Normal spectral emissivity depending on atomic composition for two nickel-based and two ferrous-based alloys at 684.5 nm

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INTRODUCTION

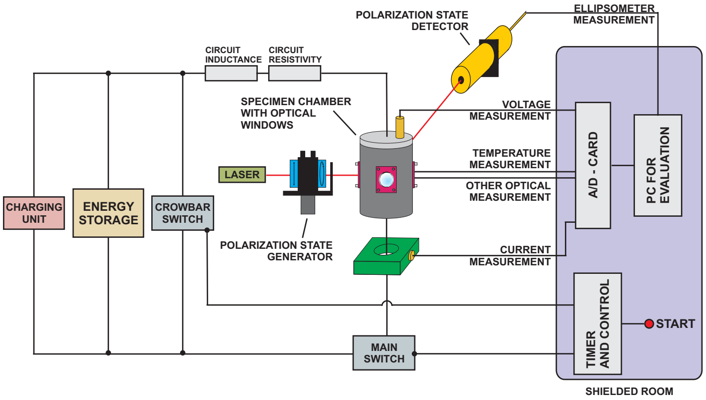
As the investigation of molten metals and alloys is very difficult according to interactions with the surrounding atmosphere, the Subsecond Thermophysik Workgroup at TU Graz uses a fast pulse-heating system to analyse wire-shaped samples. Due to the short experimental period and a well defined nitrogen ambience, this effects can be nearly supressed. To measure the normal spectral emissivity under pulse heating conditions, a laser polarimeter without moving parts, developed by R. M. A. Azzam for the determination of optical constants, was adapted for the µs experiment. During the experiment, the change in polarisation of a laser beam, reflected off the samples surface, is metered and enables the detection of normal spectral emissivity at melting and in the liquid state for the used laser wavelength.

The Stokes formalism is used to decribe the state of polarization and hence the reflected light is optically divided into the four Stokes compoments which allow an unambigous determination of the current state of polarization throughout a pulse-heating experiment. Given the incident polarization (here, +45° linear polarized light), the angle of reflection (140°), and the refractive index of the ambient medium (air or inert gas) are known, normal spectral emissivity ε at the laser wavelength (684.5 nm) can be calculated for opaque samples (transmittance T = 0) by using Kirchhoff's law of thermal radiation with the help of the following equation:

$$\varepsilon = 1 - \Re = \frac{4 n_1 n_2}{(n_1 + n_2)^2 + k_2^2}$$

Here, n_2 and k_2 are the optical constants of the material under investigation and n_1 is the refractive index of the ambient atmosphere (air or inert gas), and $\Re$ is the reflectivity.

EXPERIMENTAL SETUP

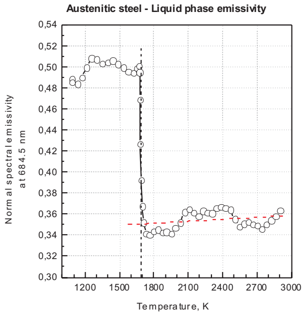


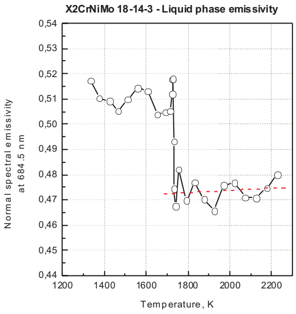
Schematic display of the used resistive pulse-heating system: the DOAP with ist emissivity measurement capability is only an addition to basic pulse-heating experiment.

Samples of about 70 mm length and 0.5 mm diameter are resistively self-heated by passing a large electrical current pulse through them. Measurements can be performed starting from room temperature in the solid state reaching far into the liquid phase. Although electrical data can be measured in the solid phase, normal spectral emissivity is only detected at the melting temperature and above. This limitation originates from the strong dependence of emissivity on the surface treatment of the sample before the experiment (mainly the samples' roughness). At melting the samples become perfectly smooth due to the surface tension of the liquid alloy.

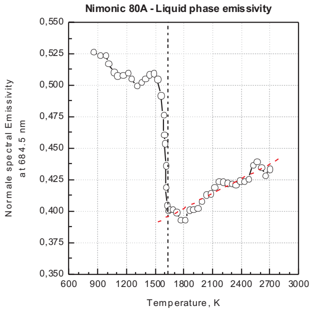
EXPERIMENTAL RESULTS

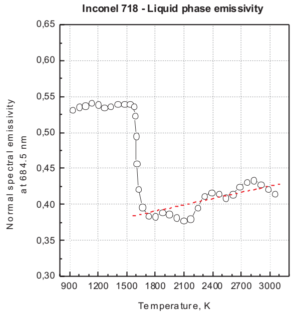
Austenitic Steels:



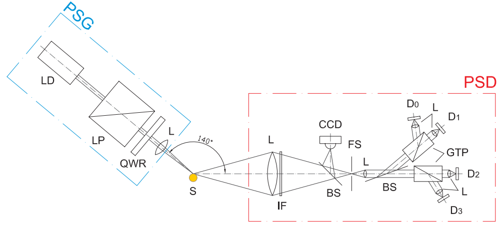


Ni-base alloys:





DETAILS - CONCLUSIONS



Schematic setup of the µs-DOAP: LD – diode laser, LP – linear polarizer, QWR – quarter wave retarder, L – lens, S – sample, IF – interference filter, BS – beam splitter, CCD – CCD-camera, FS – field stop, GTP – Glan-Thompson-prism, D0-D3 - detectors. PSG marks the polarisation state generator, PSD the polarisation state detector.

Table: chemical compositions of the investigated alloys (the missing ferrous-based alloy is copyright protected ist composition undisclosed).

	Nimonic 80A (NiCr20TiAl)	Inconel 718 (NiCr19NbMo)	A 220 (X2CrNiMo18-14-3)
Element	Content/mass%	Content/mass%	Content/mass%
Ni	75.6	53.2	14.5
Fe	0.5	18.1	63.2
Cr	19.5	18.6	17.5
Nb	-	5.2	-
Mo	-	3.02	2.7
Ti	2.5	1.01	-
Al	1.7	0.54	-
Mn	-	0.11	1.7
Si	0.16	0.16	0.3
C	0.05	0.03	max. 0.03
N	-	-	0.07
Zr	0.04	-	-

Benefits from liquid state spectral emissivity data:

(i) Better understanding of interacting effects between light and the molten metals/alloys at melting and in the liquid state
(ii) Improvement of optical temperature measurement of molten materials
(iii) Facillity for numerous simulations, e.g. for remelting processes or plastic deformation

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