Qualification of different inorganic binders for component optimization of molded refractory insulation products based on biogenic silica

Theodor Haase Award 2022 - December 14th, 2022

Objective

Production of novel molded insulating components from rice husk ash:

+

Inorganic binder

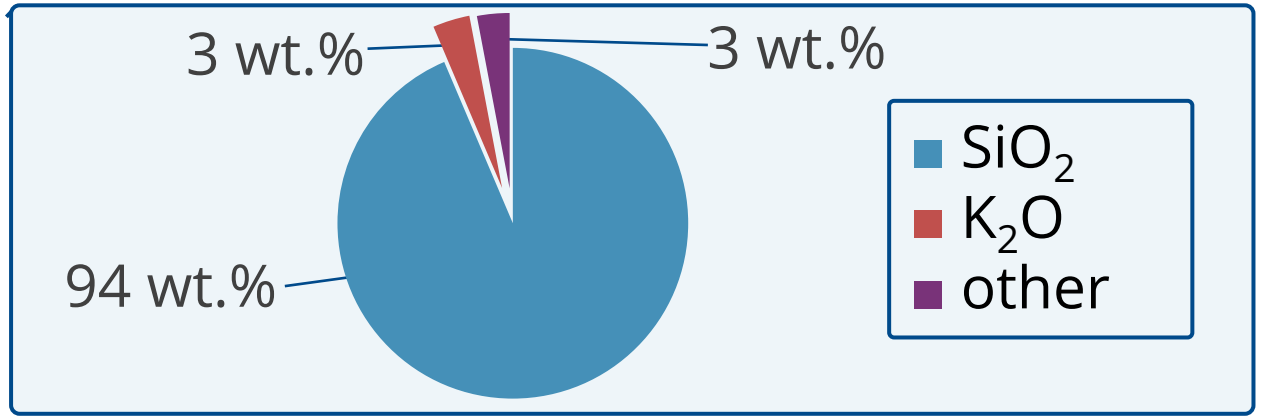
Evaluation of the components by:

Refractory properties:
X-ray powder diffraction (PXRD)
Hot stage microscopy

Mechanical properties:
Cold flexural strength
Cold compressive strength

Theory of biogenic silica

Sustainable by-product of rice production (rice husk ash):



XRF

Mainly amorphous with small amounts of tridymite and cristobalite

XRD

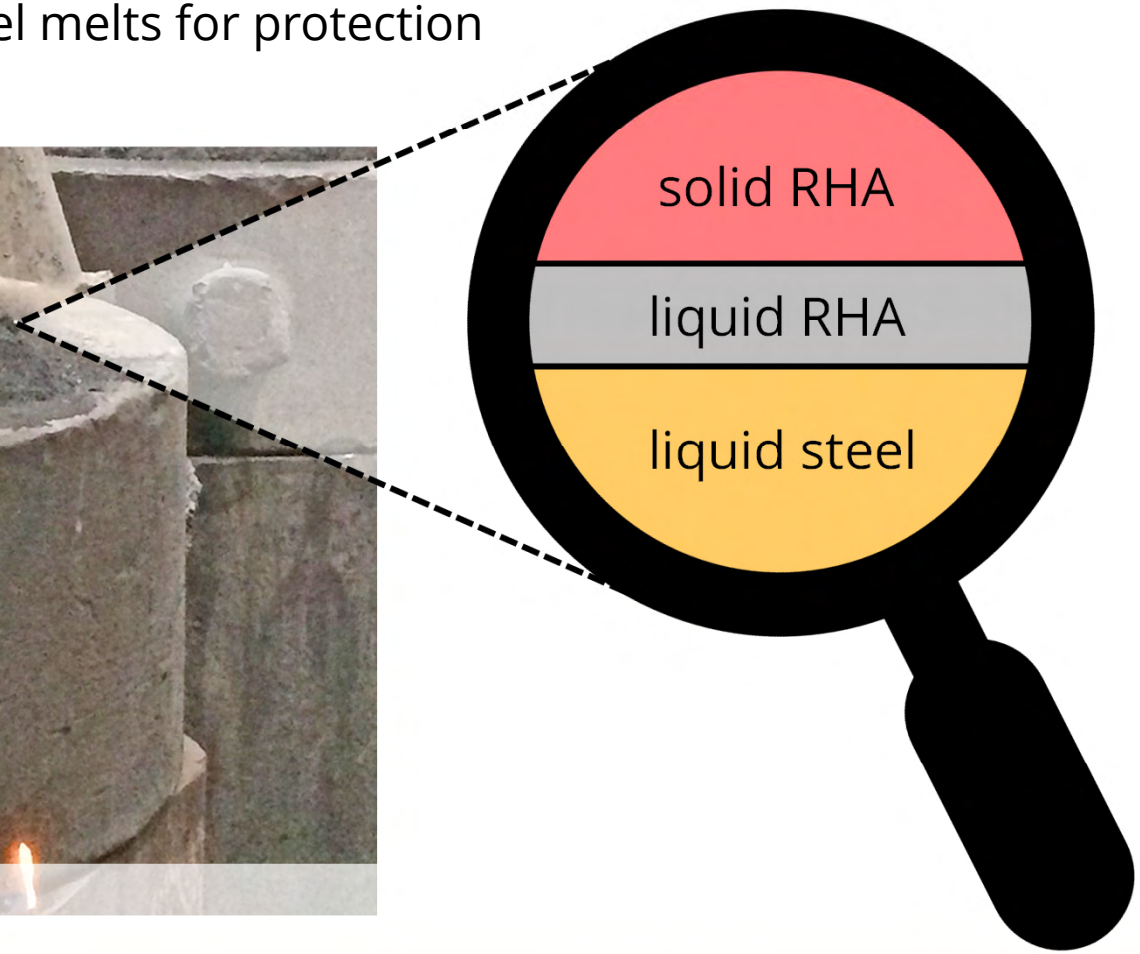
V. Stein, T. Schemmel, P.Stein. A NOVEL ENVIRONMENTAL FRIENDLY INSULATING MATERIAL FOR HIGH TEMPERATURE APPLICATIONS

SEM

Refractory applications

Typical refractory covering agent (T_m ≈ **1650 °C**) for steel melts for protection from N_2 and H_2:

V. Stein, T. Schemmel. Sustainable Rice Husk Ash-Based High-Temperature Insulating Materials.



Experimental Procedure

Solution:

Production of molded components from rice husk ash:

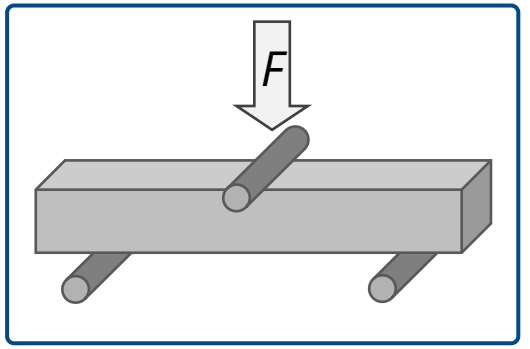
- Better handling + absence of dust
- Requirement of a binder (here: **silica sol** (40 wt.% SiO_2) and **H_3PO_4** (conc.))

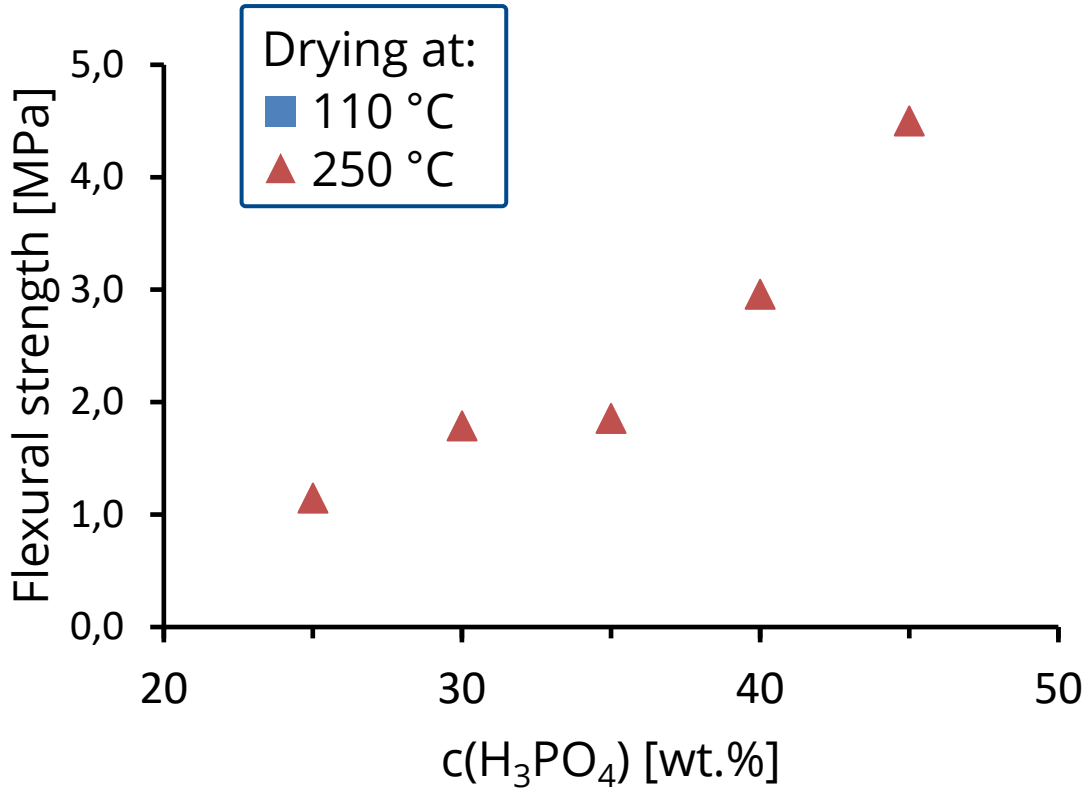
Production Process:

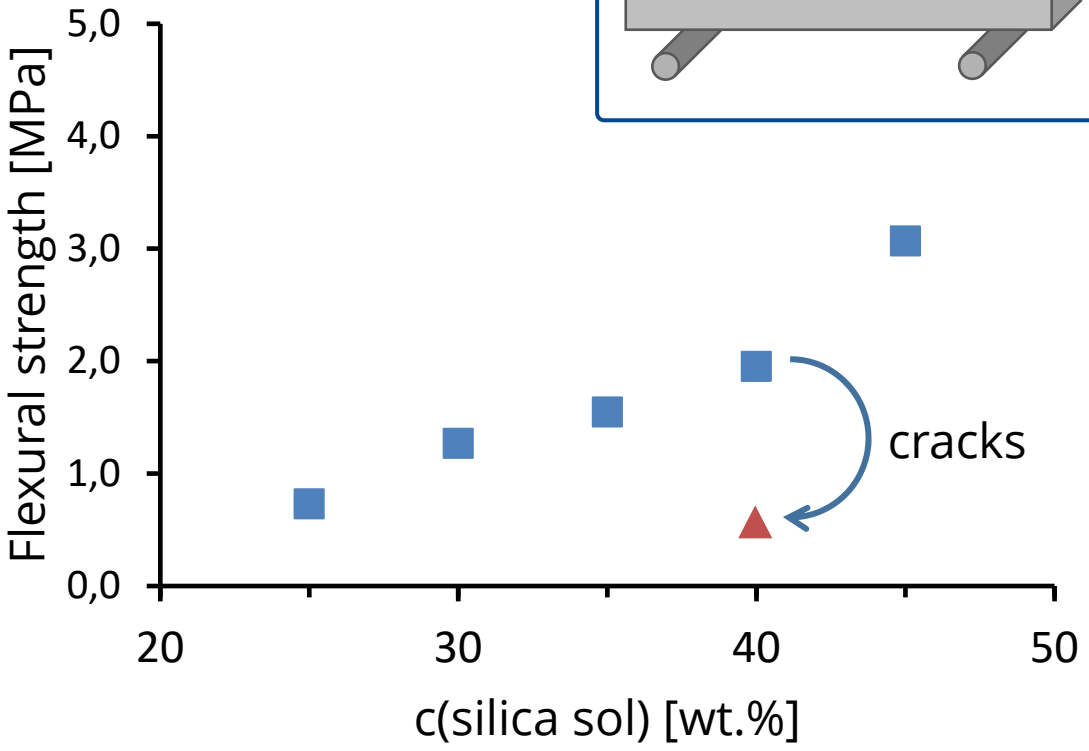
Homogenization of raw materials | Uniaxial pressing | Drying (t = 18 h)

Mechanical properties

Mechanical strength provided by both H_3PO_4 and silica sol bonding:







H_3PO_4 bonding mechanism

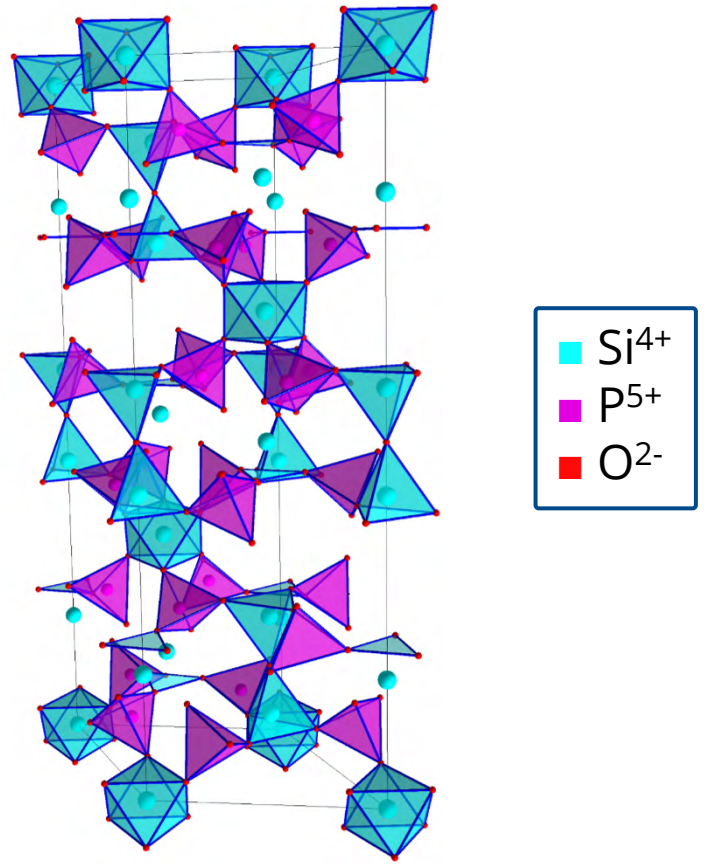
By X-ray powder diffraction:

$$5\ SiO_2 + 6\ H_3PO_4 \xrightarrow[-\ 9\ H_2O]{T \geq 250\ °C} \mathbf{Si_5O(PO_4)_6}$$

By hot stage microscopy:

$$Si_5O(PO_4)_6 \xrightarrow{T \geq 1017\ °C} SiO_2 + Liquid + P_xO_y\uparrow$$

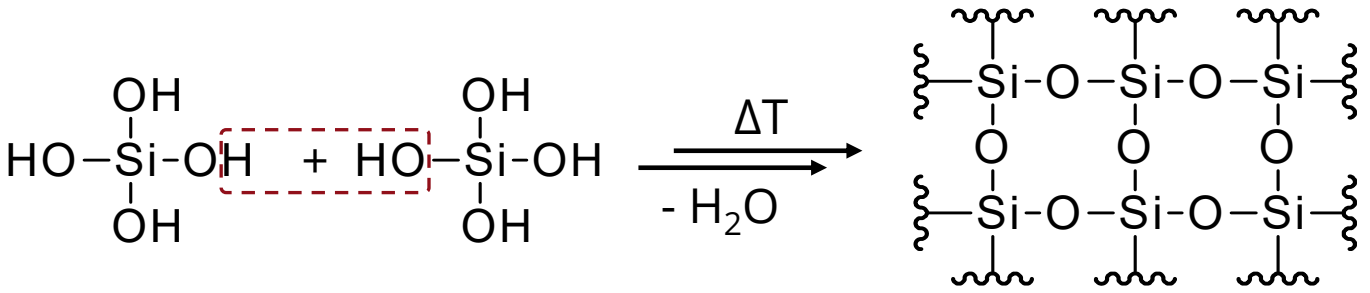
Not refractory!

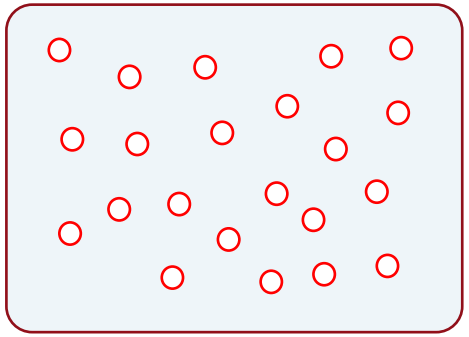


Structural representation of the $Si_5O(PO_4)_6$ phase with coordination polyhedra

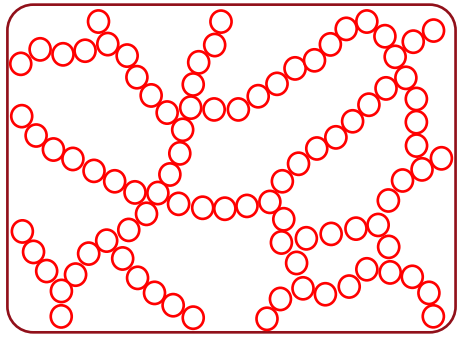
Silica sol bonding mechanism

Crosslinking by polycondensation of silanol groups to siloxanes:





colloidal silica sol



amorphous SiO_2

By hot stage microscopy:

Refractory up to T ≤ 1564 °C

Conclusion and Outlook

Only silica sol bonding meets the basic requirements for the production of refractories:

	Silica sol	H_3PO_4
Mechanical properties	✓	✓
Refractoriness	✓	✗
Problems	Crack formation at $T \geq 250$ °C	Thermal instability of $Si_5O(PO_4)_6$

Outlook

- Adjustment of the drying process to prevent the observed cracking at T ≥ 250 °C (temperature, heating rate)
- Determination of the thermal conductivity to characterize the insulation properties
- New possible application fields for refractories based on biogenic silica (e.g. industrial furnaces)

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THANK YOU FOR YOUR INTEREST

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