

Metal Injection Moulding of refractory metals

High performance
components

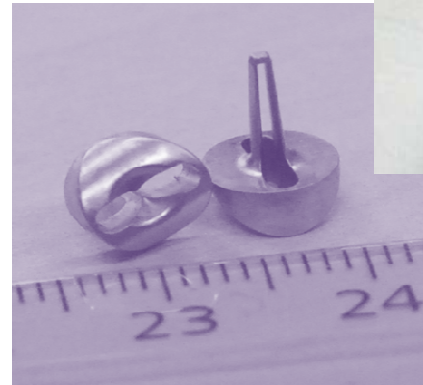
Eindhoven
28/11/2012

Jan Opschoor, M T & A

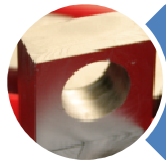
www.ecn.nl

Product portfolio

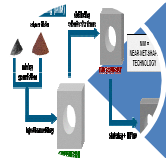
- Refractory metals: e.g. W, Mo, alloys (W 1%Yttria)
- Stainless steel
- Small components, 3D shapes
- Intricate details, complexity
- Dimensional control: 0.3%



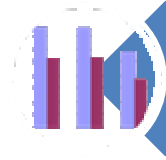
Overview



Why high performance components by MIM



MIM: the process

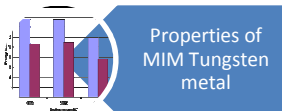


Properties of MIM Tungsten metal



Applications

Why high performance components by MIM: the product

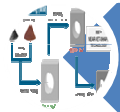


- Isotropic properties and microstructure → homogeneity
- Ultra high purity materials → homogeneity and predictability
- Free from re-crystallization and recovery → reliability
- Improved properties by unique alloying/doping → performance and predictability
- Free Shaping, avoiding machining → reliability and performance
- MIM technology, having tight control on geometry and appropriate for high volume production → reliability

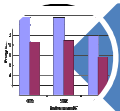
Why high performance components by MIM: the process



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal



Applications

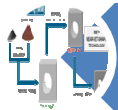
Advantages MIM process

- ➔ Less contamination
- ➔ Less energy consumption
- ➔ Less loss of material
- ➔ Less process steps

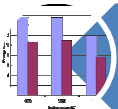
Net shaped components



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal



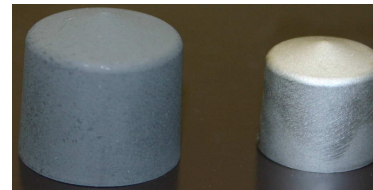
Applications



Green & as sintered
Standard Charpy
test sample



As sintered
Standard Tensile
test sample



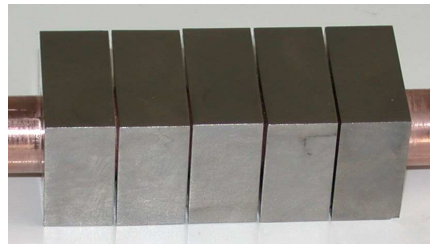
Green & as sintered
thimble for HEMJ divertor
design



Internal voids e.g. cooling
channels possible



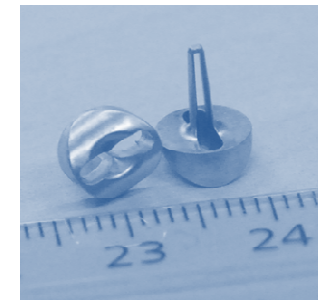
Mockup manufactured
By Ansaldo



As sintered monoblocks and mock up
for ITER divertor target



As sintered bolts

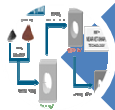


Fine structures
possible

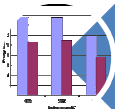
2K component for nuclear fusion application



Why high performance components by MIM



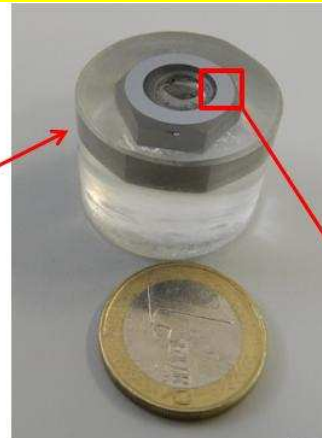
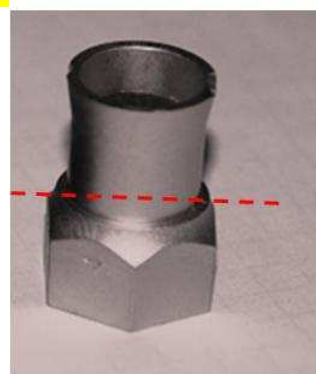
MIM: the process



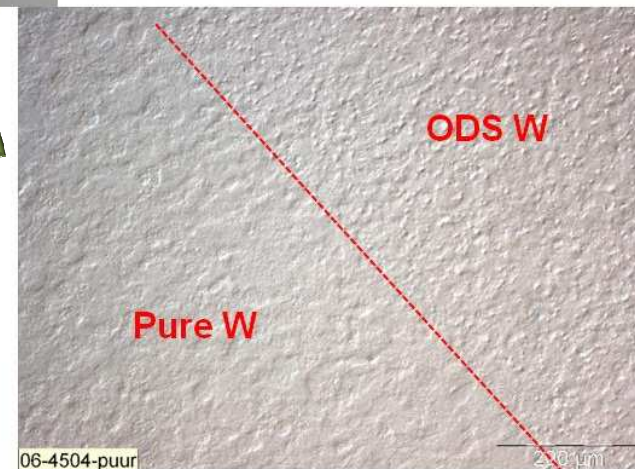
Properties of MIM Tungsten metal



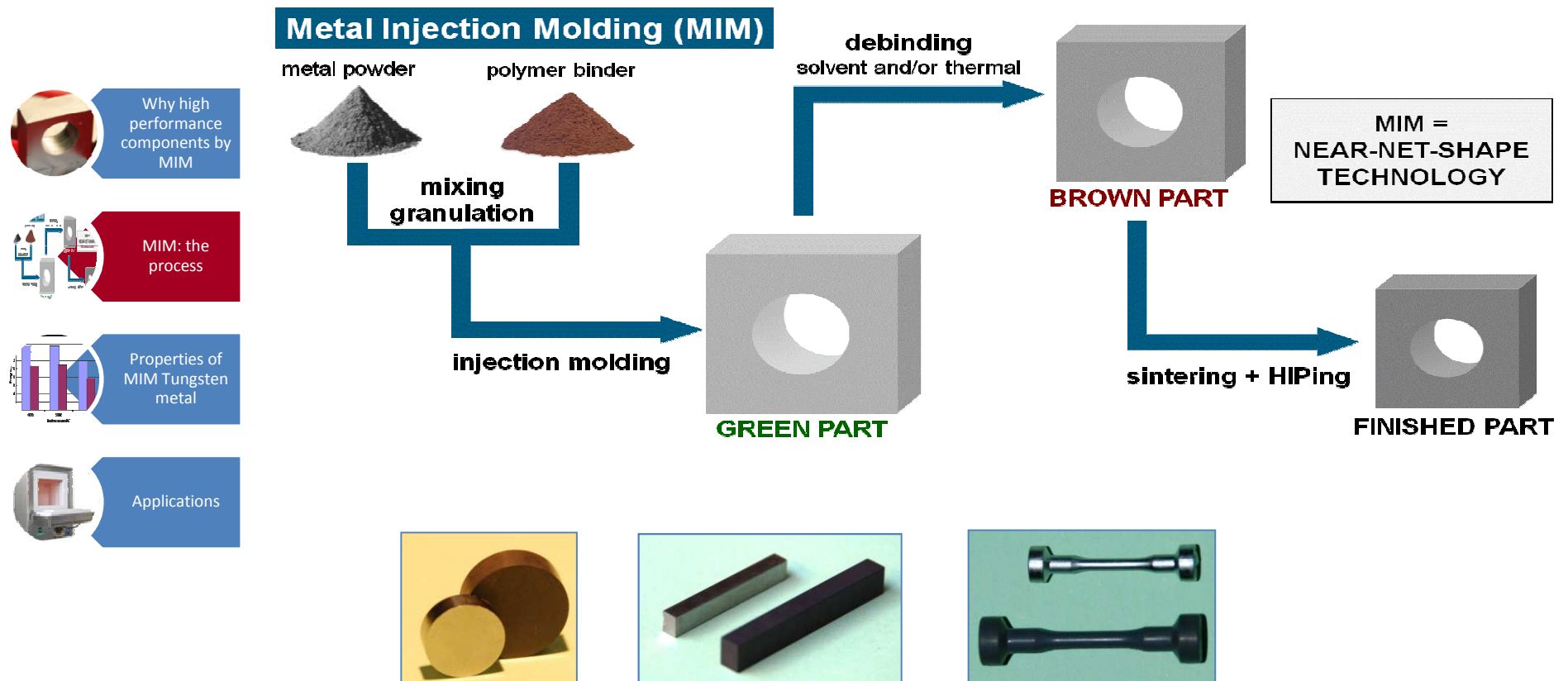
Applications



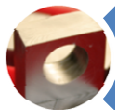
Pure $\leftrightarrow$ 1% Y_2O_3



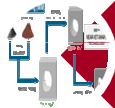
MIM: the process (1)



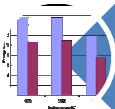
MIM: the process (2)



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal



Applications



Powder & Binder mixing



Sintering to end density



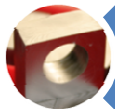
Metal injection molding



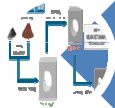
Pre-sintering



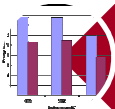
Fine and homogeneous microstructure



Why high performance components by MIM



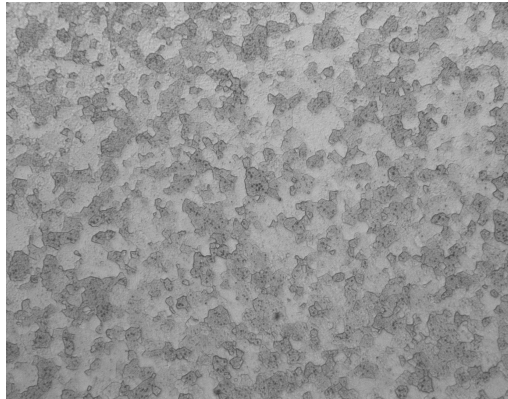
MIM: the process



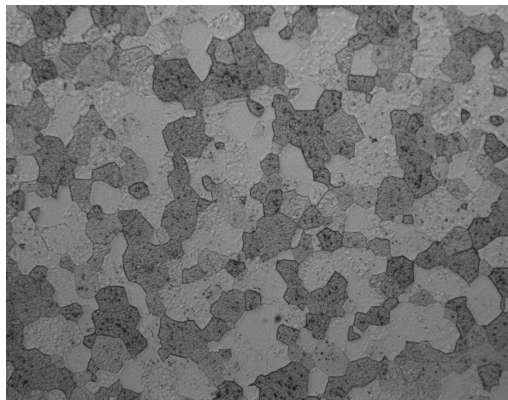
Properties of MIM Tungsten metal



Applications

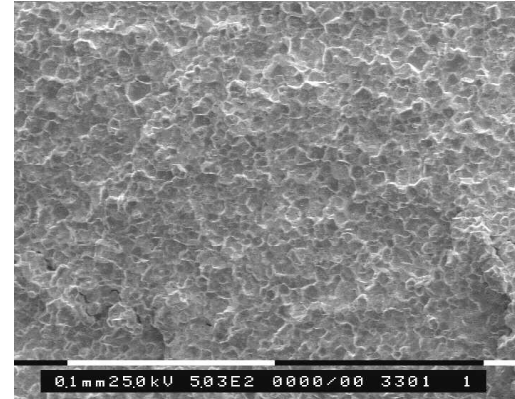


Microstructure Grade A

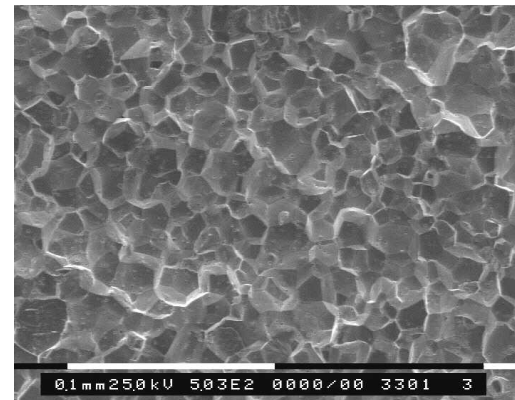


Avg. grain size
5 – 10 micron

Avg. grain size
10 – 20 micron



Fracture Grade A



High temperature tensile tests

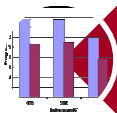
high purity tungsten



Why high performance components by MIM



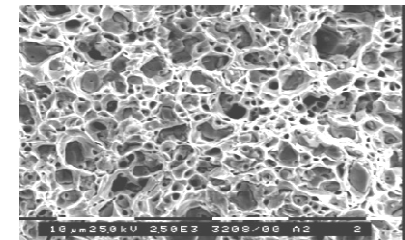
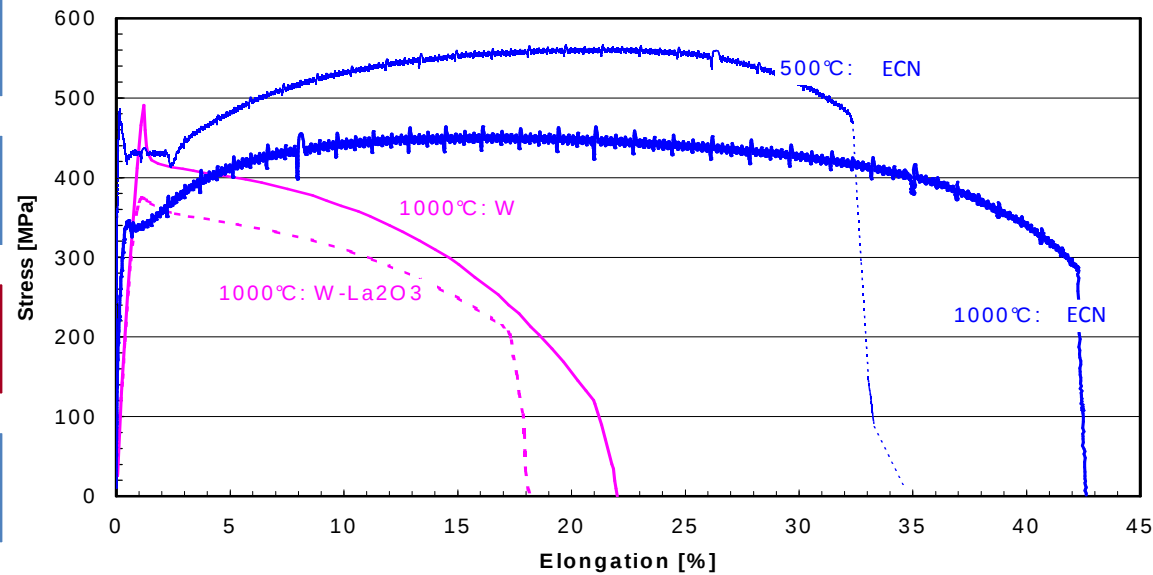
MIM: the process



Properties of MIM Tungsten metal



Applications



Fracture at 500 °C

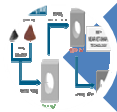
High temperature tensile tests show good high temperature strength, plasticity, and ductility.

HT Bending and Charpy tests

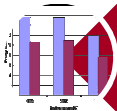
high purity Tungsten



Why high performance components by MIM



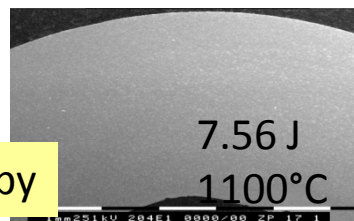
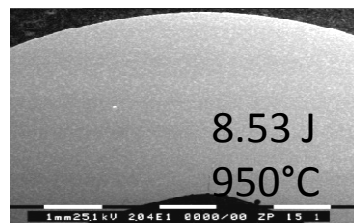
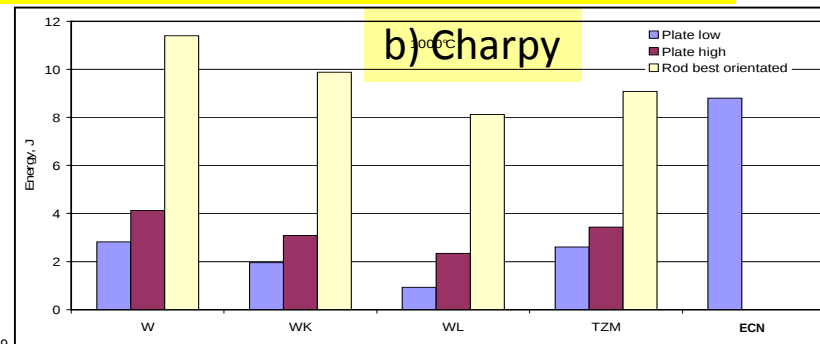
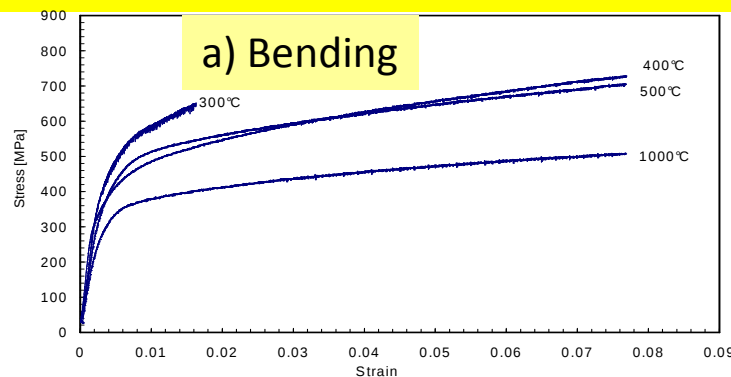
MIM: the process



Properties of MIM Tungsten metal



Applications



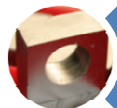
c) Charpy

- a) High temperature bending showing a high energy level and a DBTT between 300 and 400°C
- b) MiM-ed product having higher fracture energy than W plates investigated, performing as good as the rod along the best orientation.
- c) High impact energy of >7.5 J measured, and secondary and curved crack propagation found.

Charpy tests performed by M.Rieth, FZK

High heat flux testing (1)

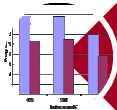
reference



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal

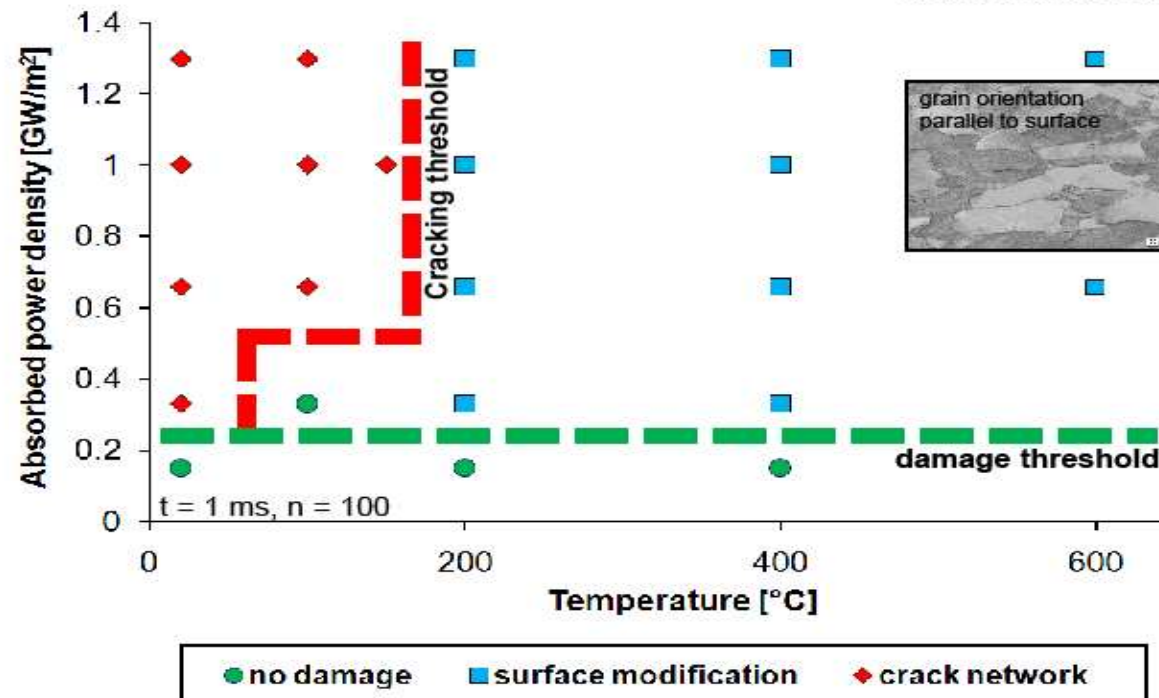


Applications

Thermal shock results: double forged tungsten

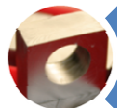


electron absorption coefficient: 0.46



High heat flux testing (2)

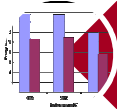
1% Yttria (ODS) doped



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal

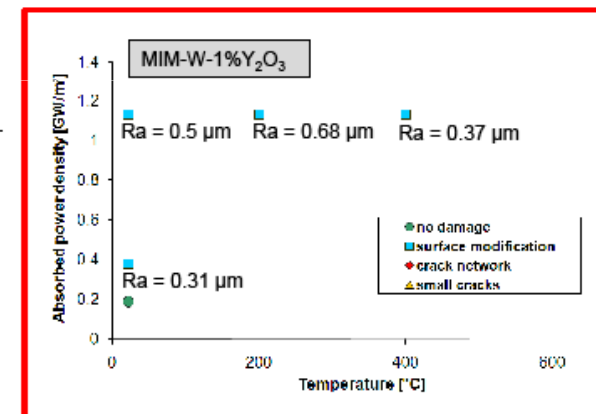
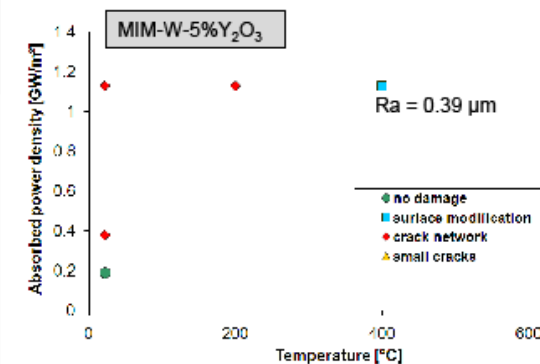
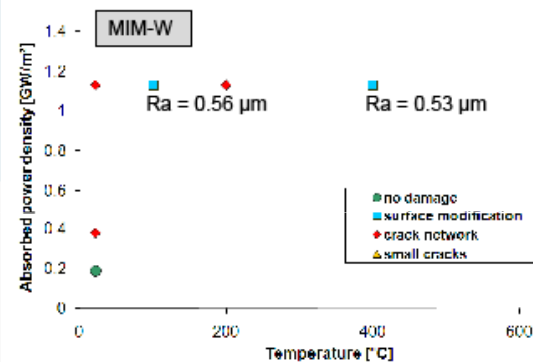


Applications

Thermal shock results: MIM-W and W-alloys

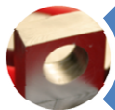


Ra (original surface) = 0.06-0.09 μm



Superior behavior of MIM-1%Y₂O₃!

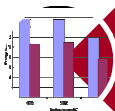
High purity



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal



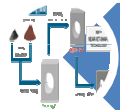
Applications

$\mu\text{g/g}$	Al	Cr	Cu	Fe	K	Mo	Ni	Si	C
ITER spec	<15	<10	<10	<30	<10	<100	<20	<20	<30
ECN	<1	<3	<1	9	<3	22	<3	<10	<5
Technique	ICP-MS								Leco

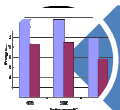
Applications (1)



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal



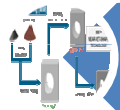
Applications

- Nuclear fusion (ITER): divertor and first wall components
- Lighting market: electrodes, lead-through's, supports
- Medical: X-ray tubes, rotary anode, co-ablation, electrodes
- Glass and ceramic making industries: Ir, Re, Mo, W,
- Metal forming industries: tools, e.g. dies

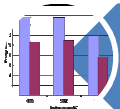
Applications (2)



Why high performance components by MIM



MIM: the process



Properties of MIM Tungsten metal



Applications

- Furnace industry:
 - Heating components, reflectors, structural material
- Electronics and electrical industry:
 - Cathodes in X-ray tubes, electron tubes etc.
 - Ultra high purity sputtering targets
 - Ultra high purity Mo-W alloy sputtering targets (LCD panels)

Conclusion

Metal Injection Moulding is a new alternative for the production of high quality refractory metal components

Thanks for your attention

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