The use of robocasting technique to manufacture cordierite

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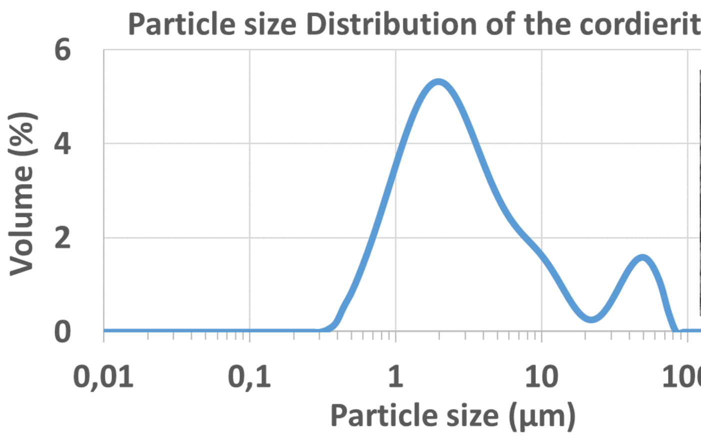
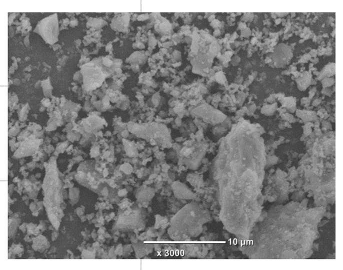
Context

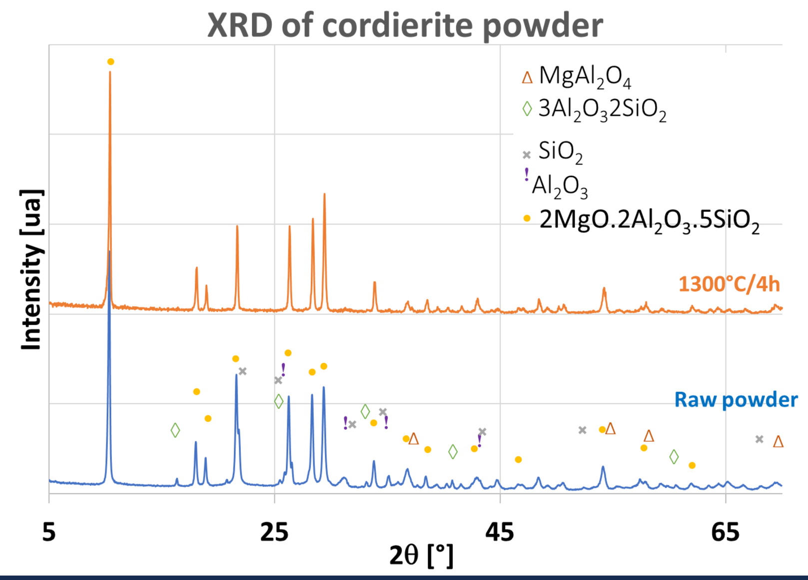
Technical ceramics present remarkable properties, such as high mechanical strength, thermal conductivity, or wear resistance. Therefore, they are used as critical components for specific applications in the fields of aerospace, automotive, energy production or cutting tools. Silicate ceramics usually present less efficient properties. However, they can be an advantageous alternative to technical ceramics in many applications operating at room or moderate temperature (<1000°C). Moreover, regarding the environmental aspect, silicate ceramics are processed from natural abundant mineral resources, show a high recyclability, and require moderate sintering temperatures. One potential technical application is their use as components in clean energy systems such as catalyst substrates. Beyond the environmental and cost aspects, the improvement of their efficiency depending on the targeted application must also be a focus point to promote their use in the industrial world. This can be achieved by manufacturing components with complex architectures and internal structures that can only be achieved by additive manufacturing. With such advanced architectures, the exchange surface can be increased for the same volume using less material, for instance in filtration or catalysis applications. This is the aim of the present study which is dedicated to the shaping method of cordierite powder by robocasting. This study deals with the formulation of a stable slurry of cordierite powder with a suitable viscosity for the robocasting process and with a sufficient solid content. The effects of 3D printing and sintering parameters on the printed parts regarding their final properties after firing such as density/porosity are also investigated.

Material and method

Raw material

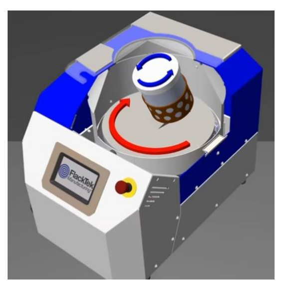






Ink mixing

- Cordierite *(Tethon)*
- Xanthan gum *(Rhodopol – Solvay)*
- Water
- Carboxilic acid *(Dolapix Ce64 – Zschimmer & Schwarz)*

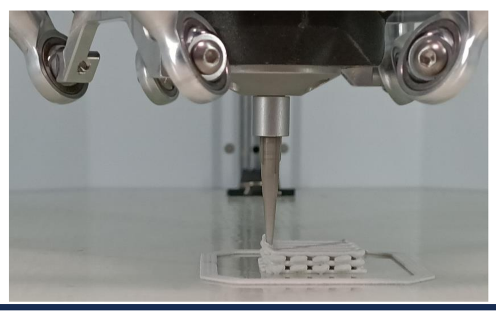


Speed mixer *1500 rpm - 30sec* + Three-cylinder rolling mill → 24h of maturation

Printing

- Nozzle diameter= 1.19mm
- Nozzle speed= 2100mm/min
- Layer height= 1.19mm

Lynxter S600D



Thermal treatment

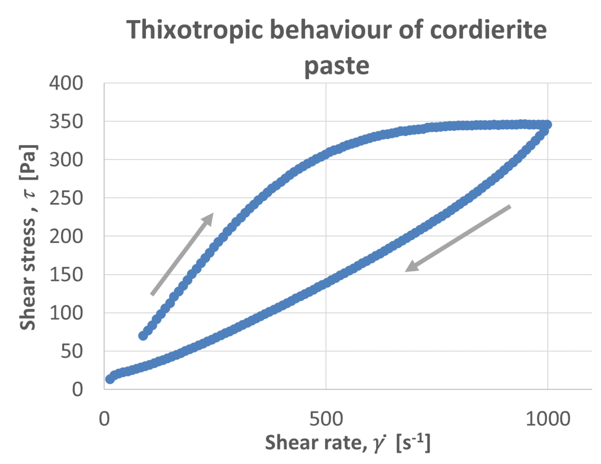
Fine controled drying step

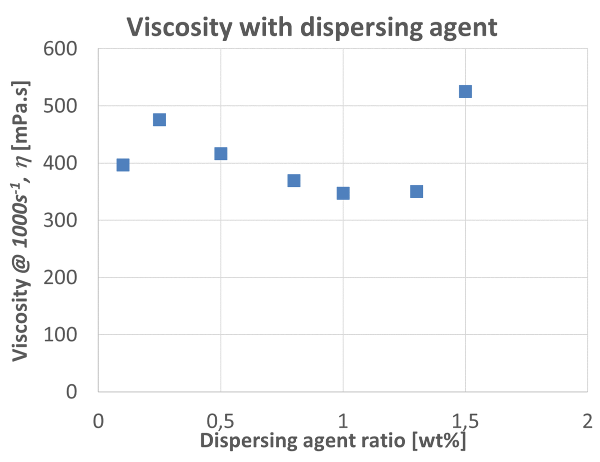
1. From 98% down to 60% of humidity @22°C in 36h
2. 12h with 60% of humidity
3. drying 80°C/1h

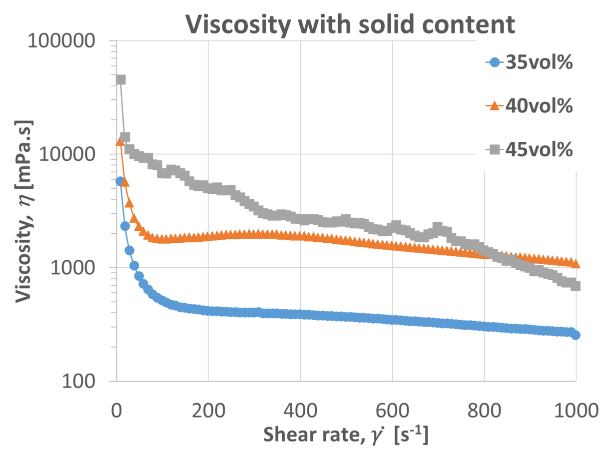
Sintering
1300°C / 4h

Results

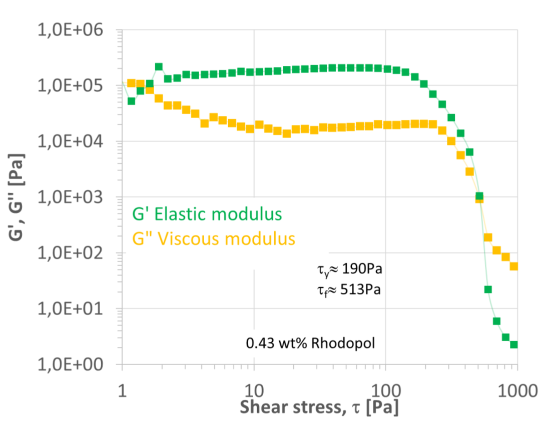
Rheological behaviour

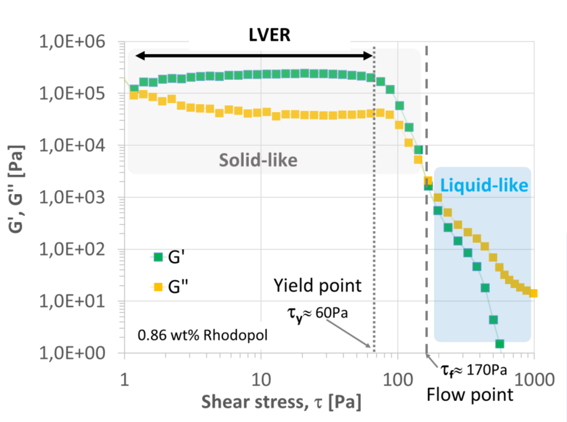


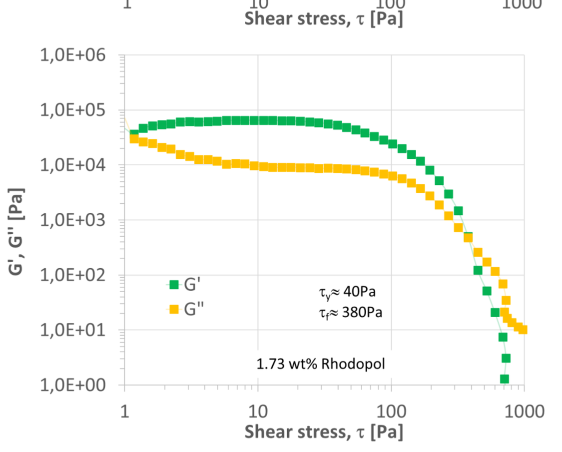


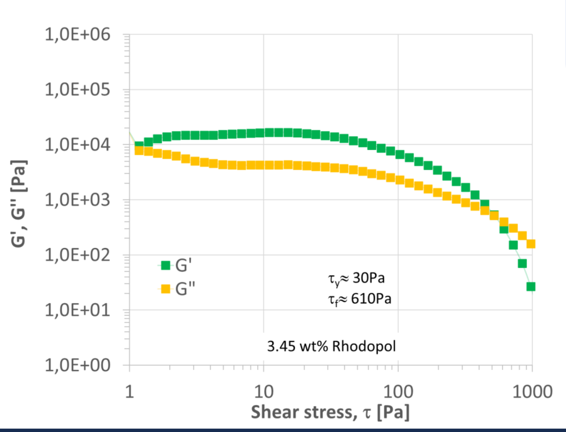


- Cordierite ink exhibits a thixotropic and a shear thinning behaviour
- The ratio of 1 wt% dispersing agent was determined to be optimal.
- Above 40 vol%, the ink begins to be less easy to work with.



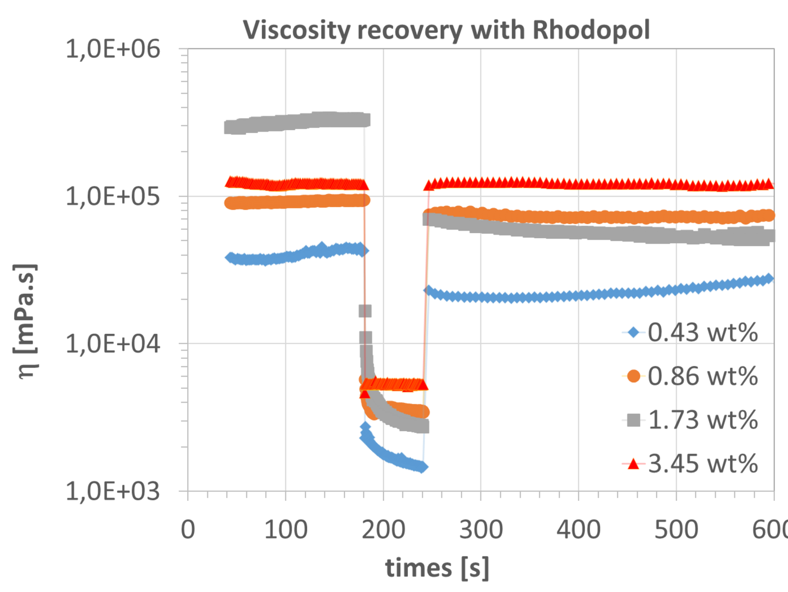




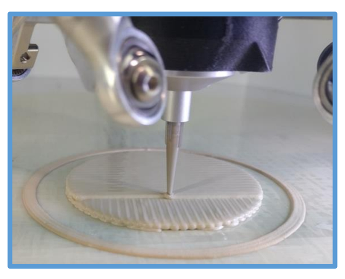


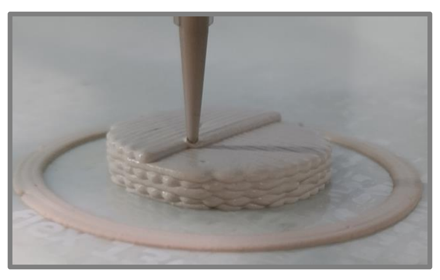
- Linear Viscoelastic Region (LVER) change as a function of the thining agent content
- Low yield points were measured

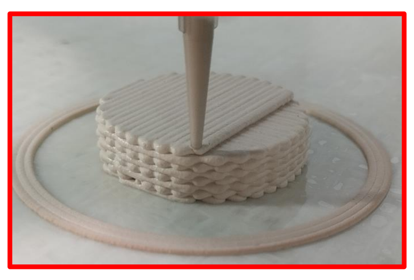
Printing behaviour

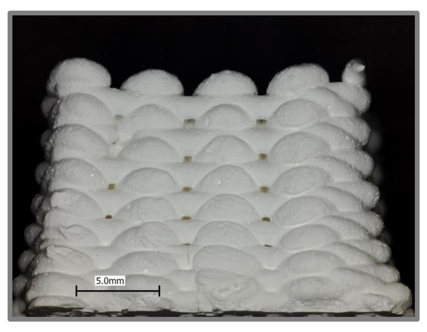


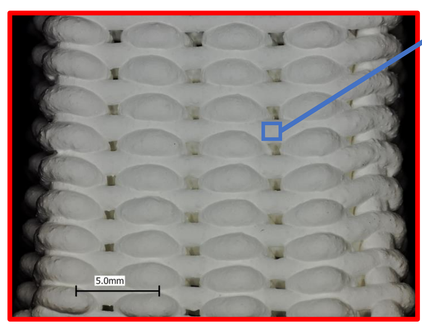
Full recovery of viscosity is achieved with 3.45 wt% Rhodopol.


0.43 wt% Rhodopol

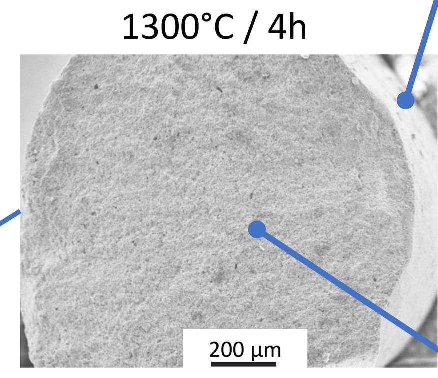

1.73 wt% Rhodopol


3.45 wt% Rhodopol

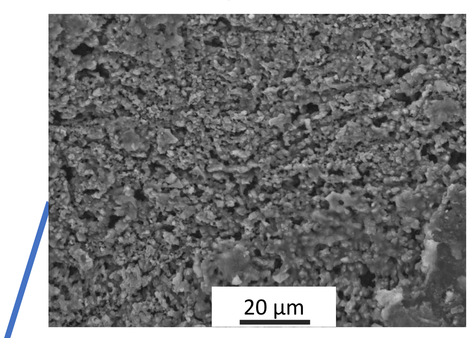




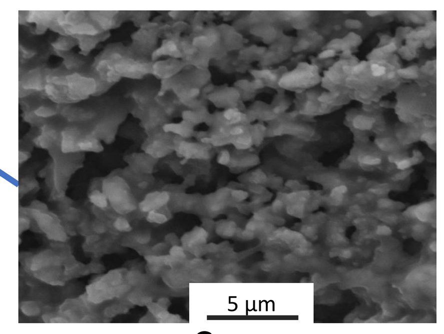
After 1300°C / 4h



skin

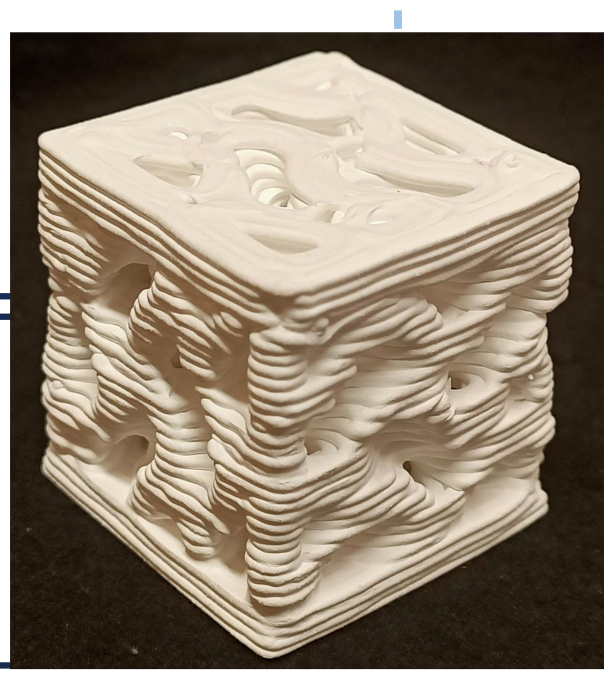


Highly porous microstructure ~46% open porosity



Core

- From 0.43 to 0.86 wt% Rhodopol, printing of scaffold is not possible
- Huge deformation occcured up to 1.73 wt%
- From 3.45 wt% Rhodopol cm-sized scaffold were printed without deformation



After thermal treatment on complex shaped parts, no cracking was observed.

Conclusion

- A stable ink formulation with suitable rheological behaviour for robocasting has been developed from a cordierite powder.
- Advanced scaffolds with highly porous microstructures have been achieved

Perspectives

- Change the printing strategy to improve the reliability of the final geometry
- Print with a cordierite powder from "industrial waste"
- Fine tuning of rheological settings to predict the ink behaviour during printing

Acknowledgement
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