

MASS PRODUCTION AND JOINING VIA MULTICOMPONENT TUNGSTEN POWDER INJECTION MOLDING

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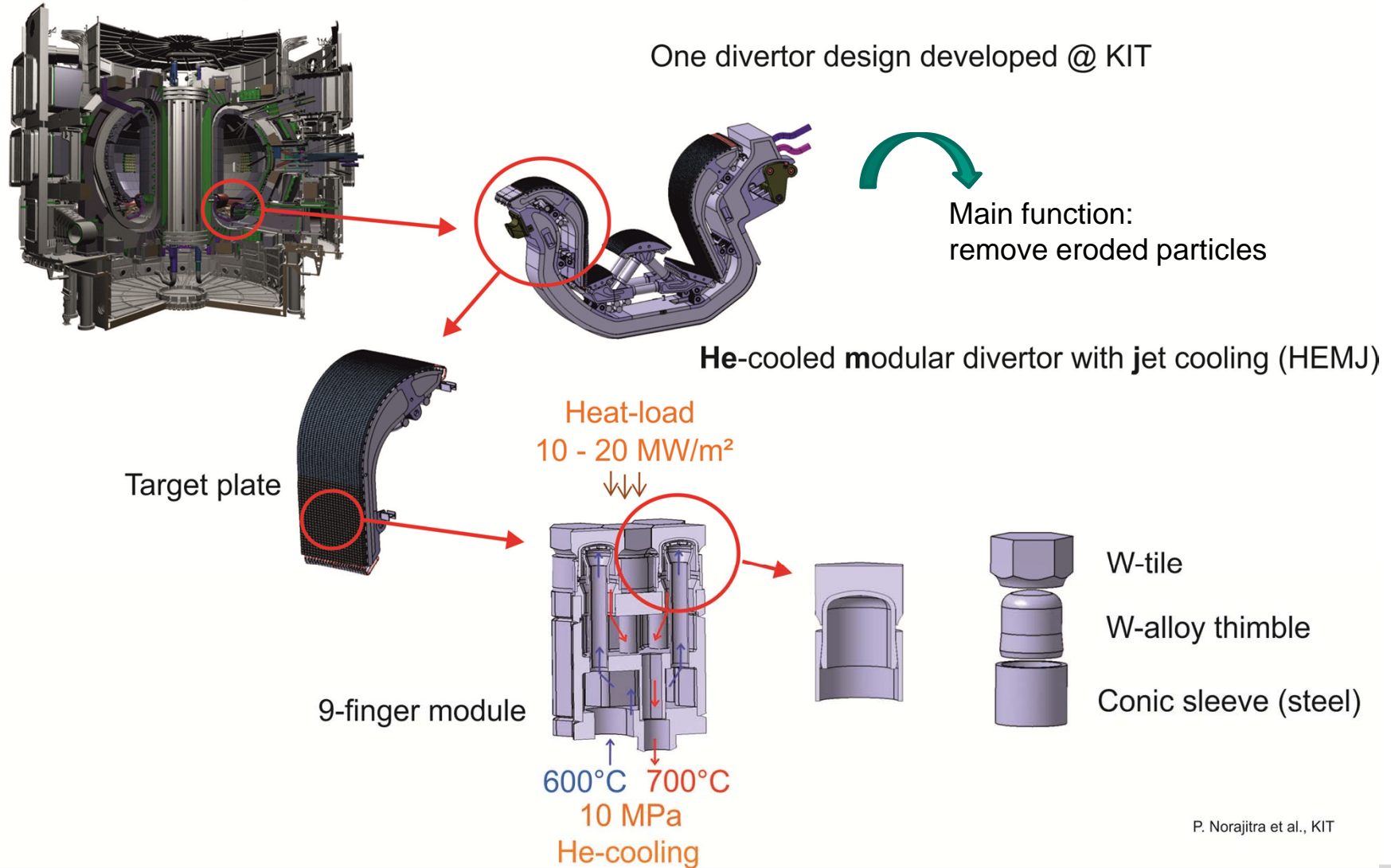
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Outline

- **Motivation**
- **What is Powder Injection Molding (PIM)?**
- **The PIM process for tungsten developed @ KIT**
- **Production of multicomponent W PIM divertor parts**
- **Summary & Outlook**

Motivation

Future fusion power reactor DEMO

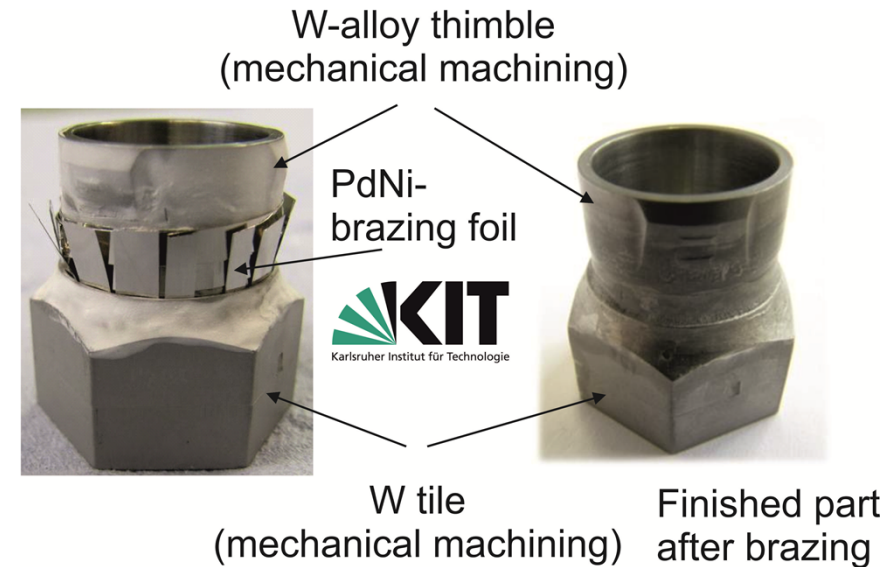


P. Norajitra et al., KIT

Motivation

He-cooled modular divertor with jet cooling (HEMJ)

- ⇒ W tile: armour material
 - ⇒ W-alloy thimble: structural material
 - ⇒ PdNi-brazing joint
 - ⇒ assembling, adjustment
 - ⇒ „handmade“
-
- ⇒ DEMO: nearly 300.000 parts
 - ⇒ lifetime nearly 2 years



- ⇒ Reasonable manufacturing method?



Producing as 2 Component W PIM part
in one step fully automatic
without additional brazing

What is Powder Injection Molding (PIM)?

...MANUFACTURING TECHNOLOGY...

Metal Injection Molding (MIM)

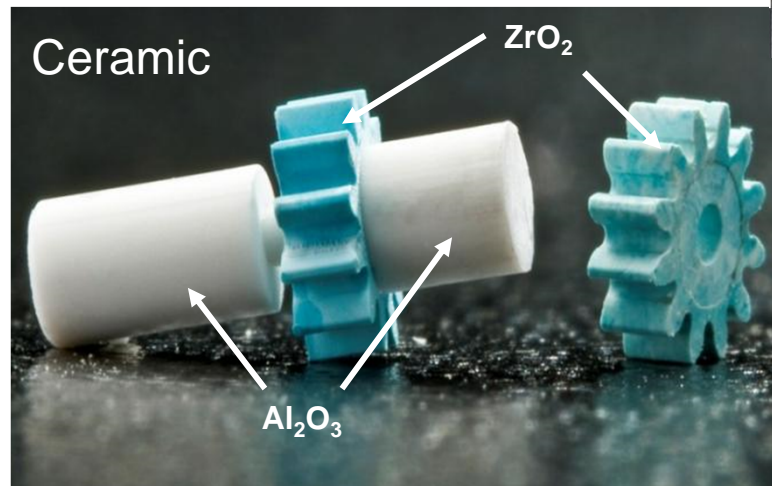
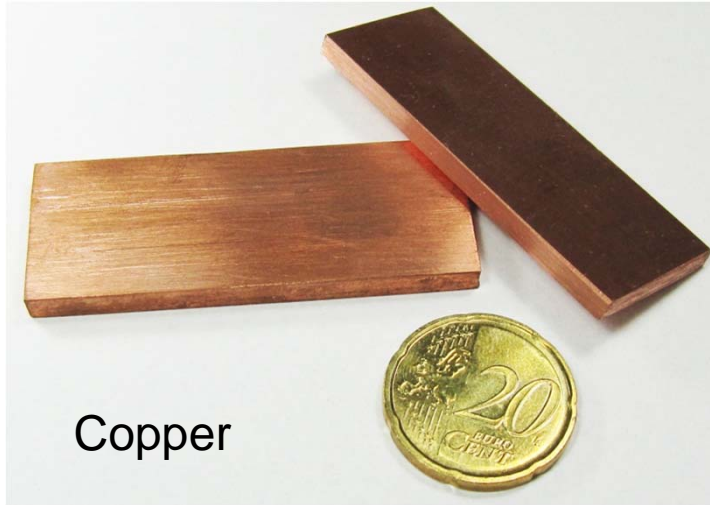


Ceramic Injection Molding (CIM)



What is Powder Injection Molding (PIM)?

...parts produced at KIT...



Smallest ZrO_2 gear wheel of the world:
outer- \varnothing 275 μ m



The PIM process for tungsten developed @ KIT

Material development



Powder



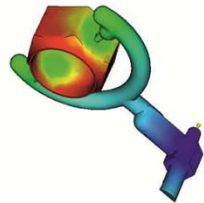
Binder

Mixing /
Kneading /
Extrusion

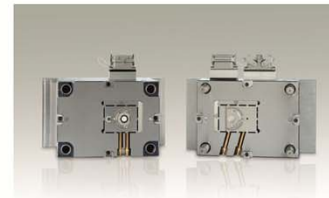


Feedstock

Design + engineering of a tool



Filling simulation



PIM-tool



Green parts (dark)
Finished parts (bright)

Debinding /
Heat-treatment



Injection molding
of green parts

The PIM process for tungsten developed @ KIT ...steps for developing new PIM tools...



Very important to know:

- Powder properties (size, shape, surface)
- Powder / Binder relationship (Feedstock)
- Heat-treatment process conditions
- Shrinkage (green part – finished part)

pre-tests /
analyzes

½ year

Filling simulation:

- Define gating system parameters (position, size, shape)
- Problems (air inclusions, mold filling, premature setting)

+



Construction of the tool

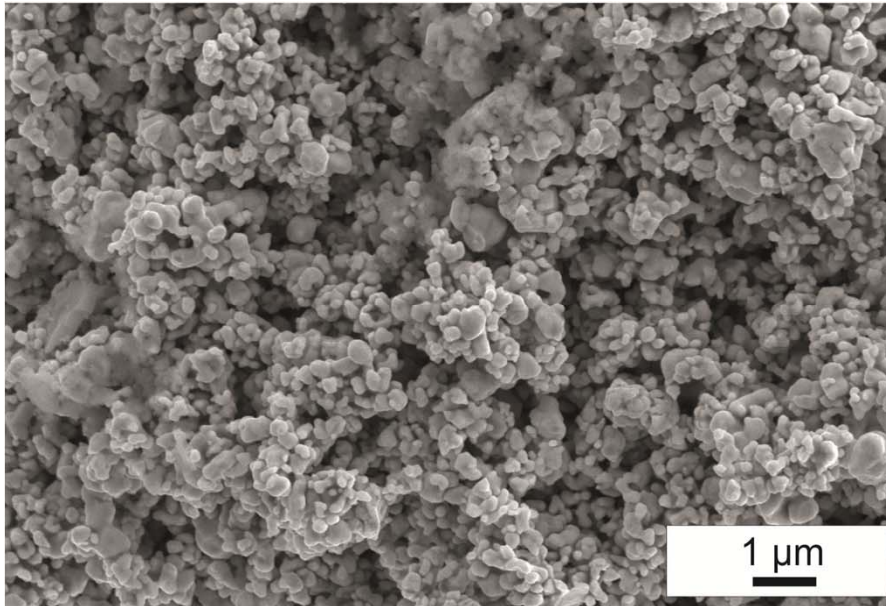
→ Running-in tests – maybe subsequent improvement

½ year

FINISHED PART



The PIM process for tungsten developed @ KIT ...used powders...



SEM Microstructure tungsten powder W1

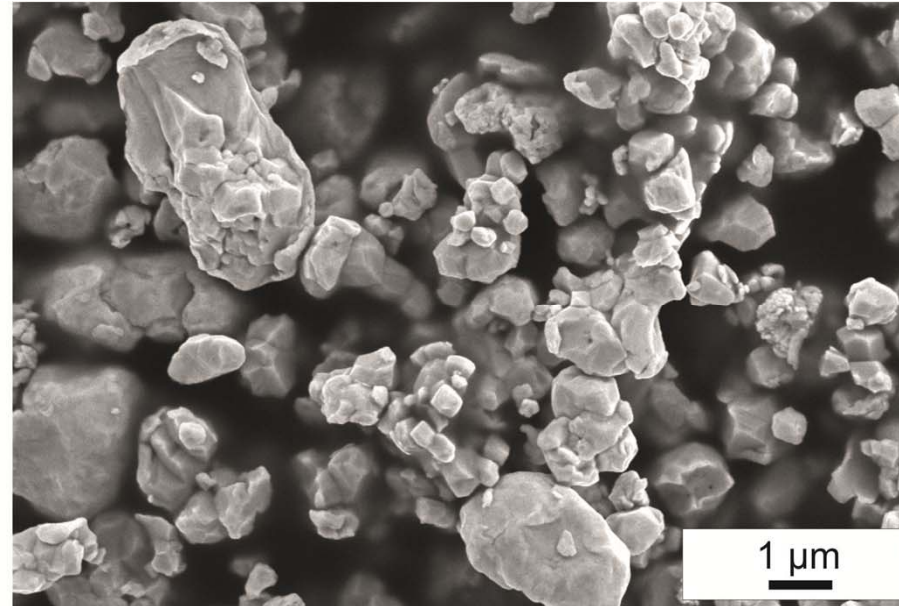
Powder particle size (as delivered):

Tungsten W1 [0.7 μm]

Tungsten W2 [1.7 μm]

Lanthanum oxide [<1.50 μm]

Yttrium oxide [<2.50 μm]



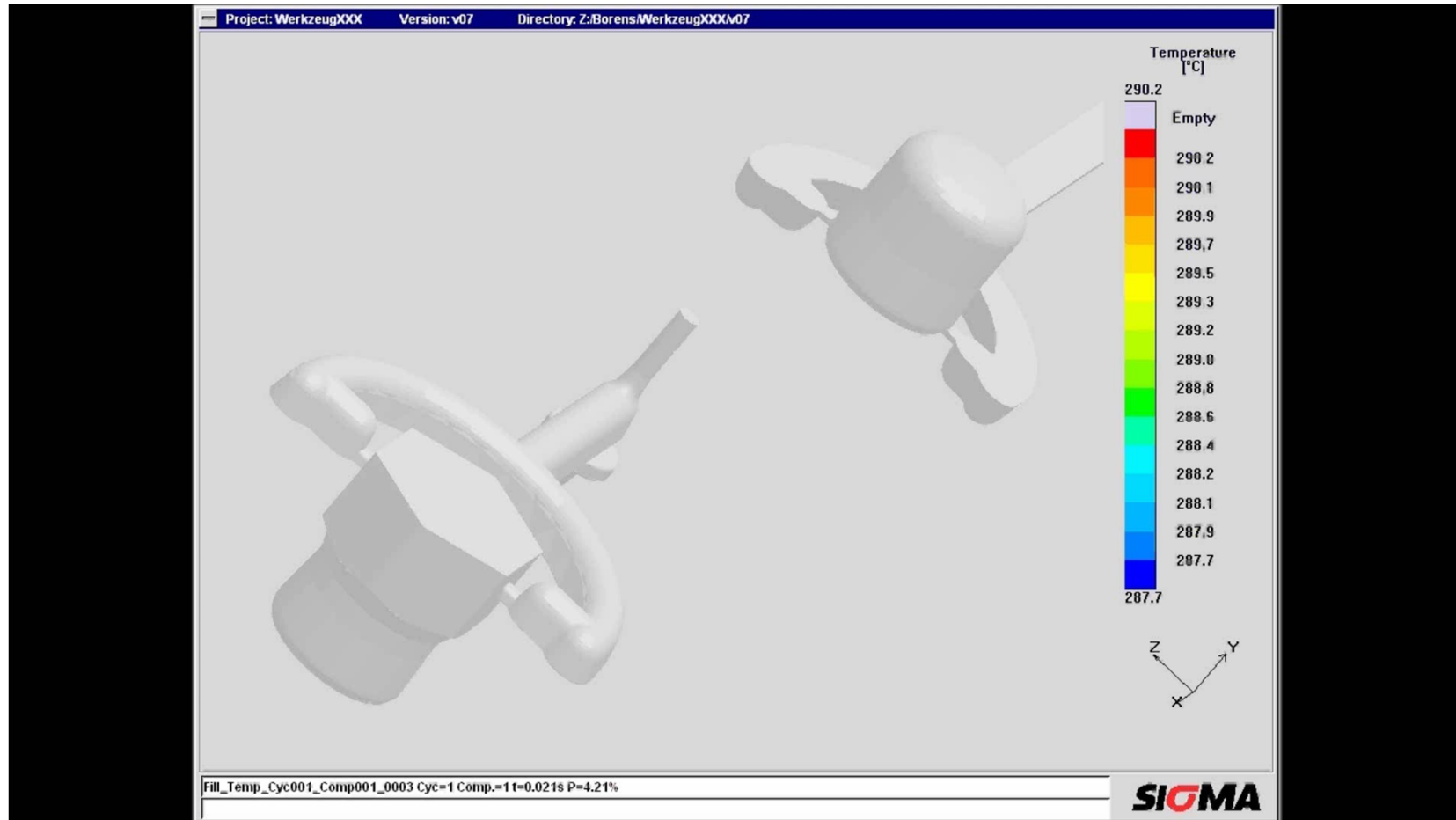
SEM Microstructure tungsten powder W2

Doped tungsten powders
(producing via wet milling for 2 h):

W-2La₂O₃

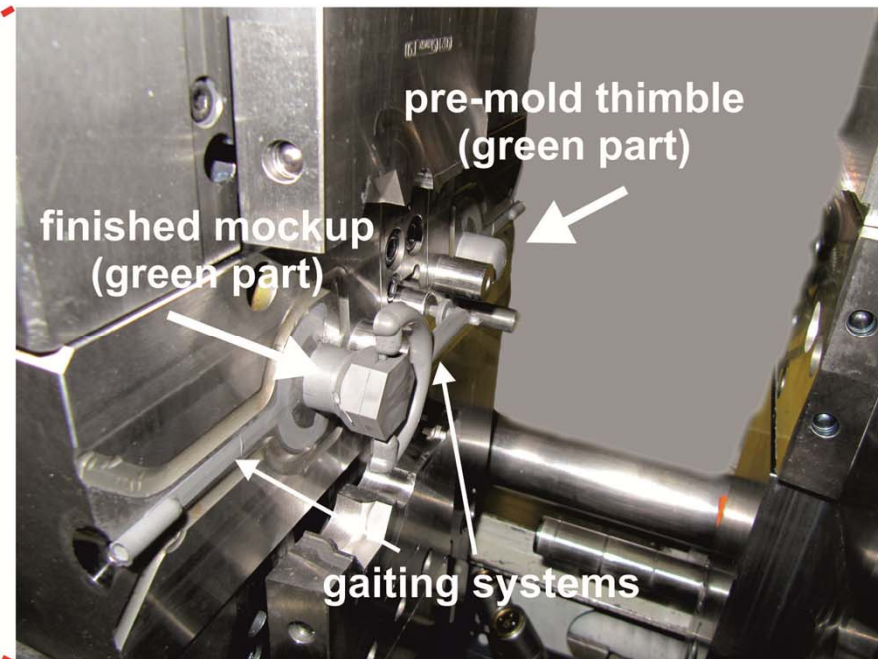
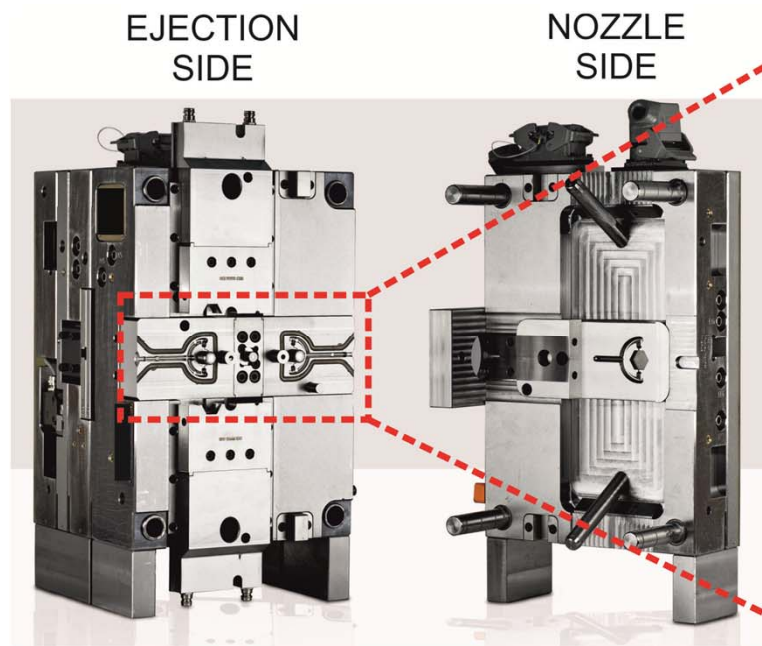
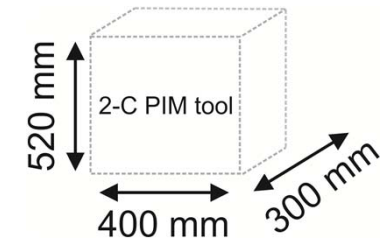
W-2Y₂O₃

The PIM process for tungsten developed @ KIT ...filling simulation...

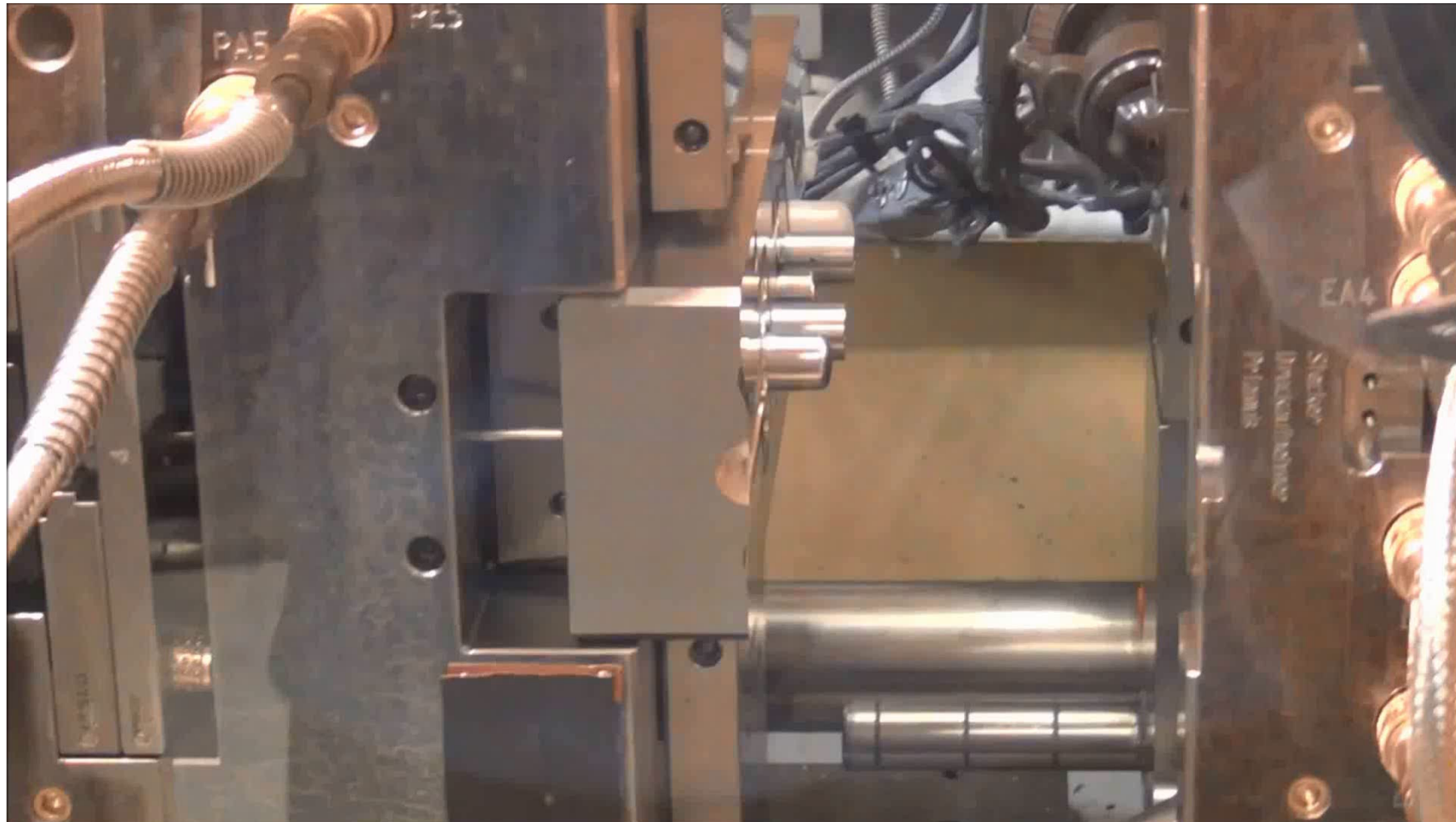


Production of multicomponent W PIM divertor parts ...the new fully automatic PIM tool...

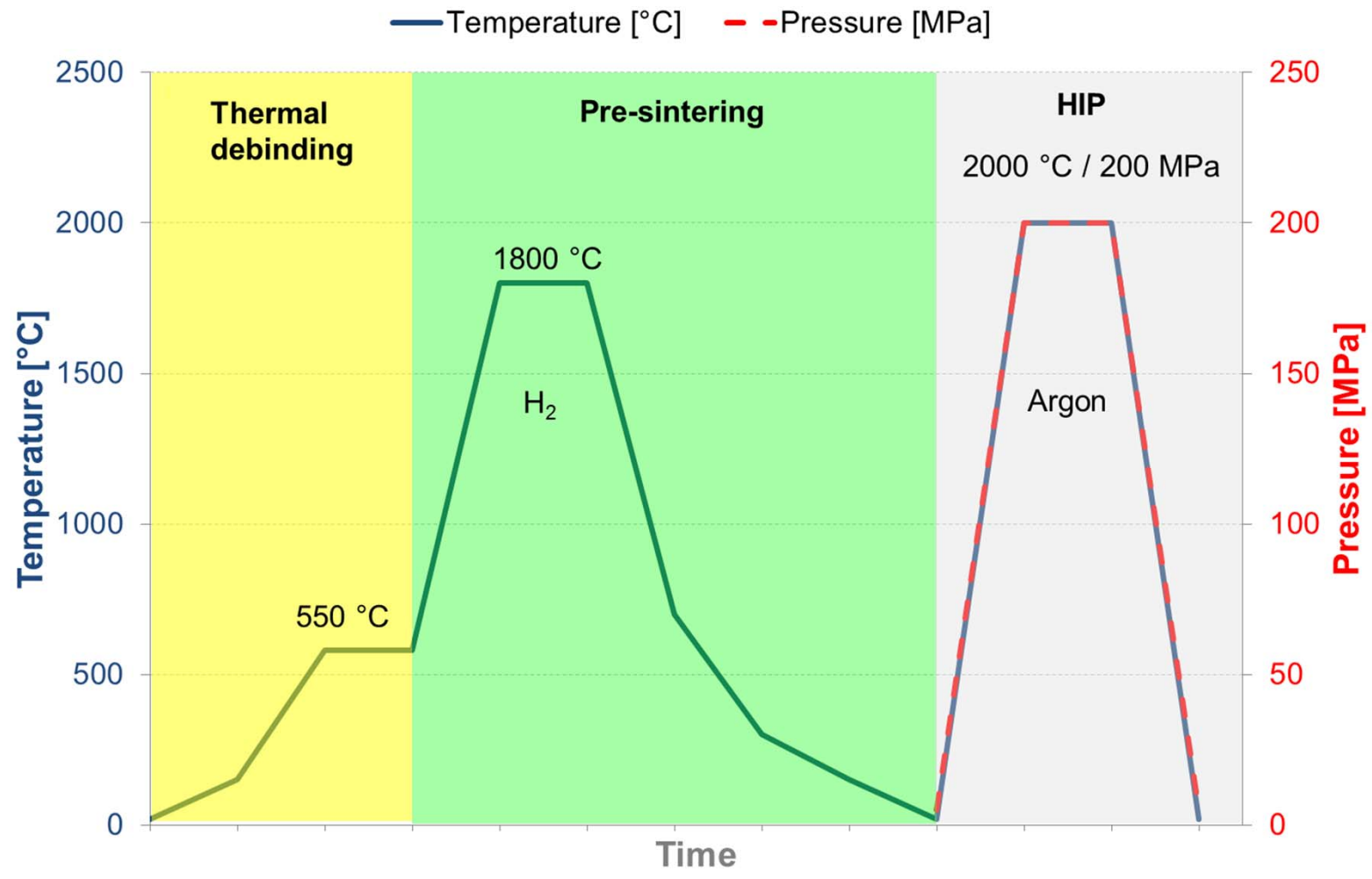
Fully automatic mass production:
50 SECONDS for 1 Part



Production of multicomponent W PIM divertor parts ...the new fully automatic PIM tool...



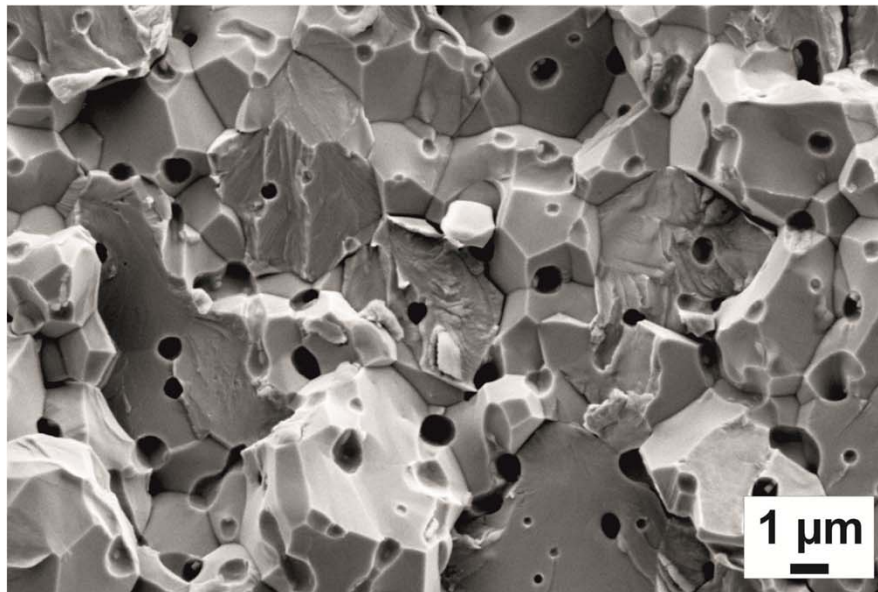
Production of multicomponent W PIM divertor parts ...the heat-treatment process...



Production of multicomponent W PIM divertor parts

...the heat-treatment process...

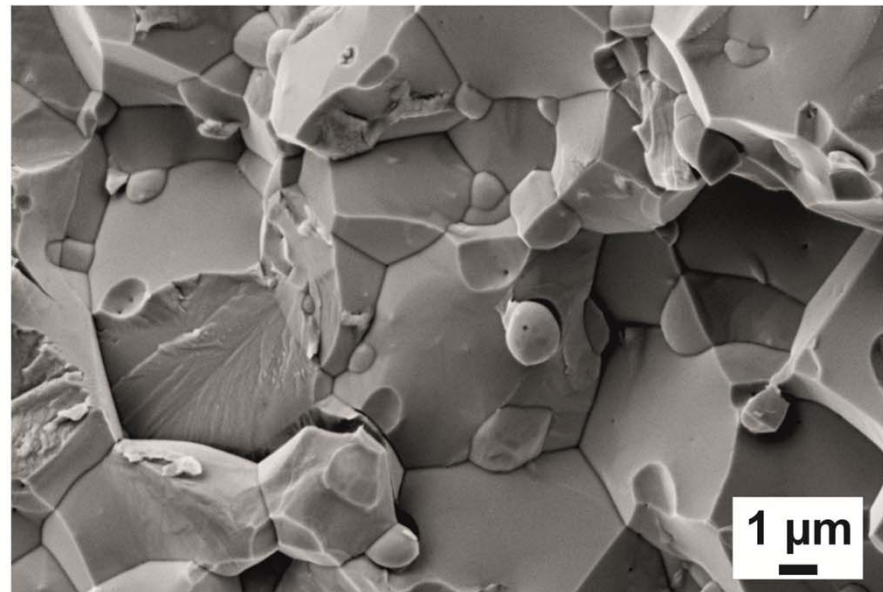
pre-sintering



SEM Microstructure pre-sintering W

Density >95% - closed porosity!!!
Vickers-hardness 420 HV0.1

pre-sintering + HIP



SEM Microstructure pre-sintering + HIP W

Density >98%
Vickers-hardness 457 HV0.1

S. Antusch et al., J. Nucl. Mater. 417 (2011) 533-535.

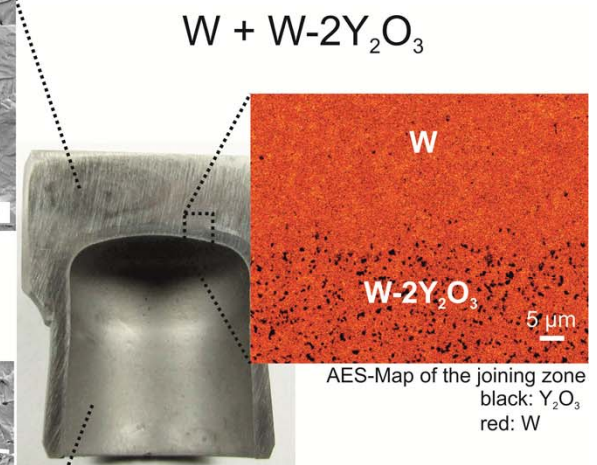
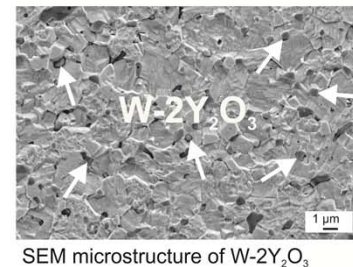
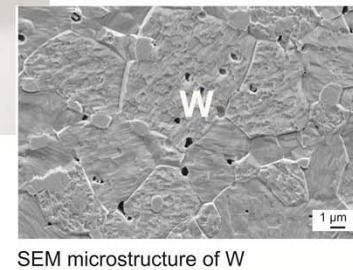
Production of multicomponent W PIM diverter parts



Production of multicomponent W PIM divertor parts



Joining without brazing



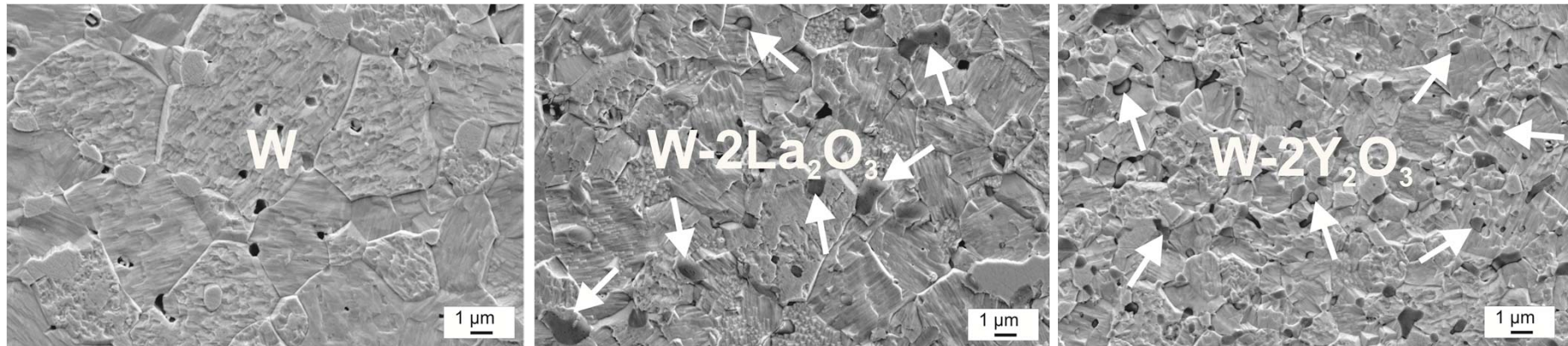
→ High quality of the joint

→ Material joining successful

→ No gaps or cracks in the seam of the joining zone

S. Antusch et al., J. of Fusion Engineering and Design (2013).

Production of multicomponent W PIM divertor parts



SEM Microstructure

Material	Theoretical density (% TD)	Vickers-hardness (HV0.1)	Grain size (μm)
W	98.6 - 99.0	457	5 - 7
W-2La ₂ O ₃	98.5 - 98.9	588	>3
W-2Y ₂ O ₃	98.3 - 98.7	619	<3

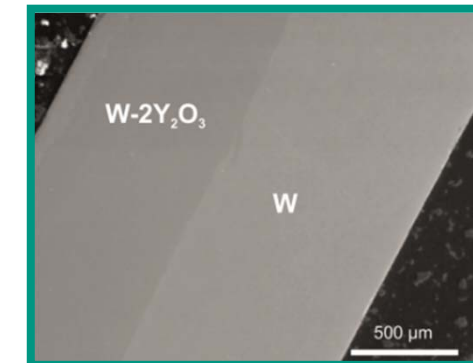
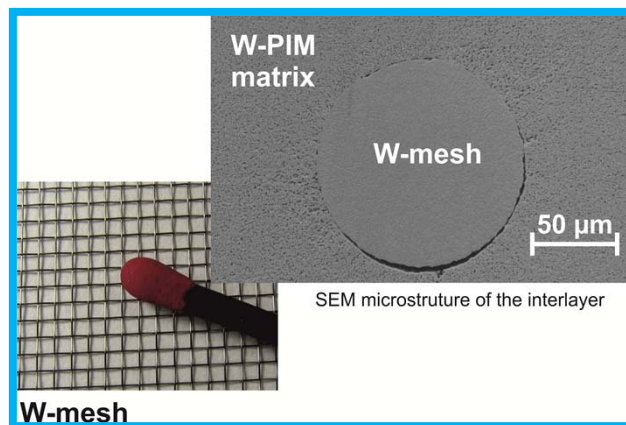
Summary & Outlook

Multicomponent Powder Injection Molding = Mass production & joining process



→ Time & cost effective near-net shape forming process

→ Shape complexity & high final density



→ Joining technique

- Ideal tool for scientific investigations:
- Rapid development of new materials
 - Investigation of properties



PL FUSION



THANK YOU VERY MUCH!

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