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Institut für Keramik,  
Feuerfest und  
Verbundwerkstoffe

# Development of 3D Printed Steel-Ceramic Composites for High-Performance Refractory Components

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Supervisors: Prof. Dr.-Ing. habil. Christos G. Aneziris  
Dipl.-Ing. Piotr Malczyk  
M.Sc. Serhii Yaroshevskiy



Freiberger Feuerfestforum  
13.12.2023

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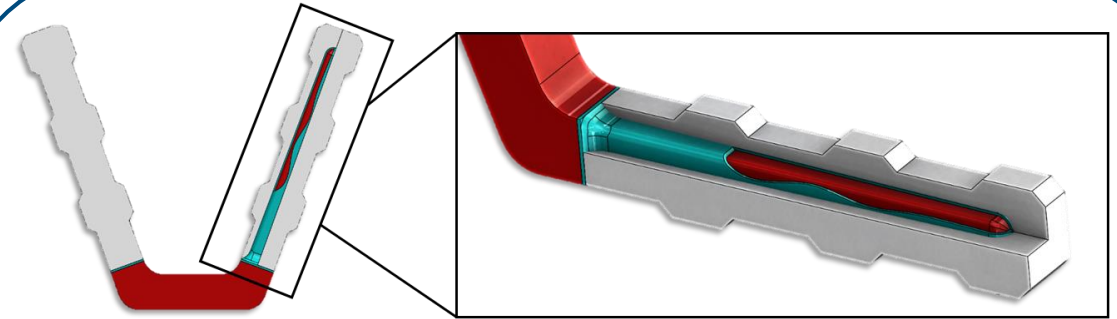


## Problem:

Increased utilization of secondary fuels facilitates corrosion of the furnace lining



## Solution



- Anchor system with multifunctionality
- Combined use of materials by FFF technology

### Material gradient of the system

**Steel**  
mechanical and  
physical properties

**Ceramic**  
corrosion resistance



## Filament Recipe

### Ceramic/Composite Solid Phase



### Thermoplastic Binder

#### Filament 1:

AR78 spinel

+

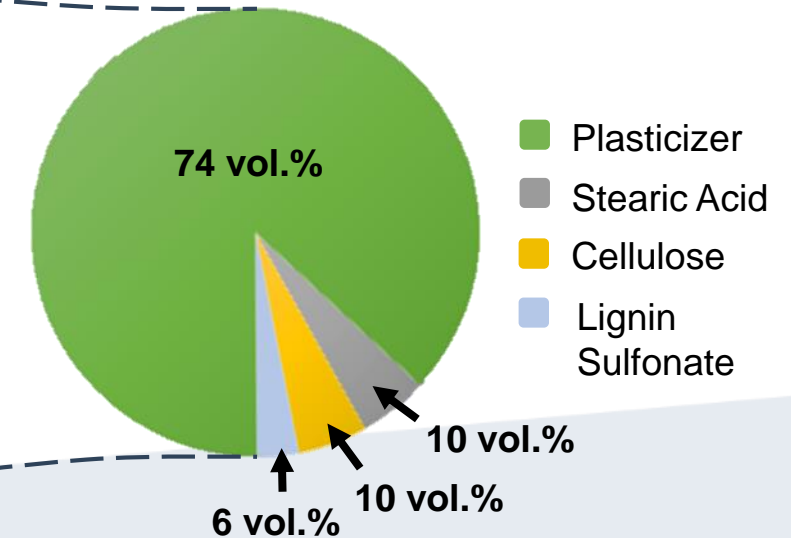
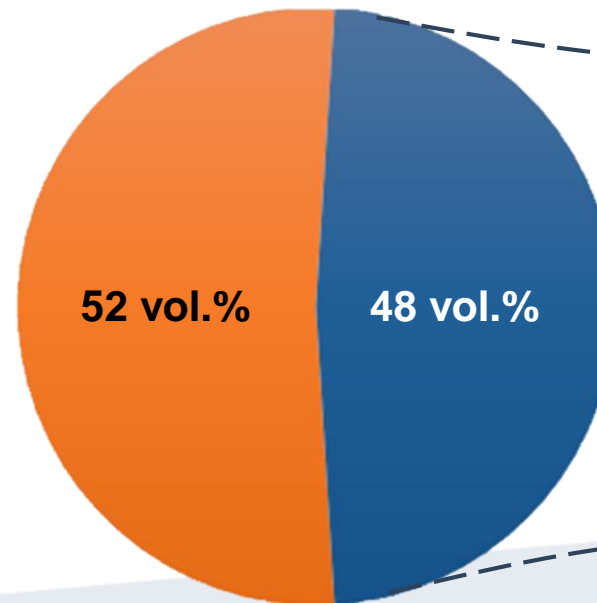
3 wt.% TiO<sub>2</sub>

#### Filament 2:

60 vol.% 316L stainless steel

+

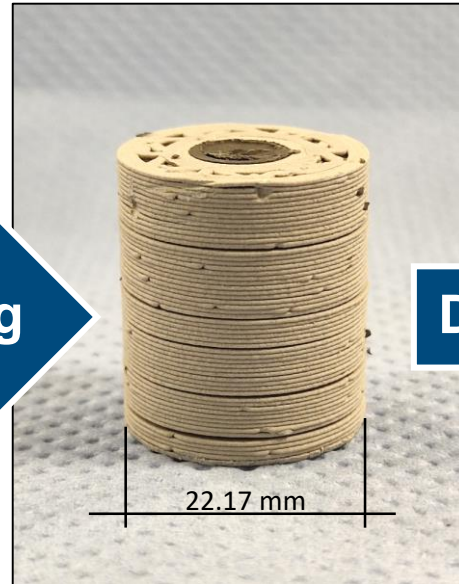
40 vol.% AR78 spinel



Patent: Aneziris, Malczyk, Yaroshevskiy, DE 10 2022 001 070.4, 29.03.2022



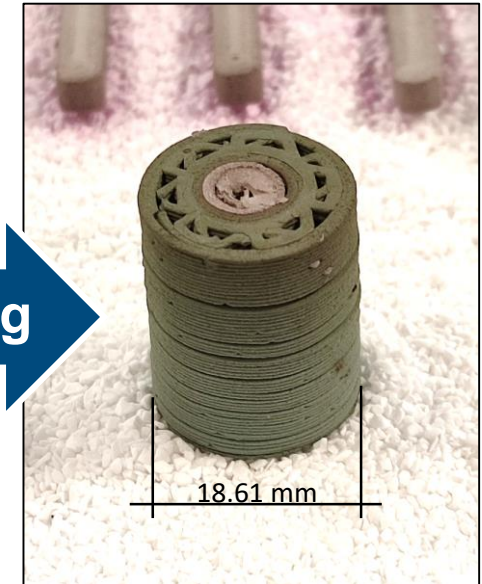
Printing



Debinding



Sintering



- Two individually controllable printheads (XERION Fusion Factory 3D Dualprinter)

- Debinding up to 450 °C (5 Steps) in **oxidizing** atmosphere

- Sintering up to 1400 °C (4 Steps) in **argon** atmosphere

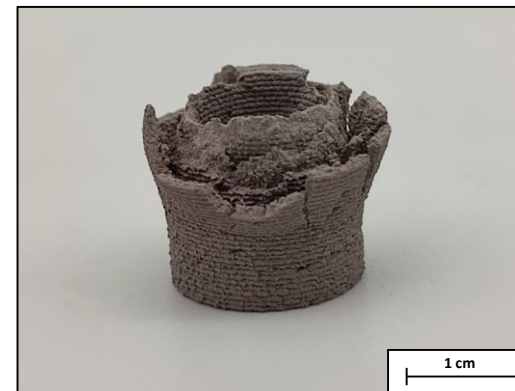
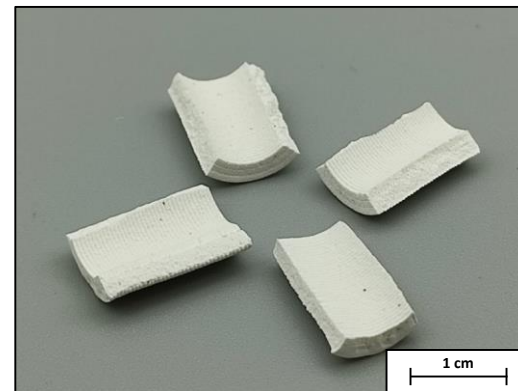
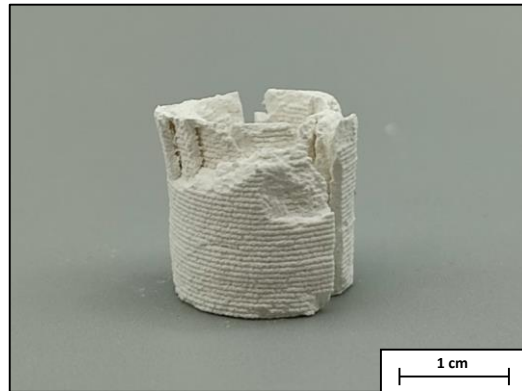
based on Yaroshevskiy et al., Ceramics 2023



## Mechanical Properties

AR78+3TiO<sub>2</sub>

316L/40AR78



		$F_{\max}$ in N
Compression mode		2596.7
Splitting tensile mode		250.5

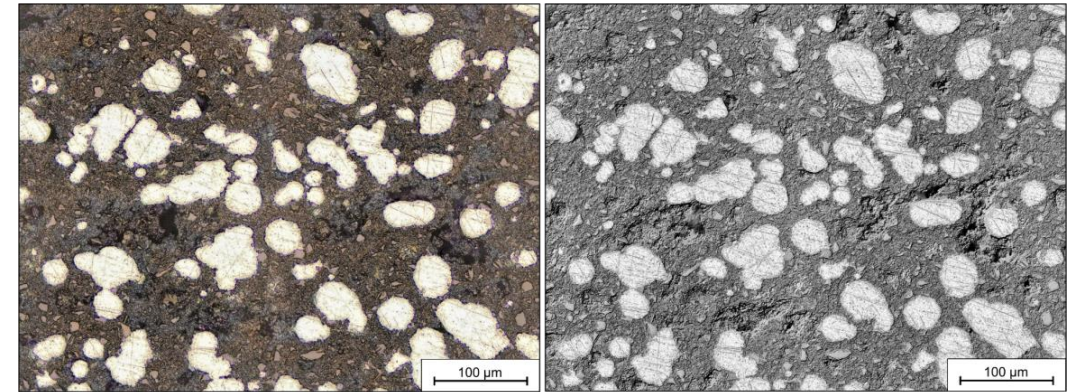
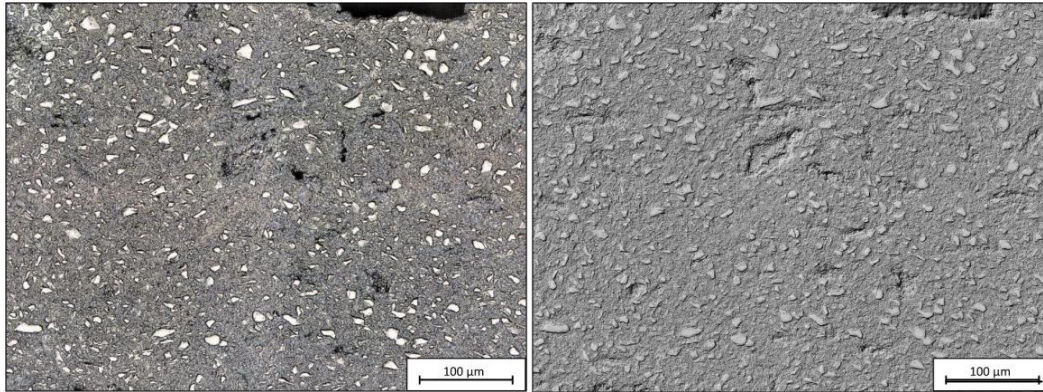
		$F_{\max}$ in N
Compression mode		1139.8
Splitting tensile mode		102.9

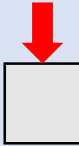
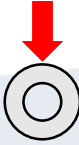


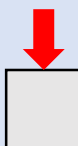

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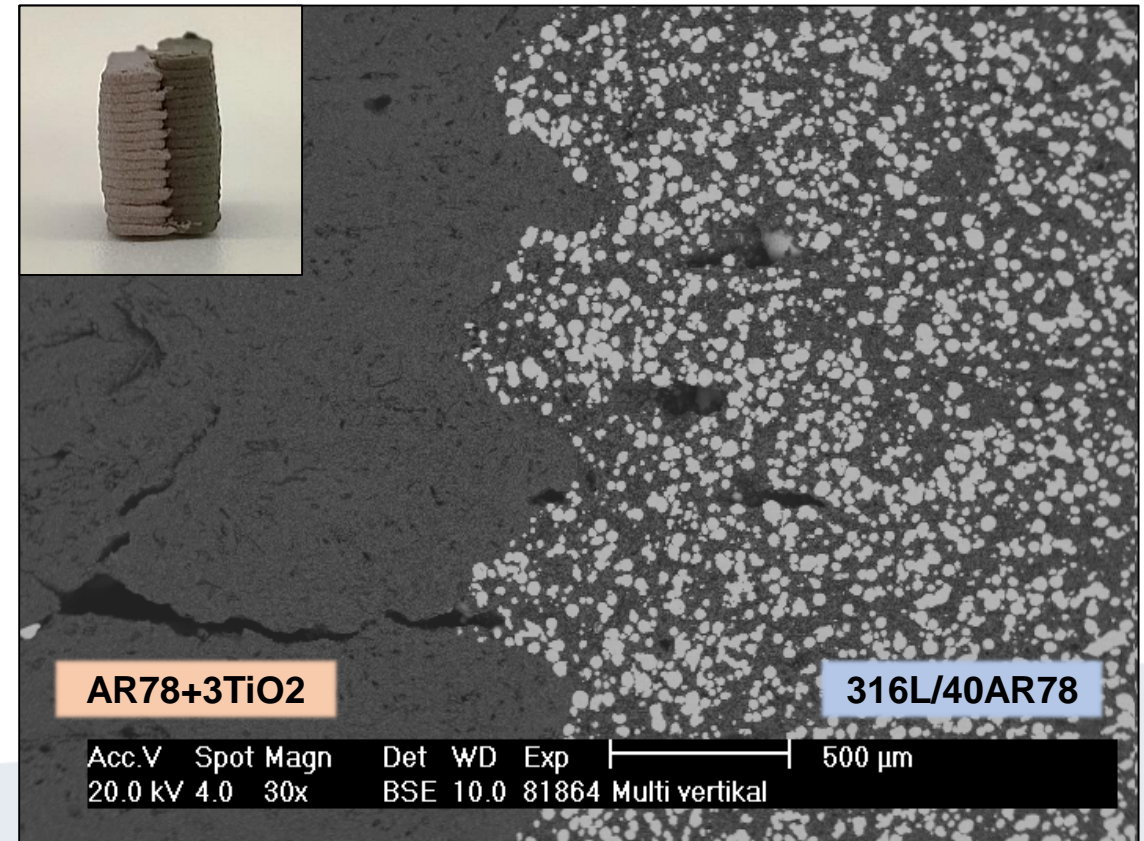
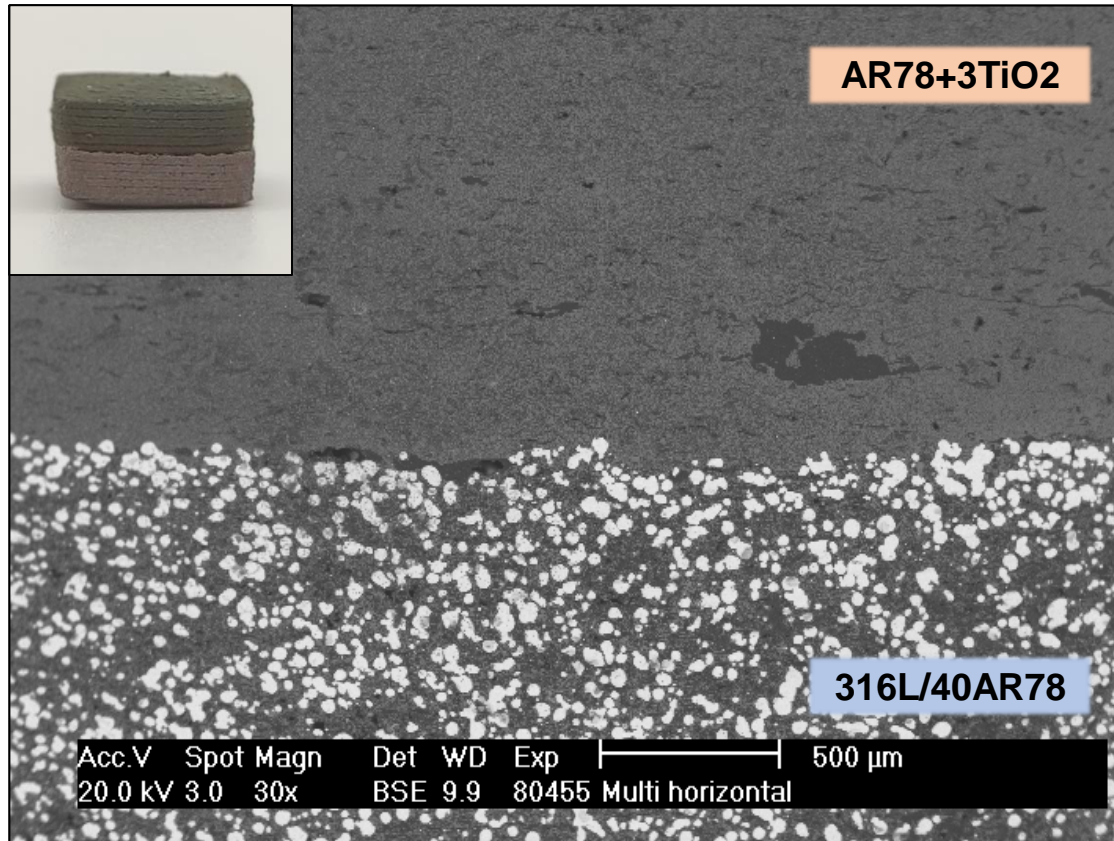


		$F_{\max}$ in N
Compression mode		2596.7
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		$F_{\max}$ in N
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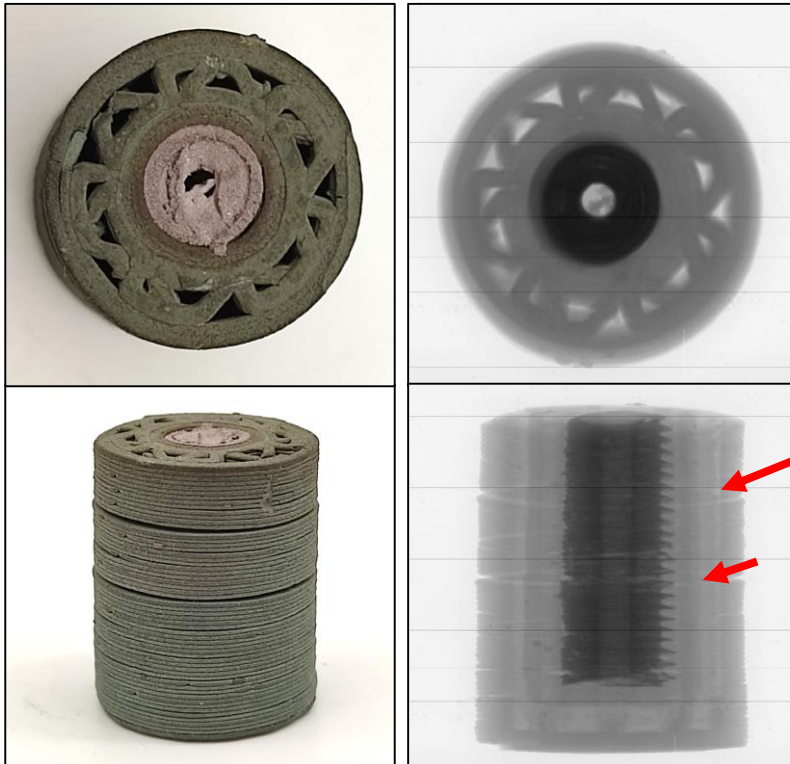


## Investigation of the Interface Layer

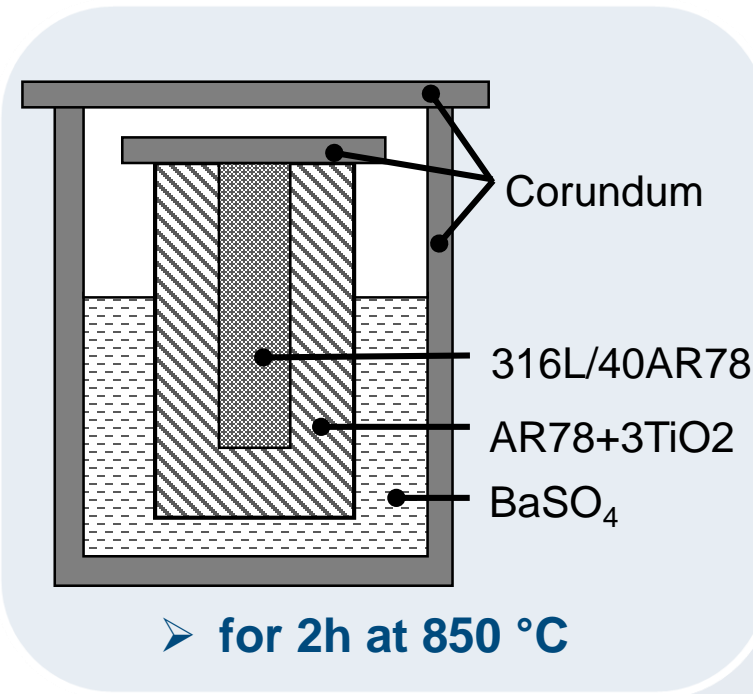




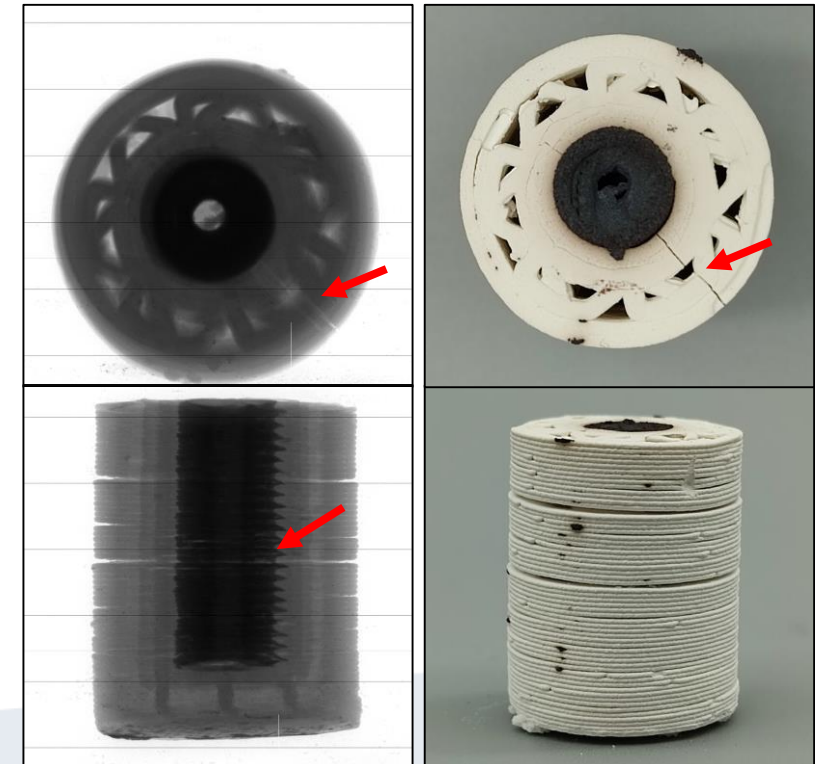
## Before Corrosion



## Corrosion Test



## After Corrosion

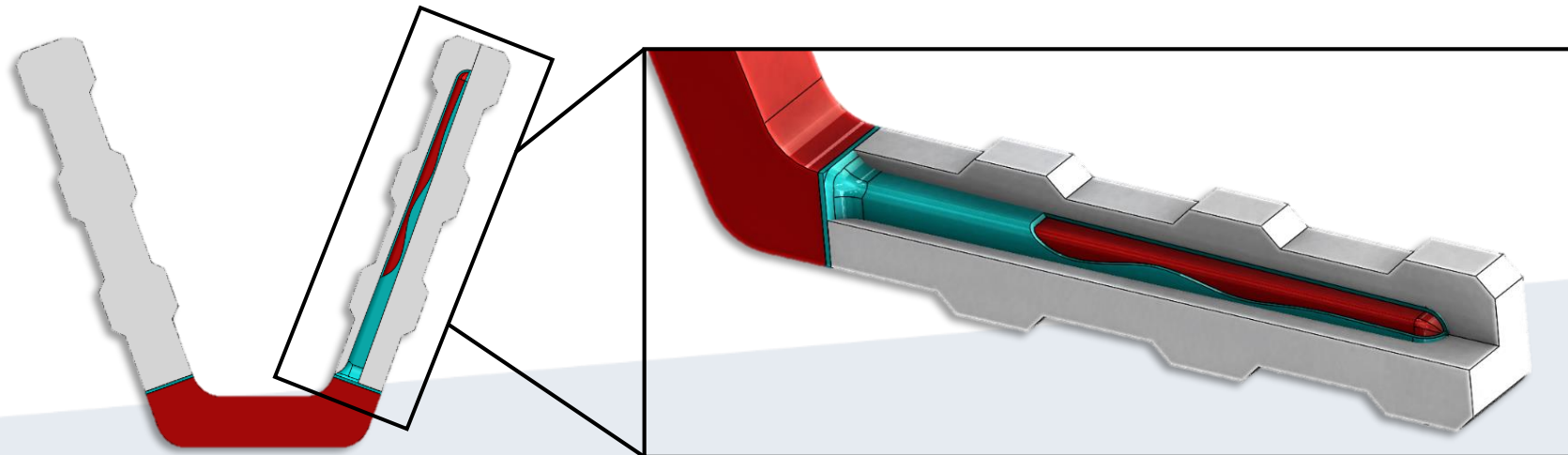




## Conclusion

- Sufficient stability of manufactured filament for the printing of single and multi-material samples
- Successful debinding without utilization of chemical solvents
- Bonding of the multi-material component without detrimental delamination
- Negligible corrosion of the multi-material component

## Future Application





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# THANK YOU FOR YOUR ATTENTION!



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