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Temperature Sensors and Heater Plate Materials Suitable for Use in High-Temperature Guarded Hot Plate

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Temperature Sensors

Requirements and limitations

- High accuracy, precision and long-term stability at upper temperature limit of HTGHP (850 °C)
- Minimal disruption of desired temperature profile in HTGHP
- Limited diameter of sensor - maximum thermocouple sheath diameter = 2 mm (CEN/TS 15548-1:2011)

-> Thermocouples

Possible placement

- Heater plates – grooves or boreholes
- Inside specimen

Thermocouple types covering the HTGHP temperature range

Base metal thermocouples

- Type K (Chromel-Alumel)
- **Type N** (Nicrosil-Nisil), better stability than Type K

Noble metal thermocouples

- **Type R** (PtRh (13% Rh)/Pt)
- **Type S** (PtRh (10% Rh)/Pt)
- Type B (PtRh (30% Rh)/PtRh (6% Rh)) (t > 250 °C)
- Au/Pt
- Pt/Pd

Thermoelectric voltages, sensitivities and class 1 tolerances at 850 °C for selected thermocouple types (EN 60584)

Thermocouple	Thermoelectric voltage (µV)	Sensitivity (µV/°C)	Class 1 tolerance (°C)
Type K	35313.1	40.5	±3.4
Type N	30415.6	39.2	±3.4
Type R	8571.4	12.6	±1
Type S	7892.7	11.0	±1

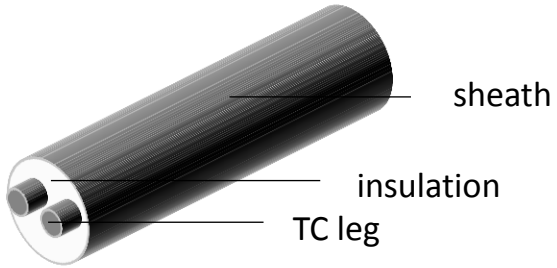
MIMS thermocouples

Mineral Insulated Metal Sheathed thermocouples

- small diameters available (e.g. 1, 1.5 mm)
- TC legs insulated
- TC legs sheathed from possible contaminants
- can be bent

Long-term stability influences

- thermocouple type
- insulation
- sheath material + number of sheath layers
- diameter of sheath



Calibration

- Large number of temperature sensors -> time consuming calibration
- Period of calibration?
- Period of replacing temperature sensors?
- Detection of temperature sensor drift?
- Batch agreement for thermocouples
- In-situ x External

- CEN/TS 15548-1, Requiered accuracy in the measurement of temperature difference between heating and cooling unit 1 %

Heater Plate Materials

Requirements

- High thermal conductivity -> temperature uniformity across the plate surface
- Stability at high temperature
- Resistance to oxidation (or resistace to further oxidation once thin oxidation film is formed)
- Maintenance of flatness (resistance to warping) under high-temperature operational conditions and repeated cycling from the room temperature to the highest designed temperature of HTGHP

Heater Plate Materials

Other properties to consider

- Mechanical properties (elasticity, stiffness)
- Electrical resistance
- Thermal expansion of material (with regard to other heater plate components)
- Good machinability (when plates are manufactured by machining)
- Opacity
- Emissivity
- Price (material, manufacturing of heater plate)

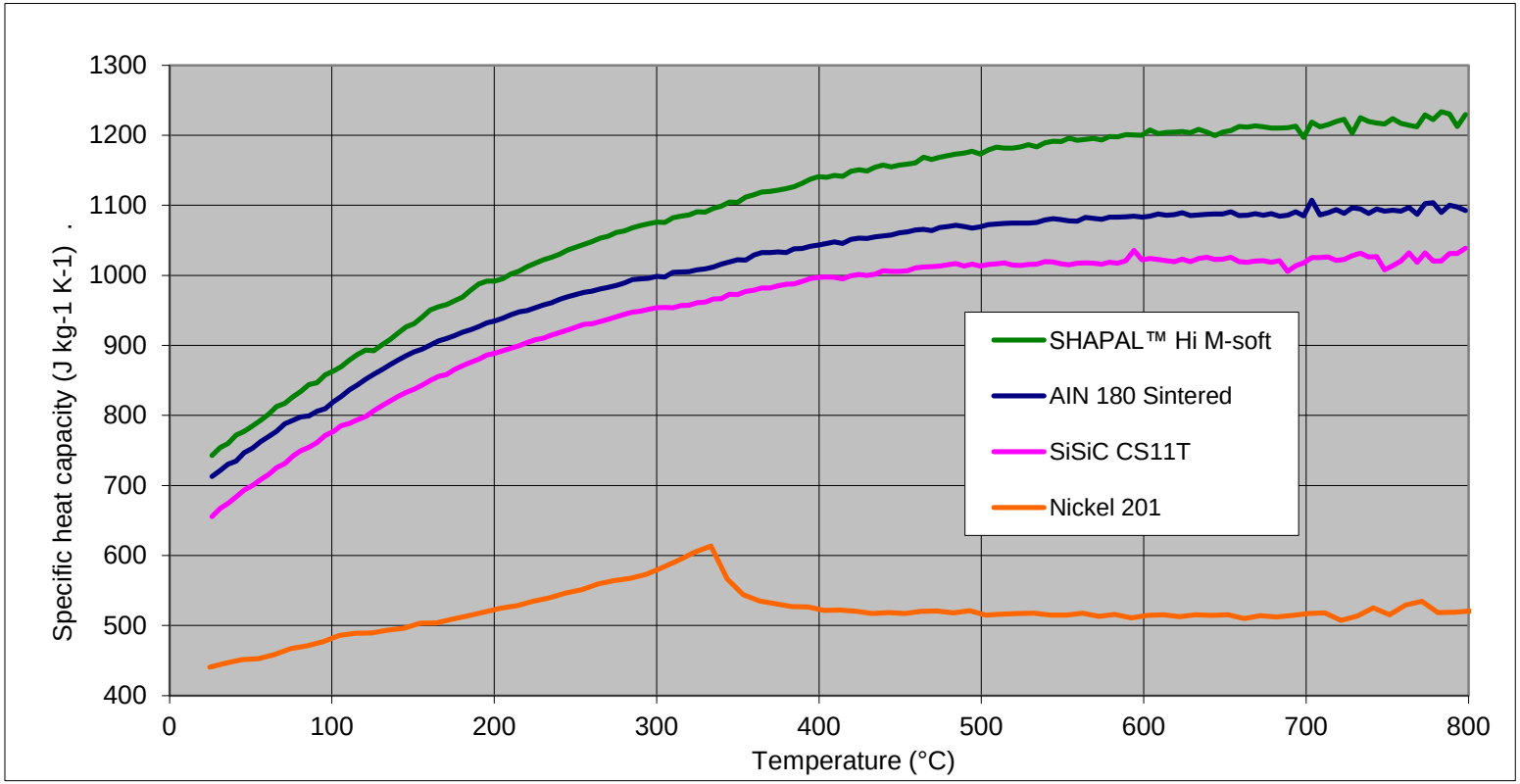
Heater Plate Materials

Overview of some potential materials

Material	Thermal conductivity	Metalic
Aluminium Nitride	+	×
Boron Nitride	-	×
Silicon Carbide	+	×
Tungsten alloy	+	✓
Nickel 201	+	✓
Inconel	-	✓
Stainless Steel	-	✓

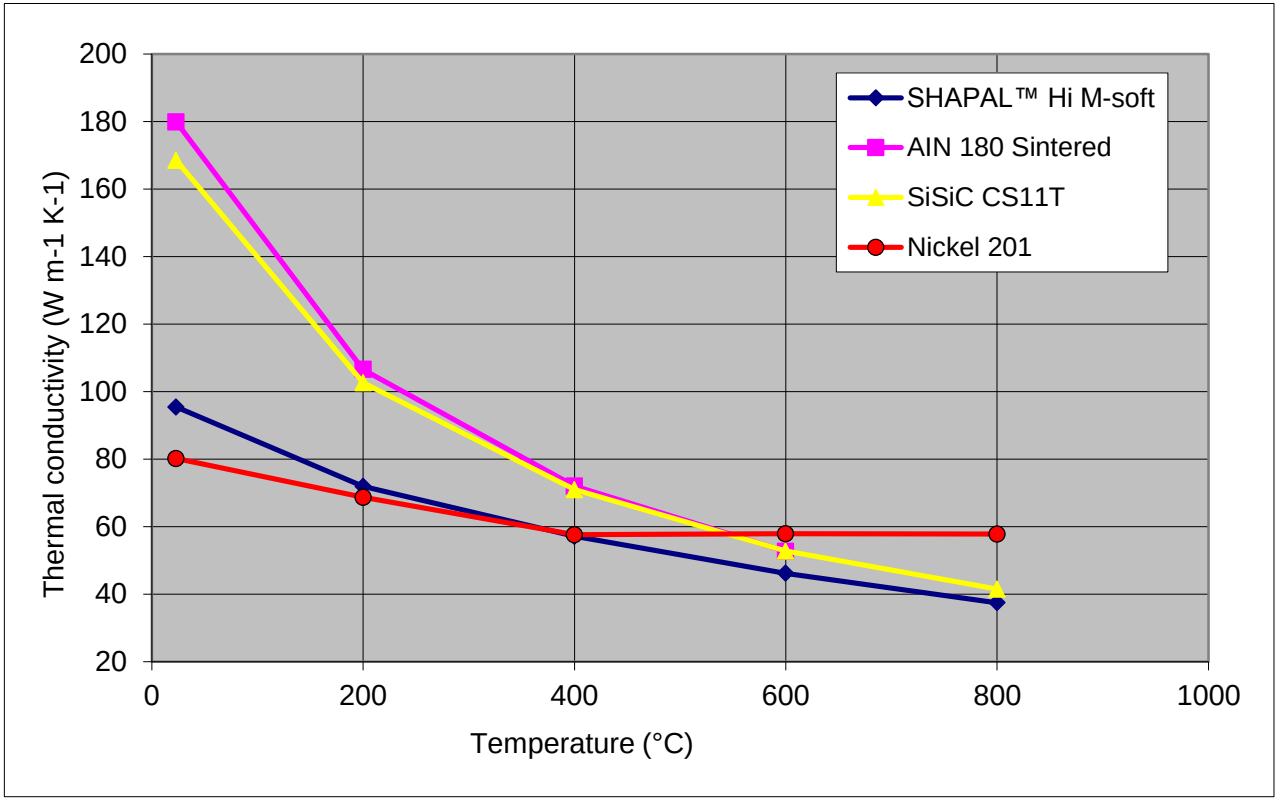
Heater Plate Materials

Properties of selected materials measured at LNE
Specific Heat Capacity (DSC calorimetry)



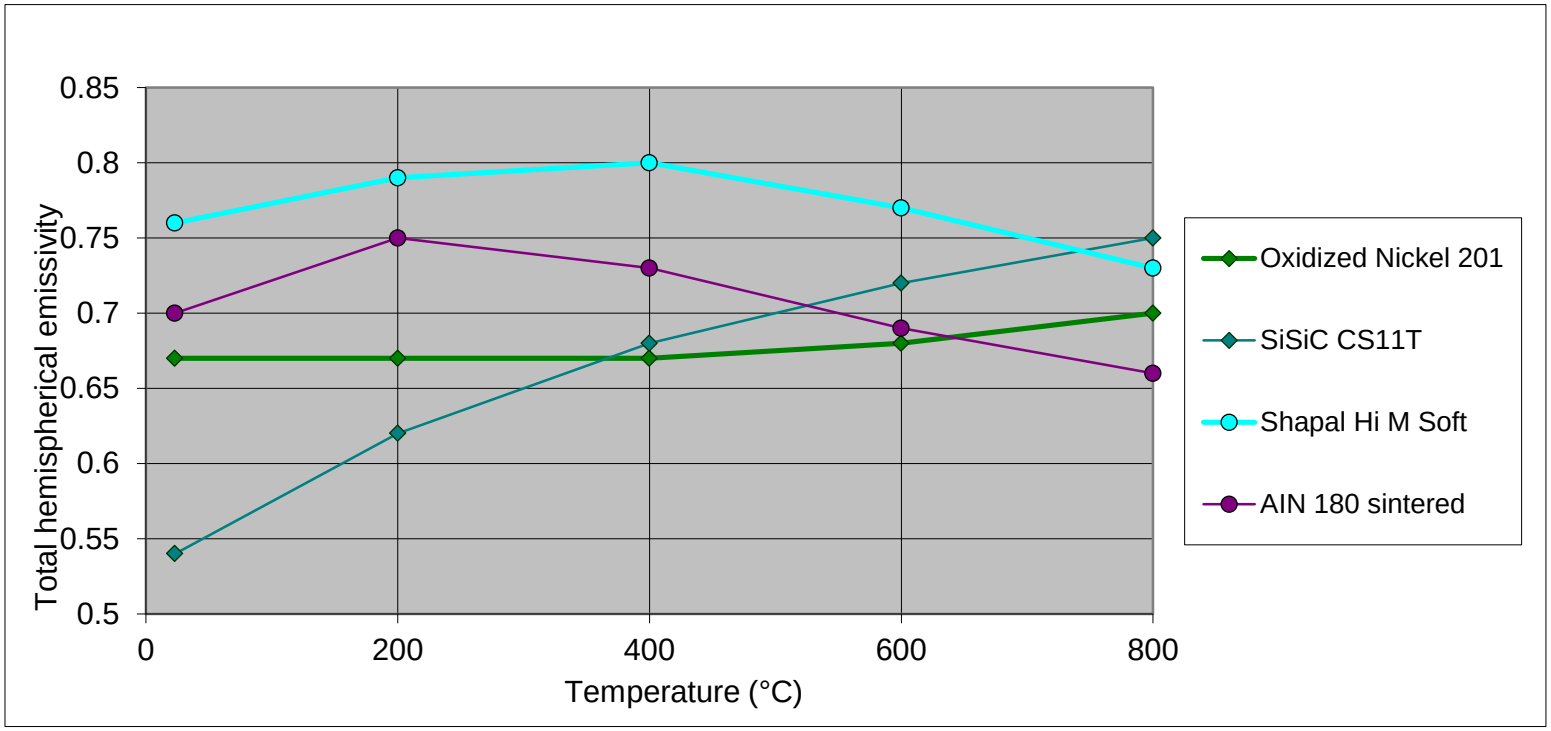
Heater Plate Materials

Properties of selected materials measured at LNE
Thermal conductivity (calculated from thermal diffusivity results)



Heater Plate Materials

Properties of selected materials measured at LNE
Total hemispherical emissivity



According to ISO 8302:1991 insufficient emissivity (<0.8), surface need to be coated