Comparison of the thermal shock performance of different tungsten grades and the influence of microstructure on the damage behaviour

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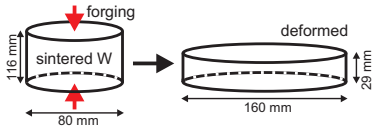
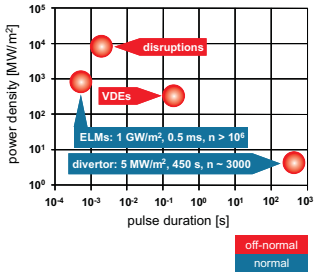
Introduction

Tungsten grades and manufacturing process:

- W-UHP (purity 99.9999 weight%)
- WTa1 (1 weight% of Ta)
- WTa5 (5 weight% of Ta)



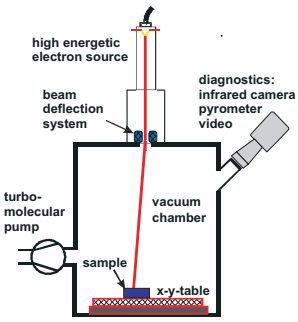
- sintered at 2000 - 2500°C
- thermo-mechanical treatment at 1600°C
- finally stress relived for 2 hours at 1000°C



Electron beam facility JUDITH 1

layout data:
- total power: 60 kW
- acceleration voltage: ≤ 150 kV
- max. loaded area: 100 x 100 mm²
- scanning frequency: ≤ 100 kHz
- pulse duration: 1 ms ... continuous

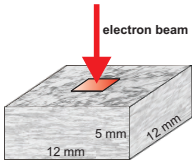
diagnostics:
- one-colour fast pyrometer 500 ... 2500°C
- IR camera system RT ... 2000°C
- video camera



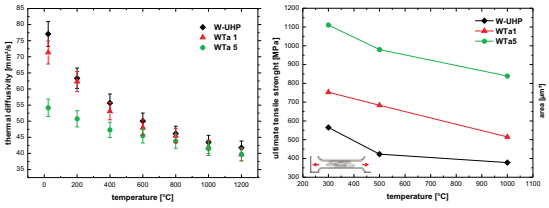
Experiments & Results

Experimental settings:

sample size:	12 x 12 x 5 mm³
loaded area:	4 x 4 mm²
base temperature:	RT up to 600ºC
power densities:	0.16 up to 1.27 GW/m²



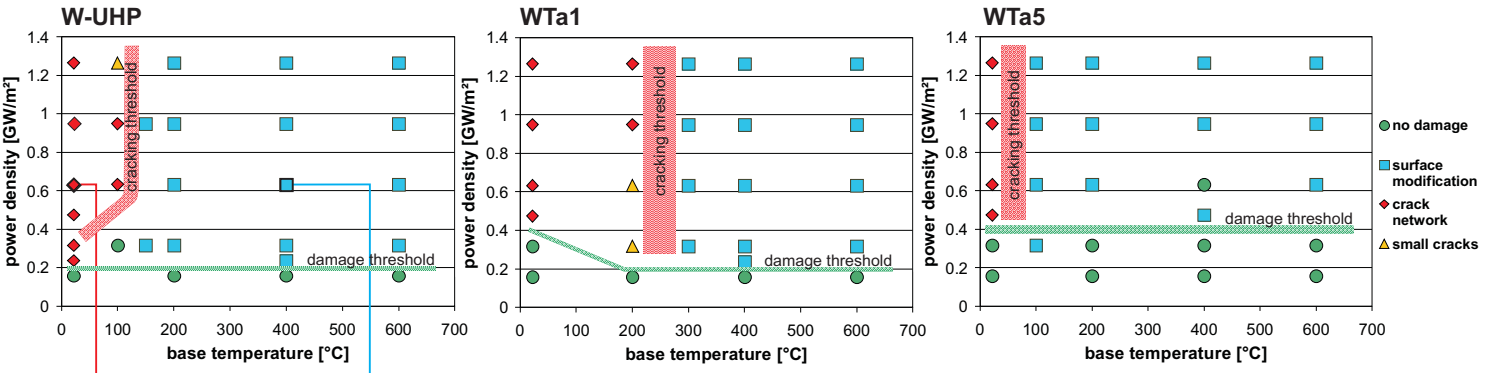
Microstructure and material properties:

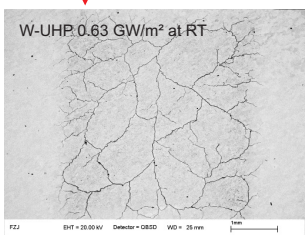


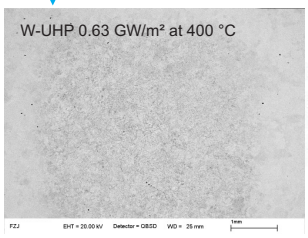
	aspect ratio (a/b)	
	cross section	top view
W-UHP	0.28	0.8
WTa1	0.23	0.54
WTa5	0.19	0.65

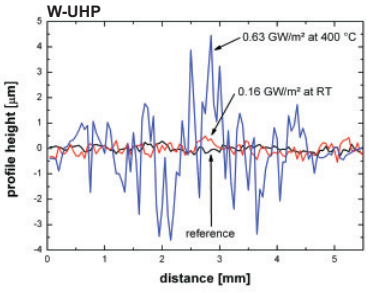
CS = cross section TV = top view

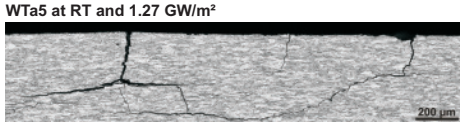
Thermal shock tests: 100 cycles with a duration of 1 ms; absorption coefficient : 0.46



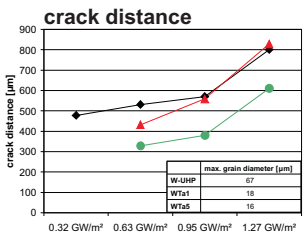






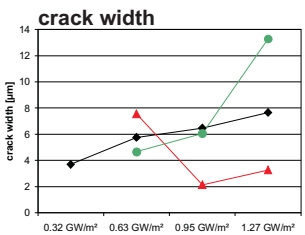


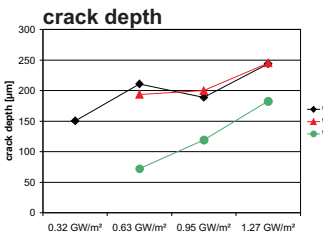
Investigation of crack networks at RT:



	max. grain diameter [µm]
W-UHP	67
WTa1	18
WTa5	16

- increase of crack distance, width and depth
- no relationship between grain size and crack distance
- temperature dependence of mechanical properties influences the crack density
- broad distribution of crack width
- clear correlation between thermal diffusivity and crack penetration depth





Conclusion

- determination of damage and cracking thresholds for the tested materials are only valid for 100 cycles
- below 0.16 GW/m² none of the tested tungsten grades shows any material damages or surface modifications
- WTa5 has the best tensile strength → the damage threshold is significantly higher than for the other materials
- temperature dependence of the mechanical properties during a thermal shock pulse might be the reason for the decrease of crack density with increasing power density
- thermal properties and grain orientation have a significant influence on the crack penetration depth and pattern

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