ZrC development status –
Material data and operational behavior

Fraunhofer **IKTS**

Parameter	Value	Unit	Aspect of application
Density (theoretical)	6.73	$g \cdot cm^{-3}$	
Density (sintered)	6.63	$g \cdot cm^{-3}$	98.5 % of theoretical density, practically completely dense from ceramist view
Open porosity	0.05	vol%	Significant interaction with surrounding atmosphere only by surface
Melting point ZrC	3532	°C	Refractory material with higher melting temperature than tungsten (3422 °C)
4-point flexural strength / room temperature	**350-450**	MPa	Frequently found strength value of ceramics (like SiC)
4-point flexural strength / 1400 °C	150-230	MPa	High strength level at high temperatures, decreasing strength with increasing temperature
4-point flexural strength **after ageing** at 1900 °C measured at room temperature	**350-450**	MPa	No decrease of strength by ageing
Fracture toughness	4	$MPa \cdot m^{1/2}$	Similar with SiC
Young's modulus / room temperature	410	GPa	High stiffness, like SiC
CTE / room temperature	5.4	$10^{-6} \cdot K^{-1}$	
CTE / 2000 °C	7.1	$10^{-6} \cdot K^{-1}$	
Spec. electrical resistance / room temperature	$6.8 \cdot 10^{-5}$	Ωcm	Metall-like electrical resistance
Spec. electrical resistance / **2000 °C**	**$2.1 \cdot 10^{-4}$**	Ωcm	Moderate positive temperature coefficient
Thermal conductivity / room temperature	31	$W \cdot (mK)^{-1}$	Moderate thermal conductivity like Al_2O_3 or Si_3N_4
Thermal conductivity / 2000 °C	38	$W \cdot (mK)^{-1}$	Moderate increase of thermal conductivity
Spec. heat capacity / room temperature	0.355	$J \cdot (gK)^{-1}$	
Spec. heat capacity / 2000 °C	0.490	$J \cdot (gK)^{-1}$	

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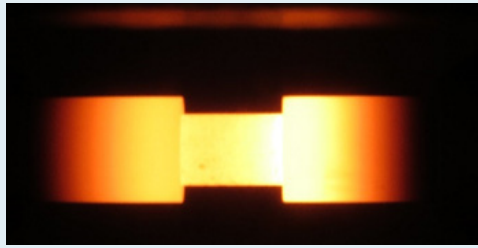hans-peter.martin@ikts.fraunhofer.de

Practical tests

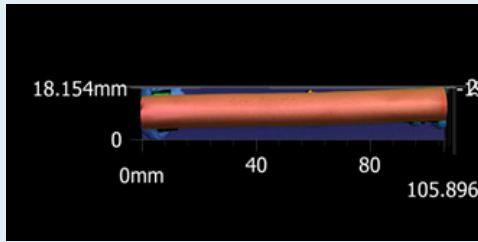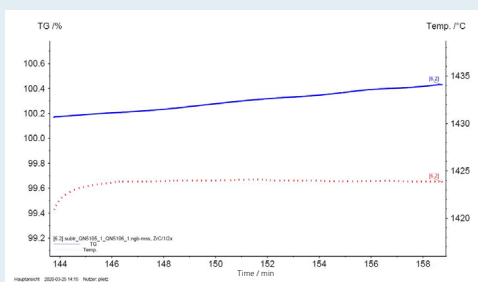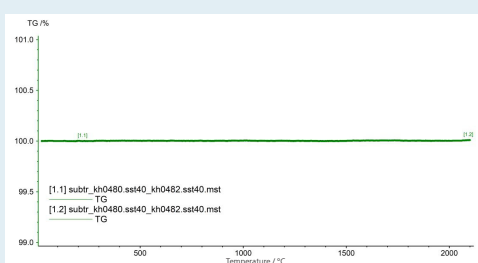| Description of testing	Illustration	Result
Mechanical loading at high temperatures, SPS / 10 **kN** load up to 1900 °C, ZrC specimen between two graphite punches, detection of the length of move of the graphite punch		Move of punch 0.7 mm
Mechanical loading at high temperatures in high vacuum test stand at 2000 °C, approx. 200 kg load generated by pneumatic cylinders for 50 h dwell time with load and temperature		Found bending 0.5 mm
Thermogravimetric measurement during annealing procedure under hydrogen up to 1400 °C		Small but permanent mass gain up to 1400 °C (0.4 %) during 3 h
Thermogravimetric measurement during annealing procedure under vacuum at 2100 °C		Constant mass, no mass change detected
High-vacuum, high-temperature test stand with ZrC heating element		Vacuum pressure 10^{-6} mbar (the same as at room temperature) at 2200 °C

Experimental data of ZrC heating elements at 2000 °C

- Electrical power > 2000 W
- Electrical current density 14-22 A·mm^{-2}
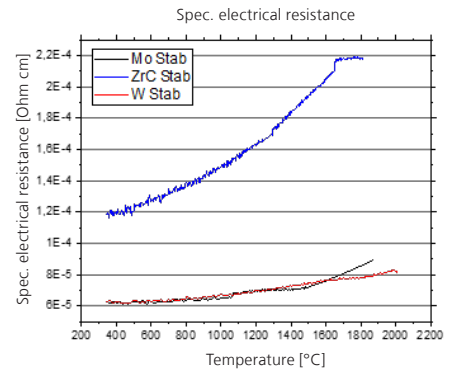- Power load on surface 60-180 W·cm^{-2}
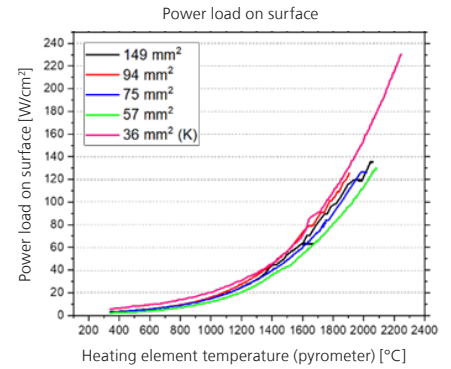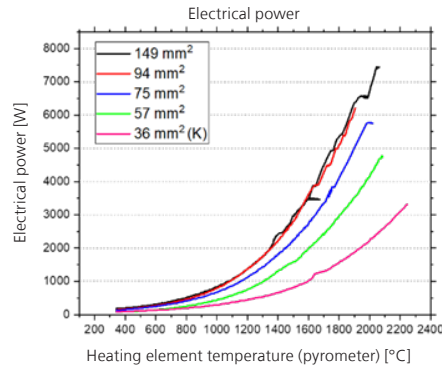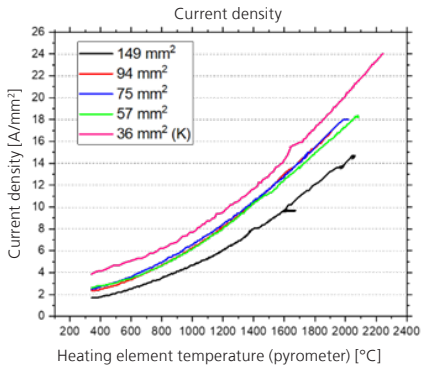
## Comparision with other materials used for heating elements up to 1800 °C
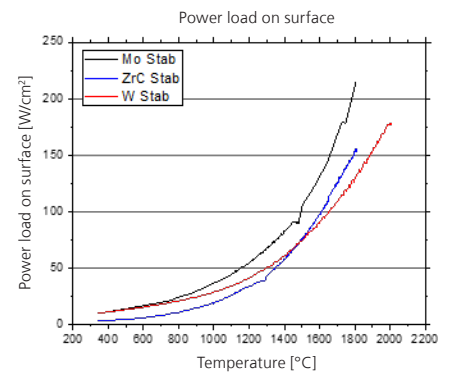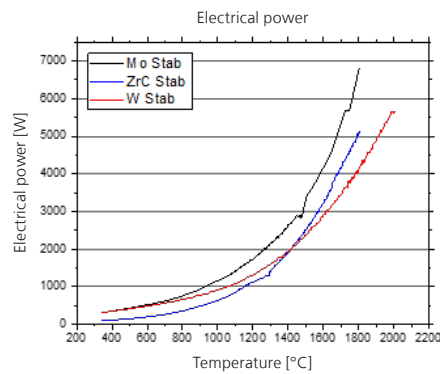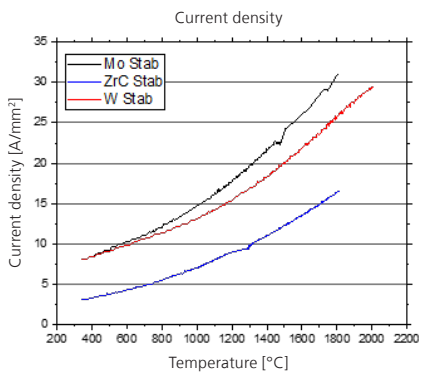
Data of heating elements at 1800 °C	Tungsten	Molybde-num*	ZrC
Spec. electrical resistance [Ω*cm]	7.83E-5	8.56E-5	2.18E-5
Power [W]	4118	6731	5062
Currency density [A/mm²]	25.7	30.9	16.4
Power load on surface [W cm²]	129	212	153

*Molybdenum is only mechanically stable up to 1800 °C

Technology orientated specimen

Sintered ZrC shapes
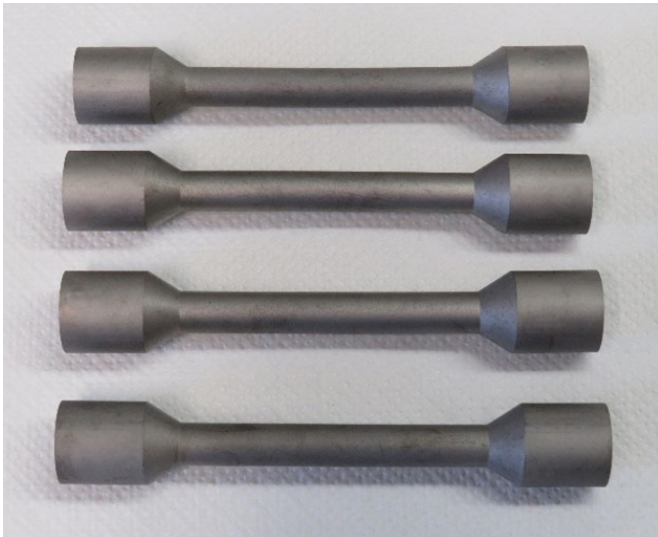
Cu rings as electrical contacts of ZrC products