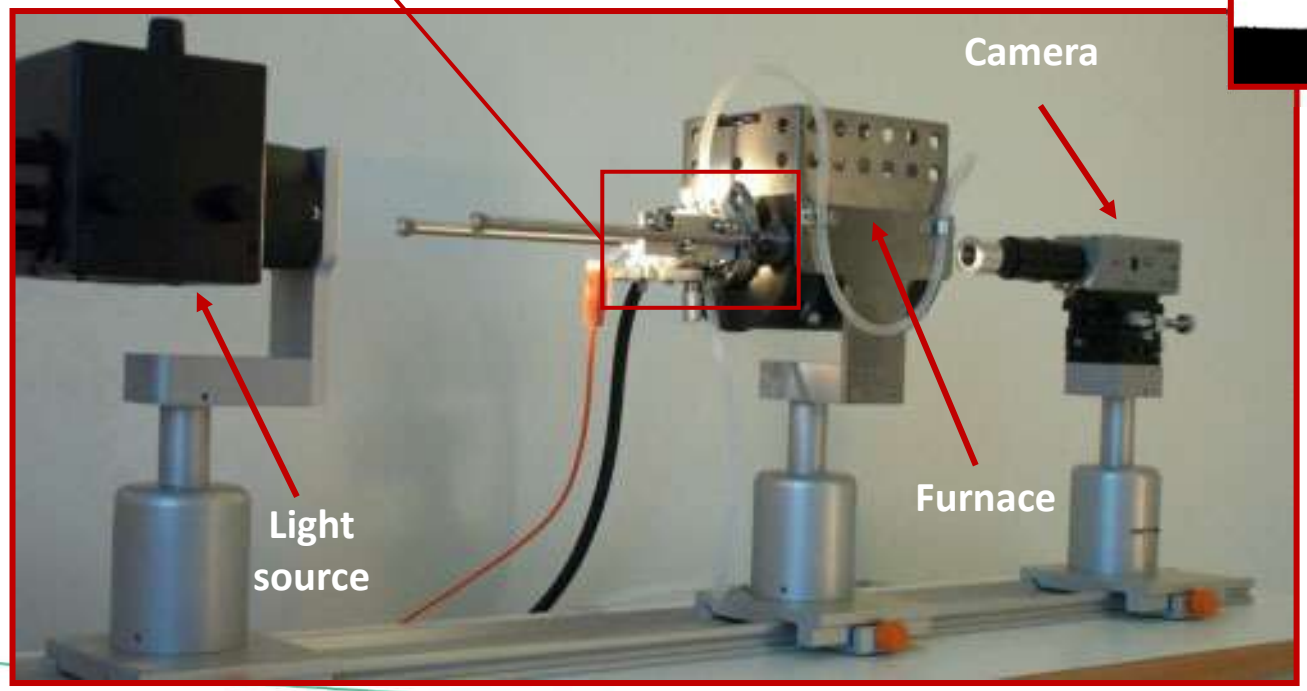
CRT + AlN @ 850°C

CRT + SiC @ 850°C



Hot-stage microscope (HSM)

Support sample
/ thermocouple

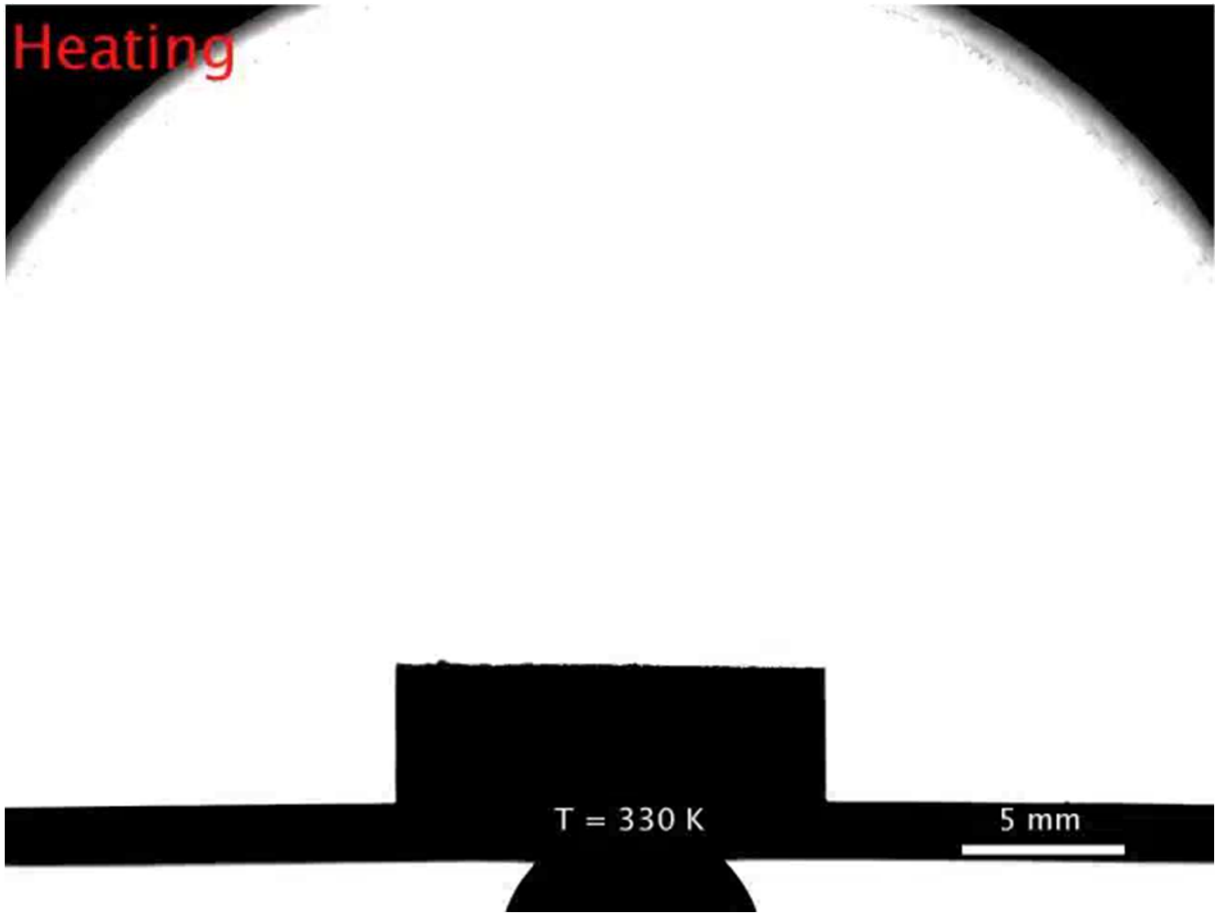


Characterization of sample evolution:

→ area (S/S_0)
→ shape factor
→ wettability

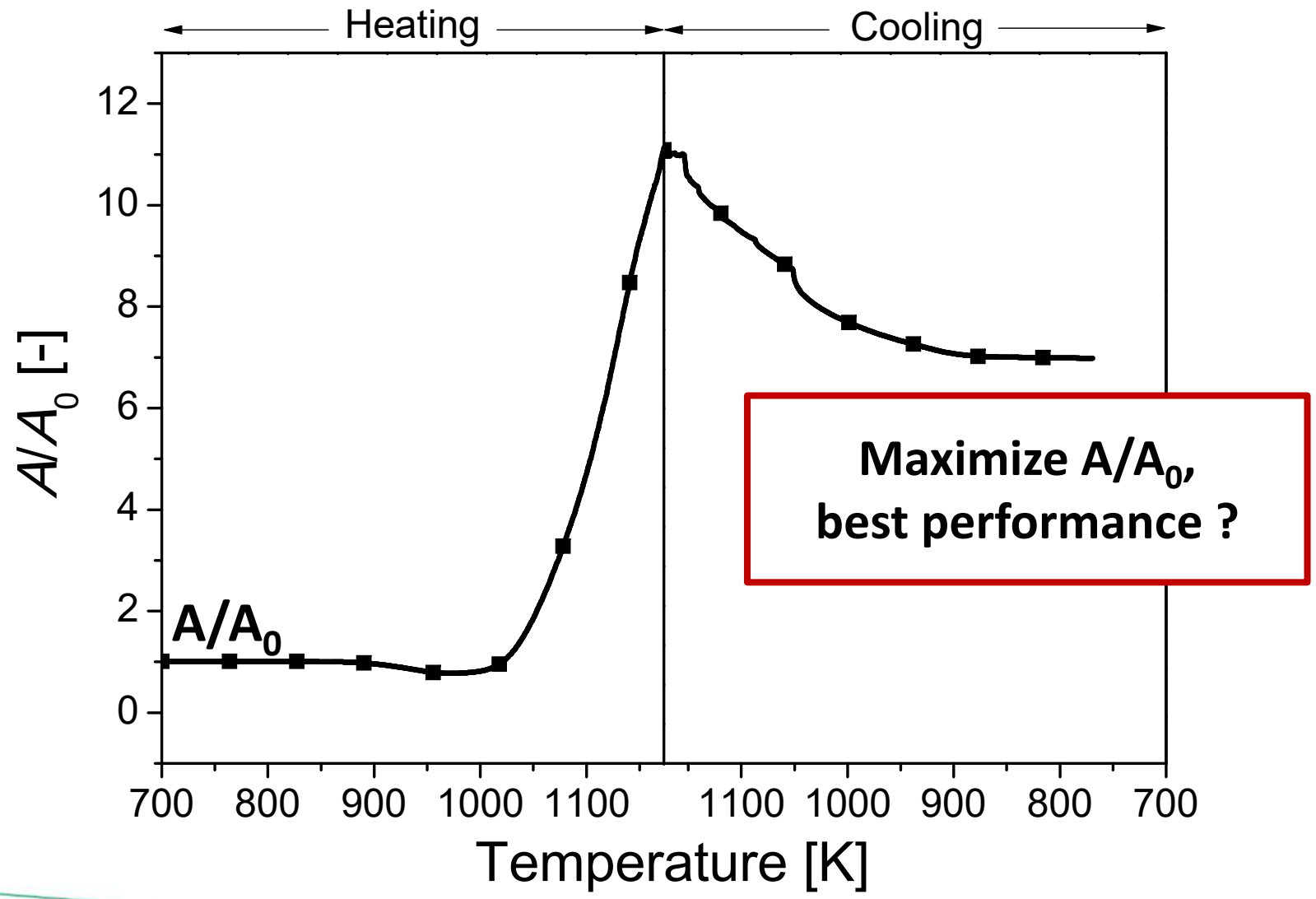
Foaming ability

CRT panel + MnO_2



Foaming ability

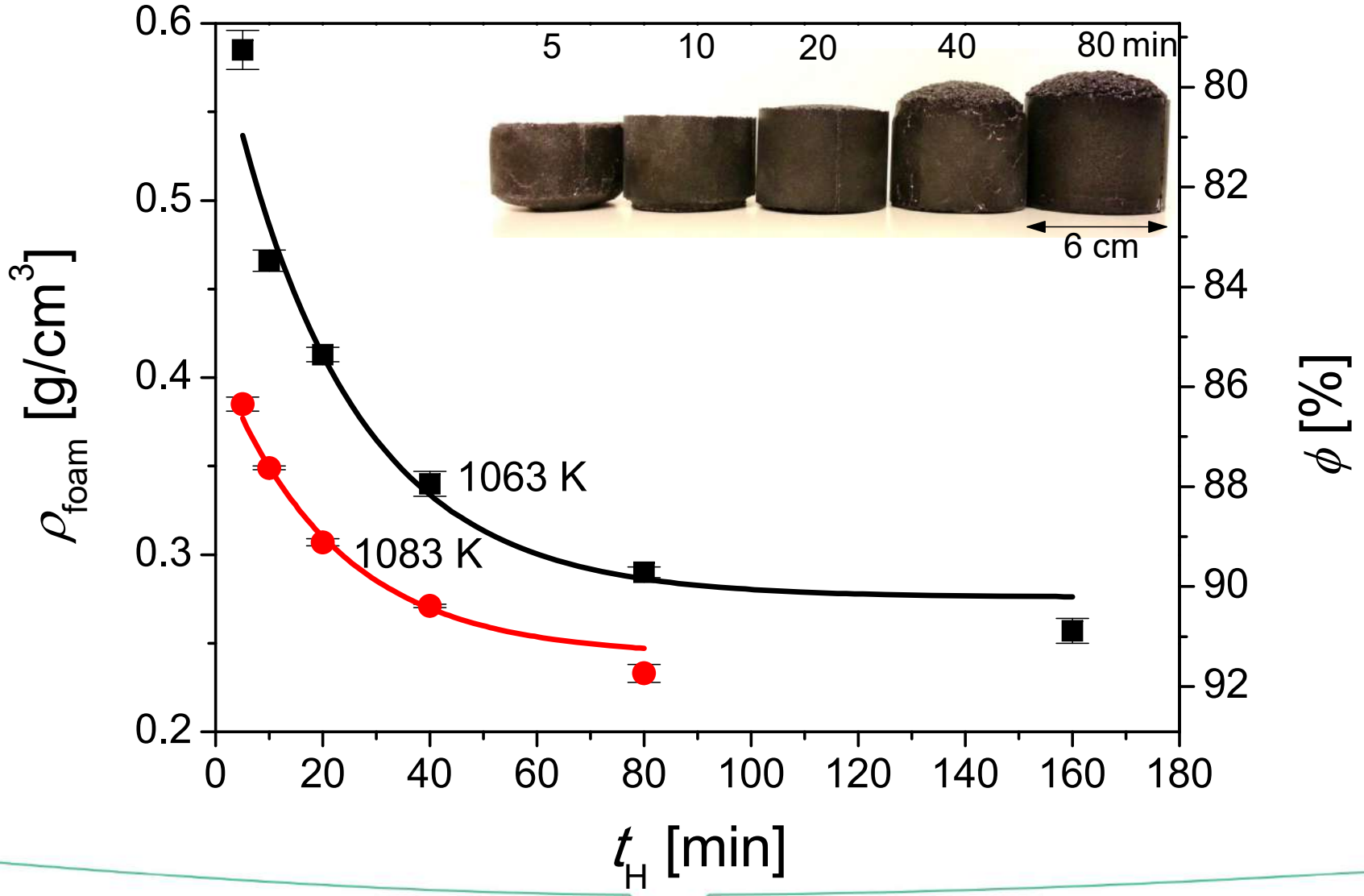
CRT panel + MnO_2



From Petersen et al, JNCS, 2017

Volume expansion

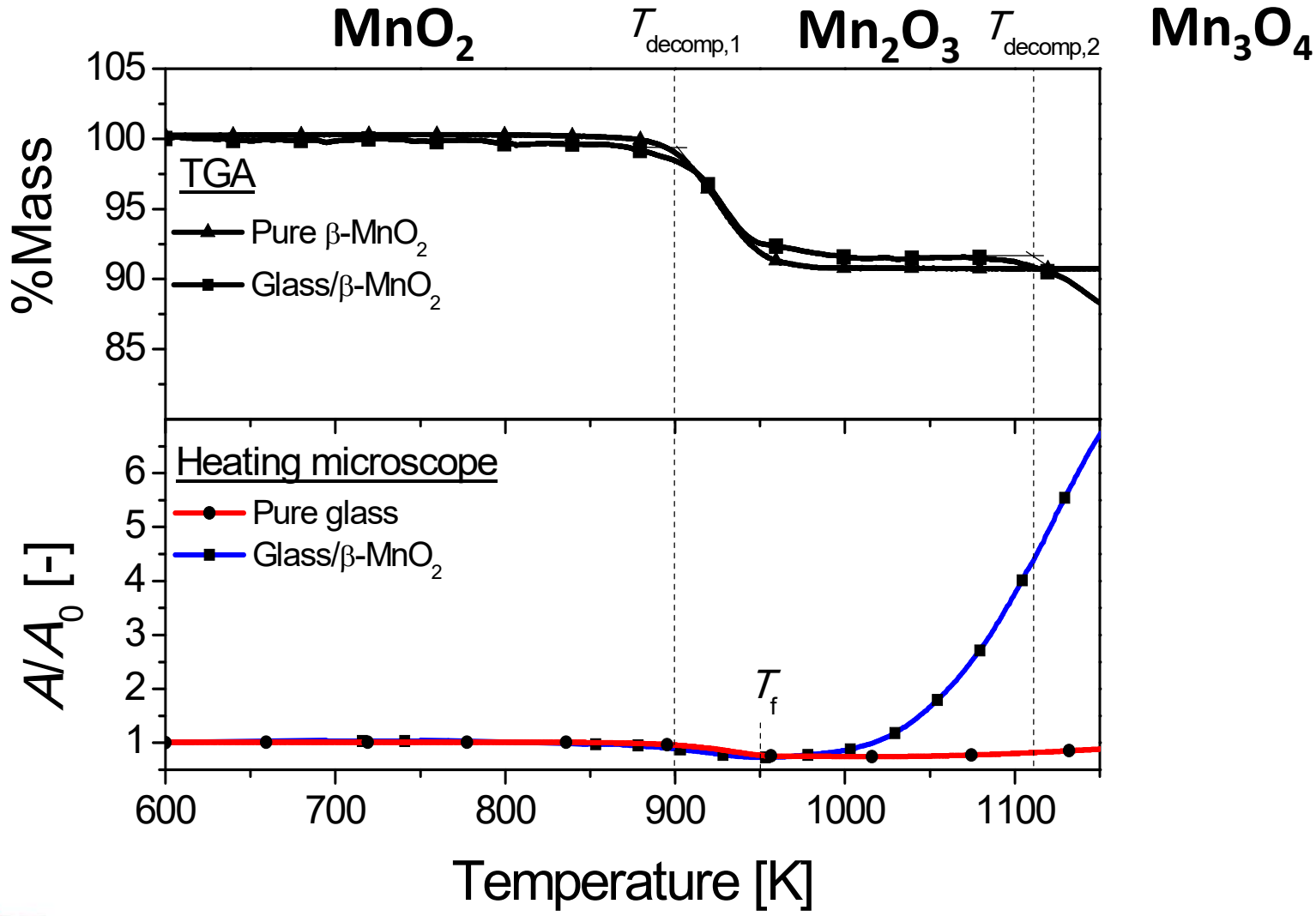
CRT panel + MnO_2



From Petersen et al, JNCS, 2015

Foaming reaction

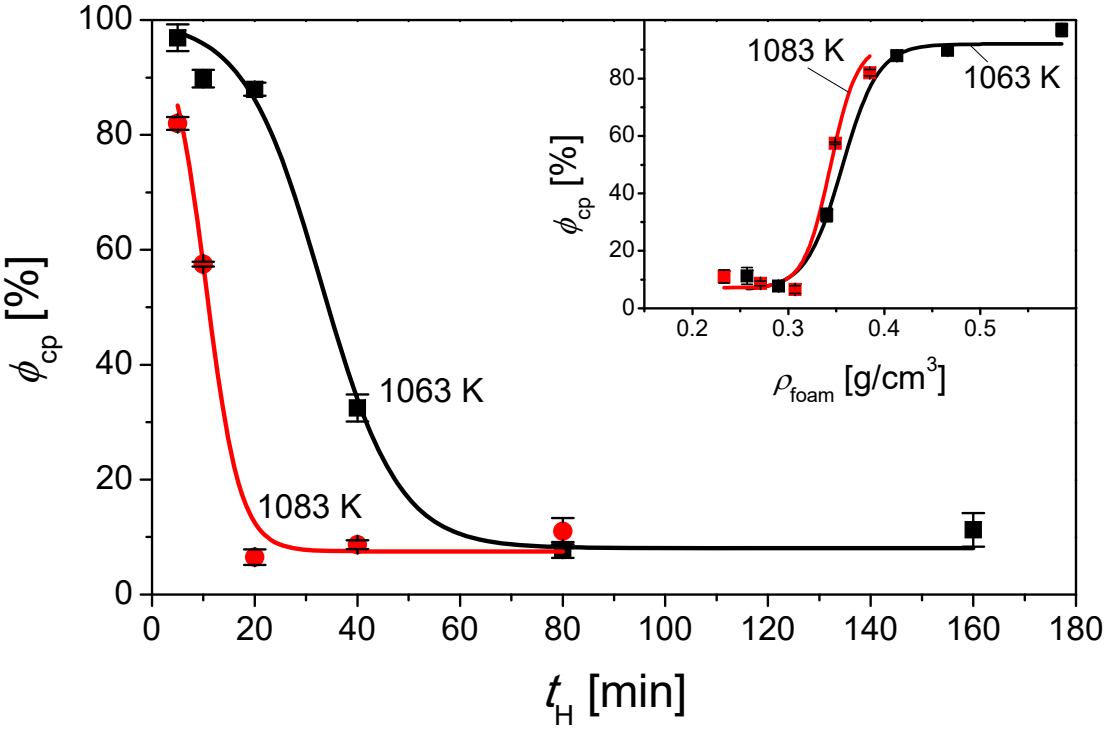
CRT panel + MnO_2

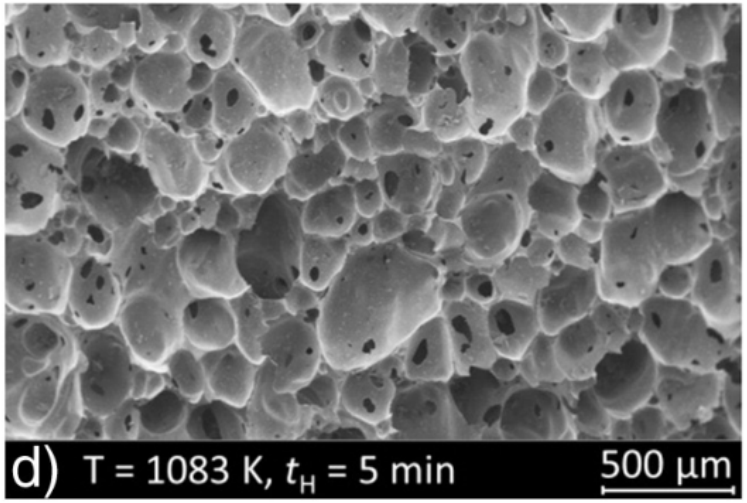


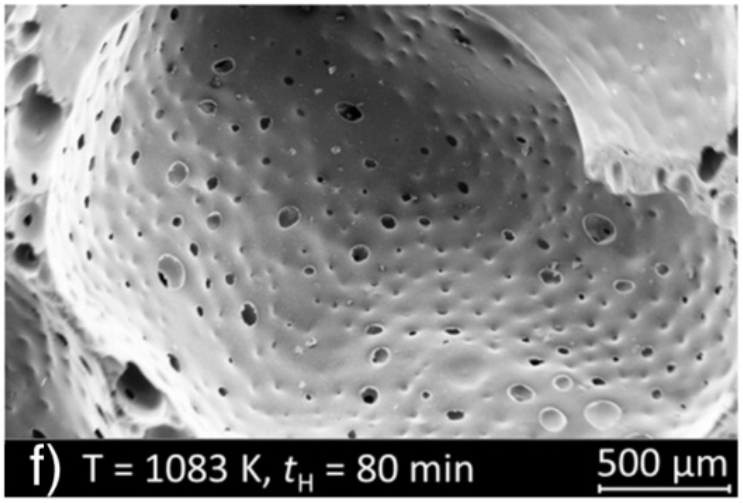
From Petersen et al, JNCS, 2015

Closed porosity

CRT panel + MnO_2

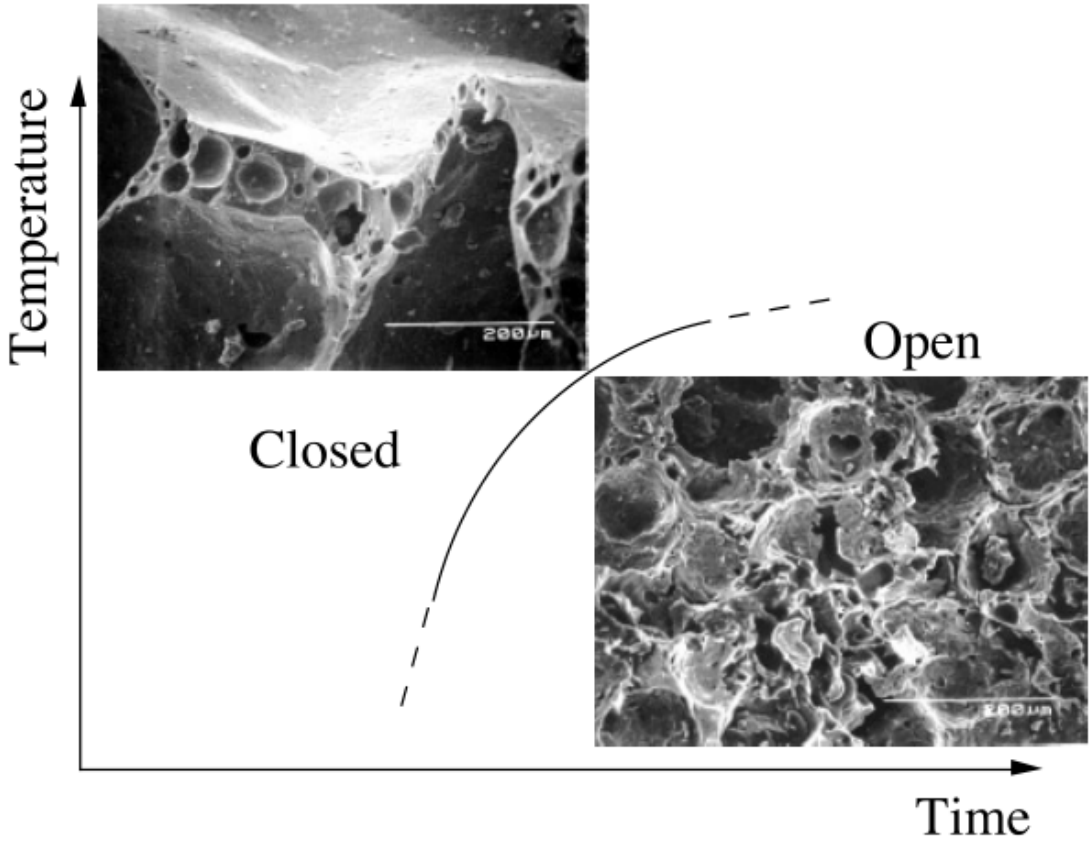






From Petersen et al, JNCS, 2015

Tuning open / closed porosity

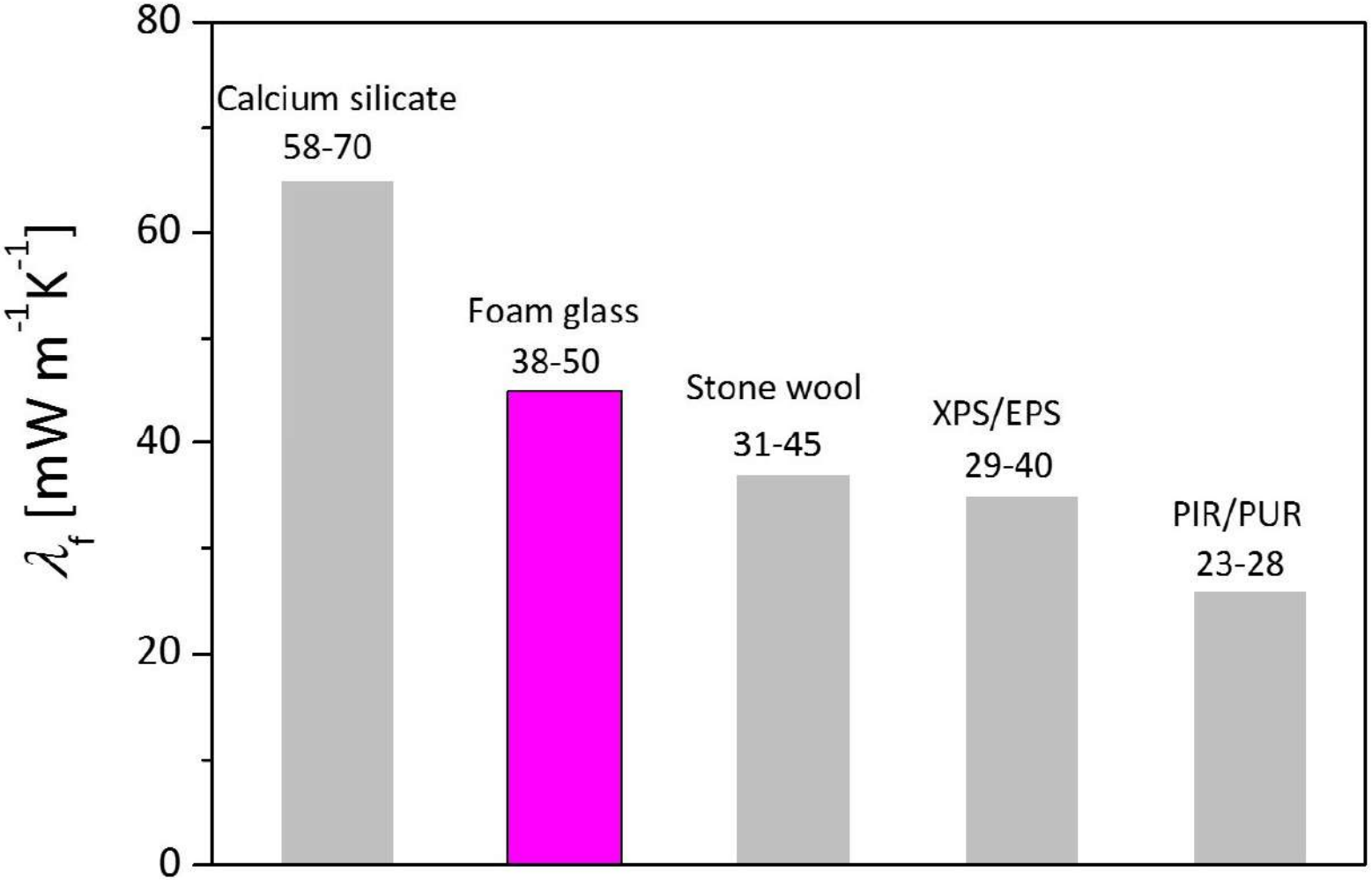


Open porosity ⇨ Heat insulation, filtration, draining application

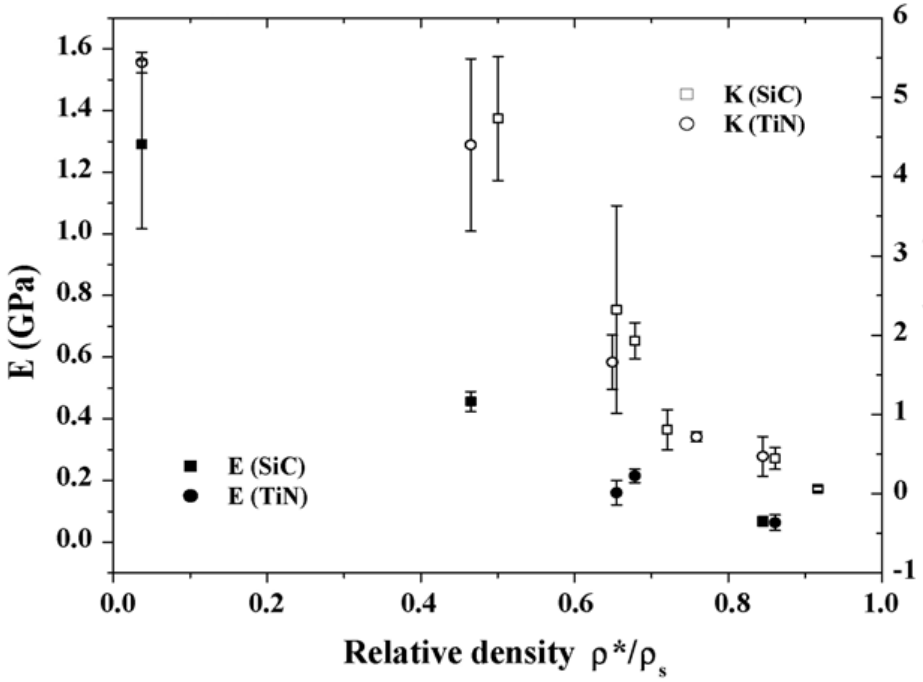
Closed porosity ⇨ Sound insulation application

From Pittet, JP. A. MathGen, 1999

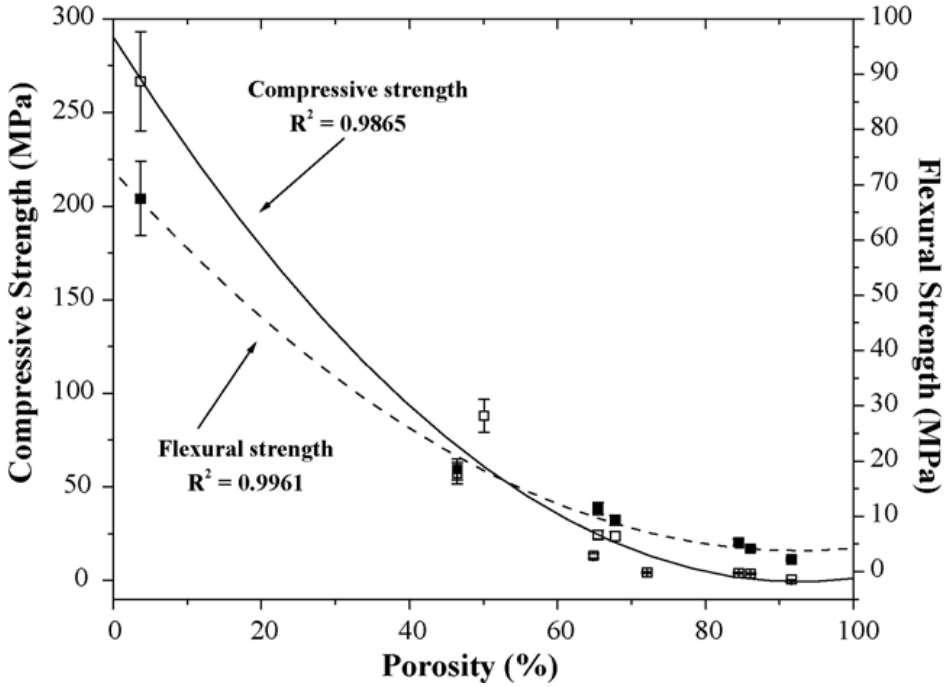
Thermal conductivity



Mechanical properties



Variation of Young's modulus E and compressive modulus K versus porosity



Variation of the compressive and flexural versus porosity

Foam glass properties

Applications

Granulates

Sheets

Road support

Green roofs

Moesgaard Museum (Viking museum), Denmark

Glass beads synthesis

Granulator: rotary plate

Rotary furnace: direct heating

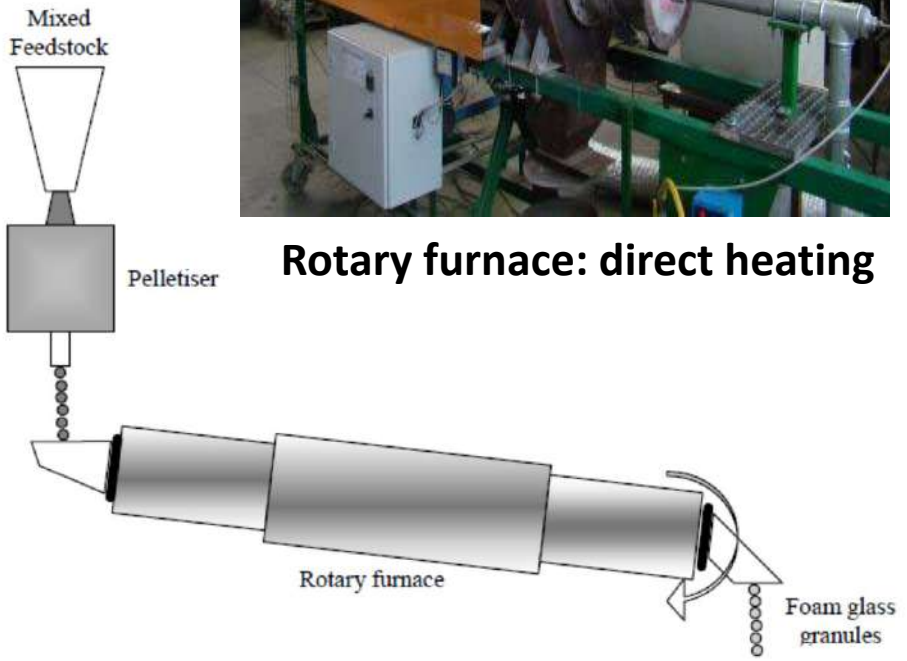


Figure 4 - Continuous production of foam glass granules using a rotary furnace.

Applications

- ✓ Formulation agents mortars and cements
- ✓ Thermic insulating
- ✓ Lightweight insulating panel
- ✓ Lightweight concrete
- ✓ Painting textural agent, painting paper
- ✓ Automotive
- ✓ Chimneys ducts insulation

Scientific production

- 10 articles in international peer-reviewed journals, 3 articles in national journals, 1 book chapters, 12 oral communications in international conferences including 5 as invited guests, 2 oral communications in national conferences as invited guests, and 2 invited seminars

→ Méar F.O., Podor R., Lautru J., Genty S., Lebullenger R. **2021**. Effect of process atmosphere on the glass foam synthesis: a high temperature environmental scanning electron microscopy (HT-ESEM) study. *Ceramics International*, 47, 26042-26049

→ Lebullenger R., Méar F.O., **2019**. Glass Recycling. In : J.D. Musgraves, J. Hu, L. Calvez, eds. Spinger Handbook of Glass, Springer, 1361-1383

- 21.09.2021 Glass recycling workshop (USTV, Nancy)

- Research contract : RECYVER 2013-2015

  "Study of a viable recovery sector for cathode ray tube glass"