Thermophysikalische Eigenschaften von 22 reinen Elementen

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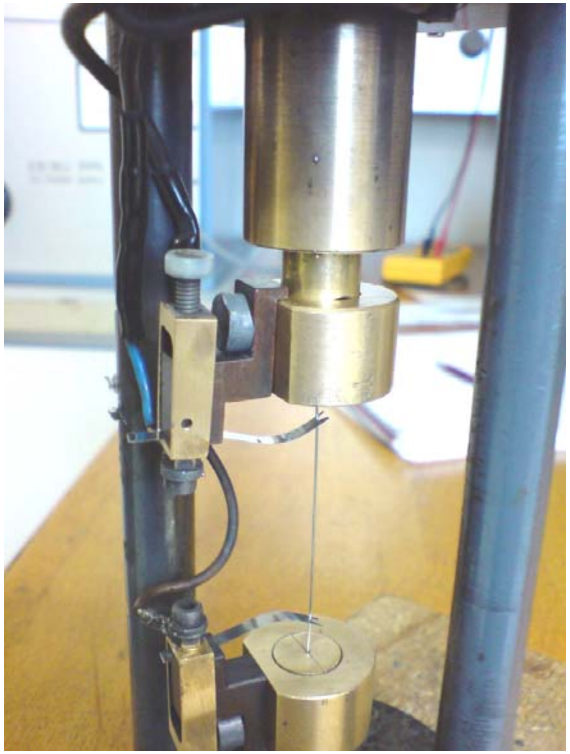
24. März 2011

Schnelles Pulsheizen

Experimentelle Details

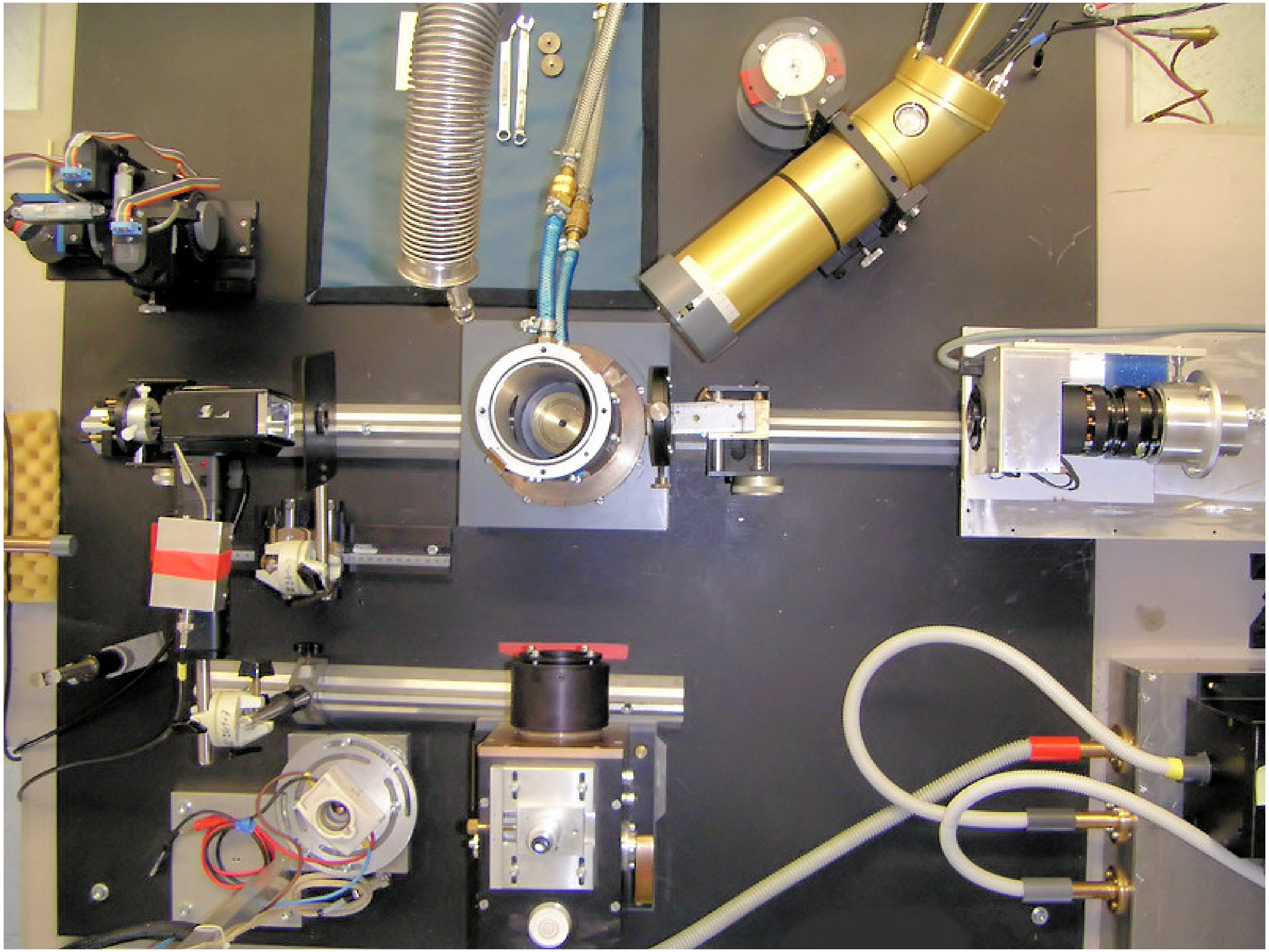
- Drahtförmige Proben
- Kondensatorbank mit 500 µF
- Ohmsches Aufheizen durch Entladungsstrom
- Probe wird bis in die flüssige Phase geheizt (10^8 K/s)



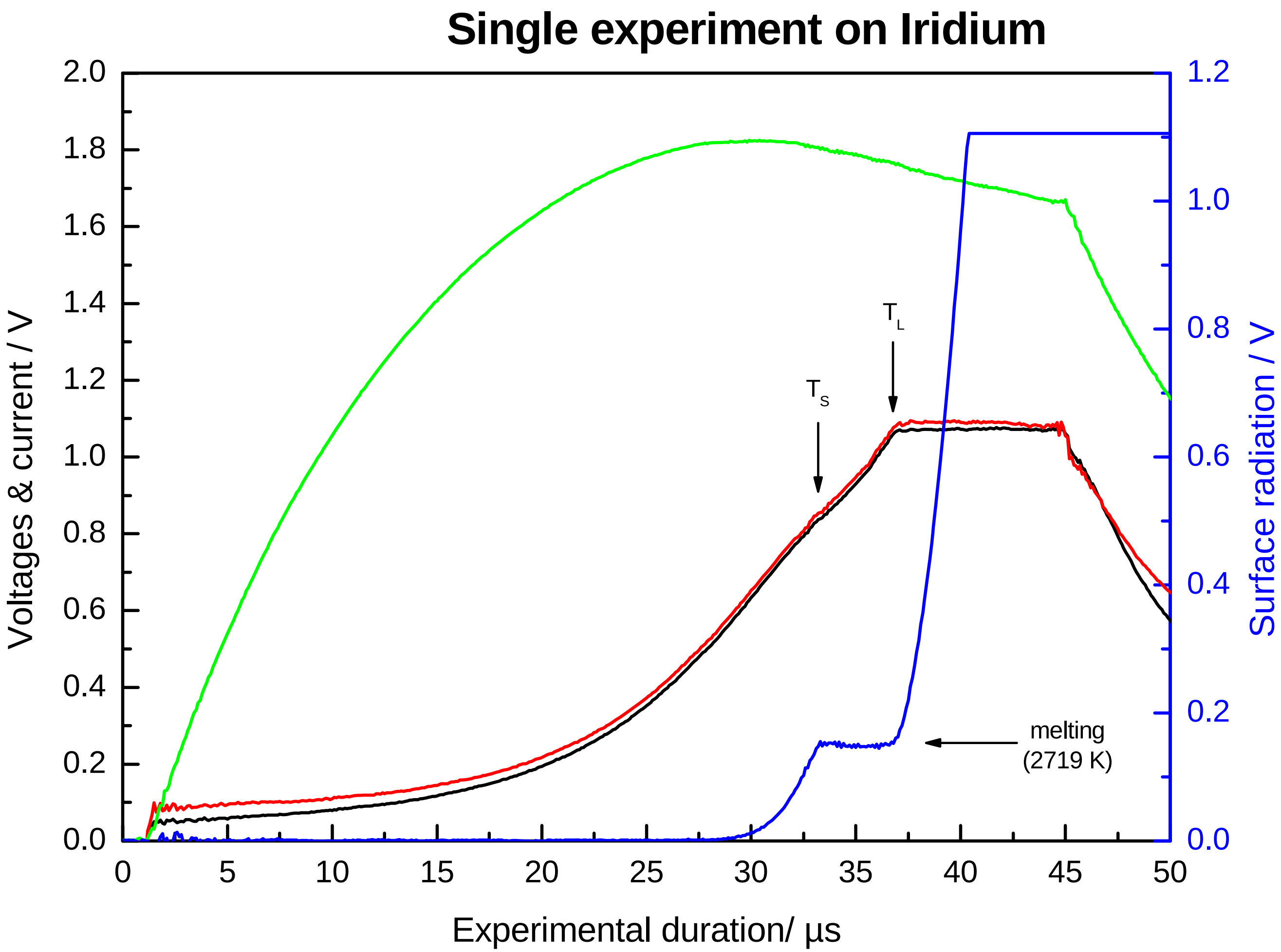
Messung von:

- Strom mit einer Pearson-Sonde
- Spannungsabfall mit Messspitzen
- Temperatur mit schnellem Pyrometer
- Thermische Expansion mit schneller CCD-Kamera

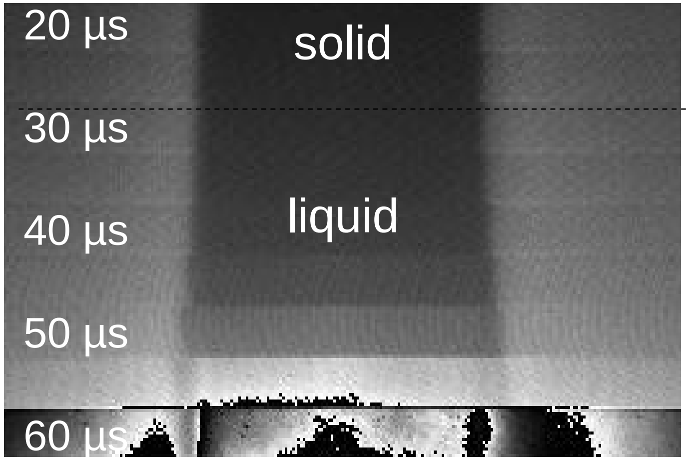
Photographie des Aufbaus



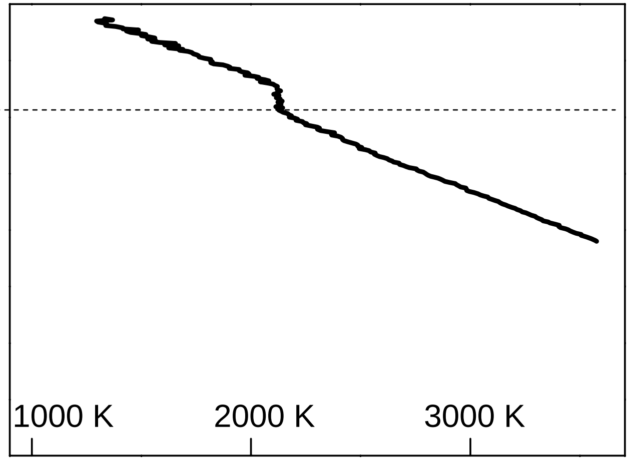
Messwerte


Single experiment on Iridium
Voltages & current / V
Surface radiation / V
Experimental duration/ µs
T_S
T_L
melting
(2719 K)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
5
10
15
20
25
30
35
40
45
50

CCD Bilder

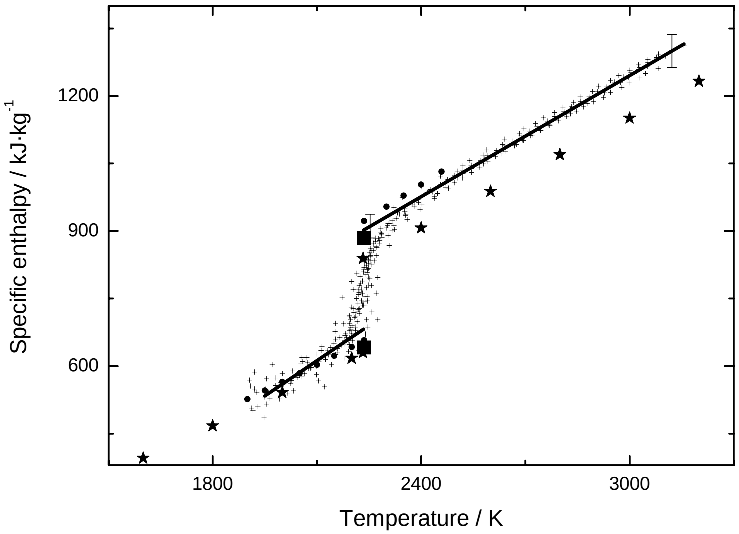


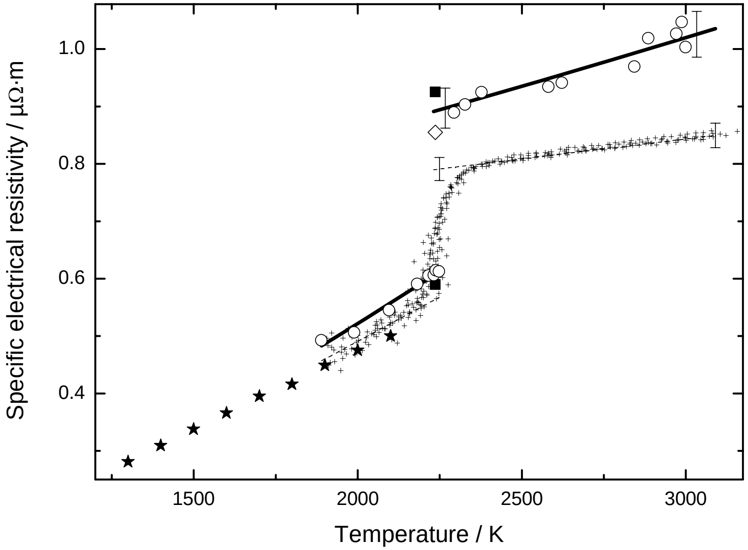
Exploding wire



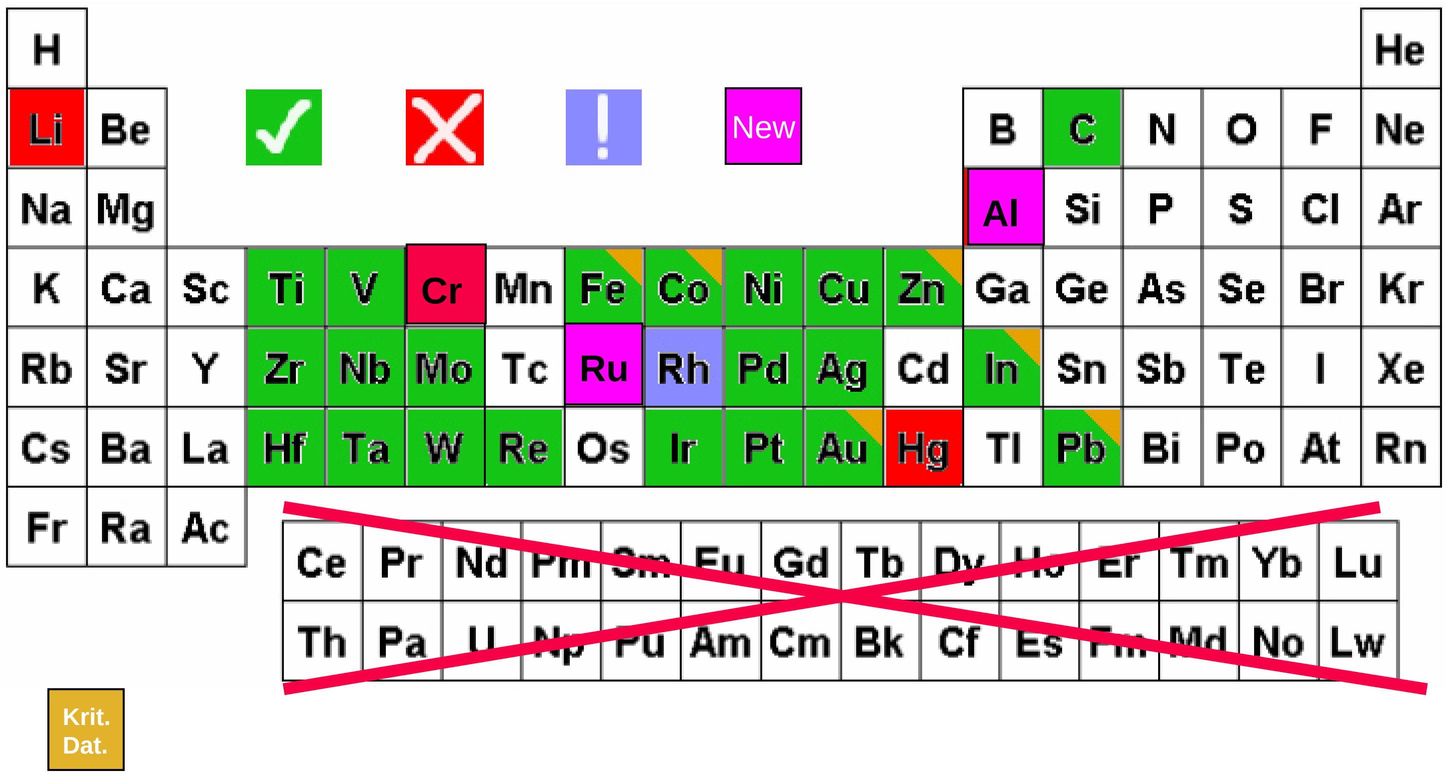
Temperature

Ergebnisse


Specific enthalpy / kJ·kg-1
1200
900
600
1800
2400
3000
Temperature / K


Specific electrical resistivity / µΩ·m
1.0
0.8
0.6
0.4
1500
2000
2500
3000
Temperature / K

Elemente die bisher von uns untersucht wurden



Weiters 30 binäre Legierungen und 4 höhere

Fe10Ni90	Fe20Ni80	Fe30Ni70		
Fe40Ni60	Fe50Ni50	Fe80Ni20	Fe64Ni36 (Invar)	
Ni55Ti45	Au82Ni18			
W74Re26	W95Re5	W96Re4		
W79Re21	W76Re24	W69Re31	Mo52Re47	
Pt70Rh30	Pt87Rh13			
Pt-5Co	Pt-5Ru	Pt-4Cu		
Pt96Cu4	Pt68Cu32	Pt50Cu50	Pt25Cu75	
Ag72Cu28				
Cu85Ni15	Cu70Ni30	Cu55Ni45	Cu35Ni65	Cu20Ni80

Cu86Mn 11Ni2Sn1

Cu85Mn11Ni4 (Manganin ?)

Ti44Al8Nb1B Ti6V4Al

all mass%

25 Stähle bzw. Nickelbasislegierungen

	Inconel 718	
L306	NIMONIC 80a	2.4631
V720	X2NiCoMo18-9-5	1.6354
N709	X3CrNiMoAl13-8-2	1.4534
A220	X2CrNiMo18-14-3	1.4435
M314	X33CrS16	1.2085
M315		
T200	X4NiCrTi25-15	1.4944
P558		
S600	HS6-5-2C	1.3343
V320	41CrMo4	1.7223
P800		
E105		
K110	X153CrMoV12	
S500SF	HS2-9-1-8	
W403	X38CrMoV5-3	
A750	X6CrNiNb18-10	
K350	X50CrMoW9-1-1	
A912	X2CrNiMoCuWN25-7-4	
N114	X7CrAl13	
M303	X38CrMo16	
T651	X20Cr13	
A286	X5NiCrTi26-15	1.4980
C263	Nimonic 263	2.4650
	X2 NiCoMoTi 18-12-4	1.6356

22 Elemente

All elements suitabel for pulse-heating measured:

Co, Cu, Au, Hf, In, Ir, Fe, Pb, Mo, Ni, Nb, Pd, Pt, Re, Rh, Ag, Ta, Ti, W, V, Zn, and Zr

Results are difficult to find:

33 different Journals

73 authors together with me

Papers dating back to 1983

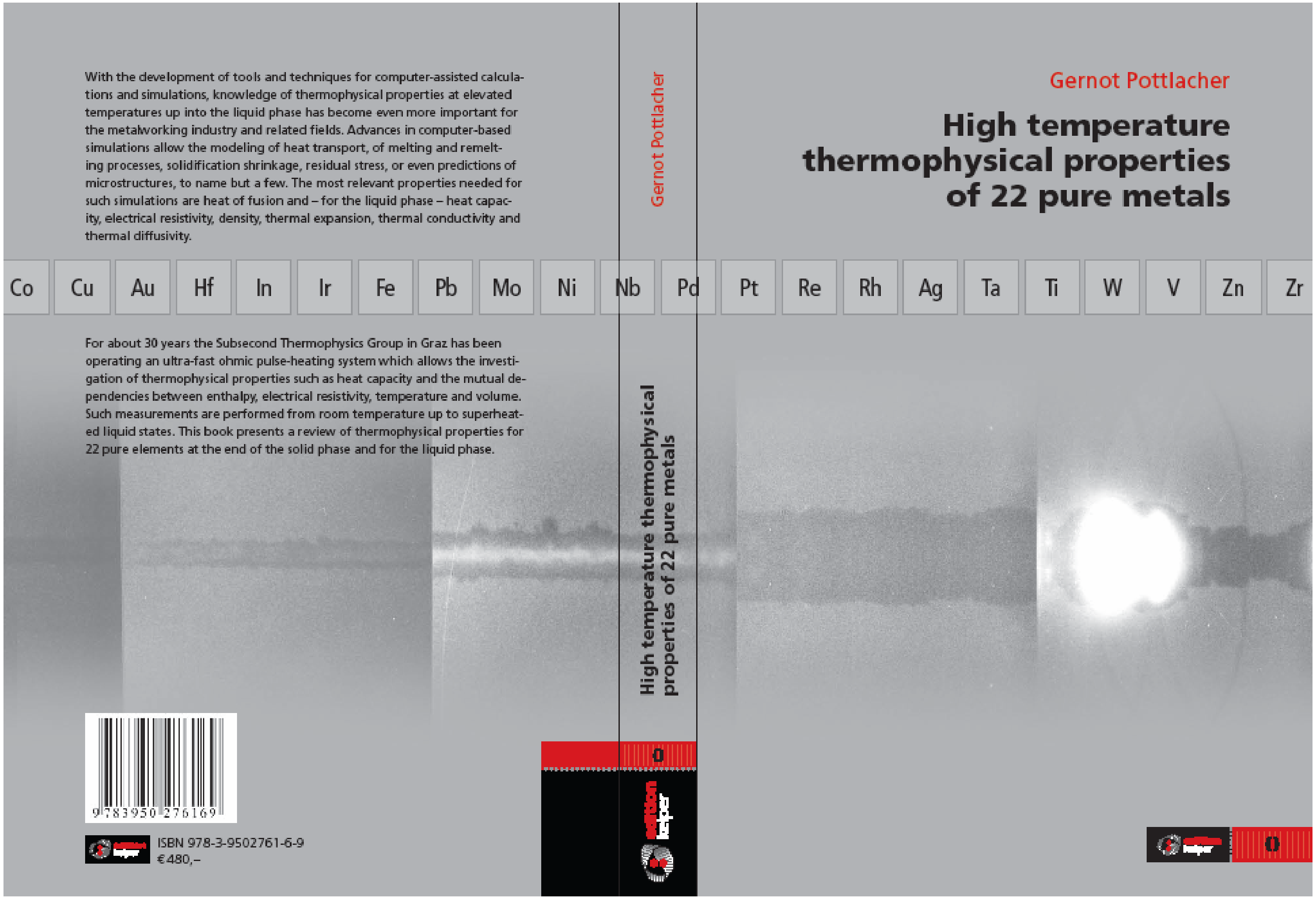
Creation of a 'Compilation' summarizing all 22 elements

International Journal of Thermophysics
High Temperatures - High Pressures
Thermochimica Acta
Journal of Non-Crystalline Solids
Rare Metals
Temperature: Its Meas. a. Contr. i. Sc. a. I.
Platinum Metals Review
ÖPG 1993
Monatshefte für Chemie
J. Chim Phys
Schrifte des Forsch. Zentr. Jülich
Measurement o. t. Thermodyn. Prop. o. S. P.
Intermetallics
Int. J. Materials and Prodict Techn.
Expektrum
World Foundrymen Organisation
Giesserei Praxis
Ber. Bunsenges. Phys. Chem.
Journal of Alloys and Compounds
Elsevier: Handbook of Thermal
Materiaux 2006
Journal of Physics: Conference Series
Journal of Physics: Condensed Matter
ASAP Projects 3th and 4th Call

Pottlacher, G.
Cagran, C.
Jäger, H.
Kaschnitz, E.
Wilthan, B.
Seifter, A.
Tanzer, R.
Schützenhöfer, W.
Didoukh, V.
Lohöfer, G.
Boboridis, K.
Brunner, C.
Hosaeus, H.
Gallob, R.
Nadal, M. -H.
Eyraud, V.
Obendrauf, W.
Harding, R. A.
Hess, H.
Sachsenhofer, F.
Reschab, H.
Krishnan, S.
Otter, C.
Neff, W.
Bauer, W.
Rutsch, S.
Barth, G.
Hüpf, T.
Jaenicke-Roessler, K.
Reiter, P.
Hemberger, F.
Schneidenbach, H.

Brandt, R.
Rink, M.
Höflechner, W.
Holsapple, J.
Brooks, R. F.
Hixson, R. S.
Brillo, J.
Roebuck, B.
Dick, A.
Pichler, J.
Mathelitsch, L.
Lichtenauer, O.
Winkler, M. A.
Kerber, G.
Groboth, G.
Hohenester, A.
Wickins, M.
Egry, I.
Rhode, M.
Pößnecker, W.
Melnitzky, S.
Doytie, D.
Preis, K.
Ebert, H. - P.
Doytier, D.
Hohenauer, W.
Bridy, D.
Keller, B.
Bührig-Polaczek, A.
Suga, H.
Neureiter, C.
Pfaff, E.
Nell, E.
Kriebel, M. E.
Graf, A.

Buchrücken


With the development of tools and techniques for computer-assisted calculations and simulations, knowledge of thermophysical properties at elevated temperatures up into the liquid phase has become even more important for the metalworking industry and related fields. Advances in computer-based simulations allow the modeling of heat transport, of melting and remelting processes, solidification shrinkage, residual stress, or even predictions of microstructures, to name but a few. The most relevant properties needed for such simulations are heat of fusion and – for the liquid phase – heat capacity, electrical resistivity, density, thermal expansion, thermal conductivity and thermal diffusivity.
Co Cu Au Hf In Ir Fe Pb Mo Ni Nb Pd Pt Re Rh Ag Ta Ti W V Zn Zr
For about 30 years the Subsecond Thermophysics Group in Graz has been operating an ultra-fast ohmic pulse-heating system which allows the investigation of thermophysical properties such as heat capacity and the mutual dependencies between enthalpy, electrical resistivity, temperature and volume. Such measurements are performed from room temperature up to superheated liquid states. This book presents a review of thermophysical properties for 22 pure elements at the end of the solid phase and for the liquid phase.
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€ 480,–
Gernot Pottlacher
High temperature thermophysical properties of 22 pure metals
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Aufbau

Common Uses
Relevance in Live
e.g. Rhodium

Common Uses

The most important usages for rhodium are as an additive in alloys to increase strength and high temperature durability as well as corrosion protection, and as a component of industrial catalytic systems.

- Thin coatings of rhodium, formed via electroplating, are used as protection against scratches and tarnishing. In these application, its high and uniform reflectivity in UV as well as IR ranges are exploited. Applied for silverware, jewelry, optical instruments, mirrors, and reflectors in lighting devices. [10] [12]
- In the production of nitric acid, Pt10Rh is used as a catalyst for the oxidation of ammonia. [12]
- The chemical industry uses rhodium as catalyst for the manufacture of acetic acid and for the hydroformylation of alkenes [66]
- Pt10Rh is the most common used Pt-Rh alloy. In glass industry it is used for feeder dies and for handling glasses of high melting point, and as well employed for rayon spinnerettes. [12]
- The alloys Pt10Rh, Pt20Rh and Pt40Rh are utilized as windings in high-temperature furnaces (up to 1800°C) that operate under oxidizing atmospheres. [12]
- Standard thermocouples are commonly made of Pt10Rh versus Pt (Type S), employed for the temperature range from 630.74°C to 1064.43°C (gold point). Other configurations are Pt13Rh/Pt (Type R) and Pt30Rh/Pt6Rh (Type B). Unlike the above mentioned ones, iridium-rhodium thermocouples (Ir40Rh/Ir, Ir50Rh/Ir and Ir60Rh/Ir) are only recommended for operation in inert atmospheres and in vacuum. [12]
- Crucibles are made of Pt3.5Rh alloy, offering little weight-loss at high temperatures. [12]
- Bushings made of ZGS[10] platinum-rhodium are used in the fabrication of continuous filament glass fiber. The material is resistant to creep-induced sagging. [12]
- Excellent gray filters are gained by thin coatings of rhodium on glass via vacuum deposition. [8]

Relevance in Life

Rhodium metal powder and dust are inflammable in air. Skin irritations may occur by contact with a number of its compounds. [10]

Aufbau

Thermophysical properties obtained by pulse-heating

- Enthalpy
- Rhodiuim

Enthalpy

Table 40: Specific enthalpy results of rhodium, H in kJ·kg^{-1}, polynomials taker from [74].

	$T_m = 2236\,\text{K}$ [19], $at.wt. = 102.9055$ [18]	
solid	$H(T) = -486.154 + 0.523 \cdot T$ $c_p = 523\,\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$ $C_p = 53.820\,\text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$	$1900\,\text{K} < T < 2236\,\text{K}$
liquid	$H(T) = -98.980 + 0.448 \cdot T$ $c_p = 448\,\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$ $C_p = 46.102\,\text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$	$2236\,\text{K} < T < 3150\,\text{K}$
	$H_s = 683,\ H_l = 903,\ \Delta H = 220$	

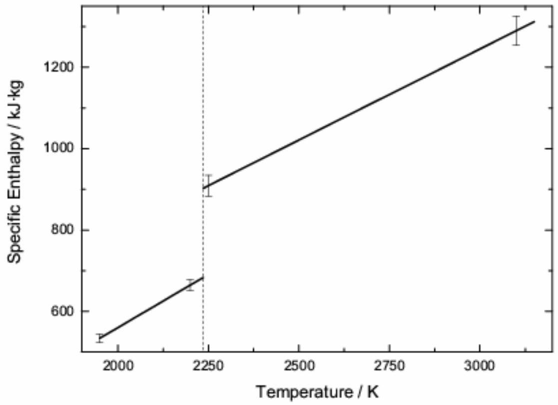


Figure 40: Specific enthalpy of rhodium as a function of temperature.

Aufbau

Thermophysical properties obtained by pulse-heating

- Volume expansion
- Rhodium

B: Thermophysical properties obtained by Pulse-heating

Volume expansion

Table 39: Volume expansion results of rhodium, polynomials taken from [74]. Density at 20°C: 12423 kg·m^{-3}[75].

	$T_m = 2236\,\mathrm{K}$ [19]	
solid	$V/V_0(T) = 0.943 + 5.994 \times 10^{-5} \cdot T$	$1400\,\mathrm{K} < T < 2236\,\mathrm{K}$
liquid	$V/V_0(T) = 0.893 + 1.055 \times 10^{-4} \cdot T$	$2236\,\mathrm{K} < T < 3500\,\mathrm{K}$

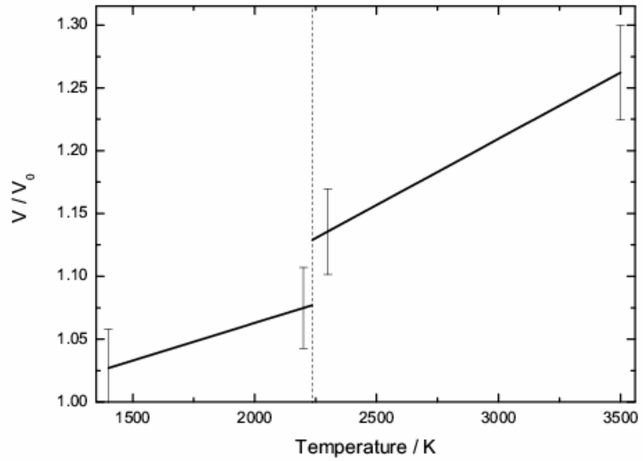


Figure 39: Volume expansion of rhodium.

Aufbau

Thermophysical properties obtained by pulse-heating

- Resistivity
- Rhodium

Resistivity

Table 41: Specific resistivity results of rhodium, ρ in $\mu\Omega$·m, polynomials taken from [74].

	$T_m = 2236\,\mathrm{K}$ [19]	
solid	$\rho_{\mathrm{IG}}(T) = -0.126 + 3.085 \times 10^{-4} \cdot T$ $\rho(T) = -0.202 + 3.617 \times 10^{-4} \cdot T$	$1950\,\mathrm{K} < T < 2236\,\mathrm{K}$
liquid	$\rho_{\mathrm{IG}}(T) = 0.635 + 6.975 \times 10^{-5} \cdot T$ $\rho(T) = 0.516 + 1.680 \times 10^{-4} \cdot T$	$2236\,\mathrm{K} < T < 3150\,\mathrm{K}$
	$\rho_{\mathrm{IG,s}} = 0.564$, $\rho_{\mathrm{IG,l}} = 0.791$, $\Delta\rho_{\mathrm{IG,s\text{-}l}} = 0.227$	
	$\rho_{\mathrm{s}} = 0.607$, $\rho_{\mathrm{l}} = 0.892$, $\Delta\rho_{\mathrm{s\text{-}l}} = 0.285$	

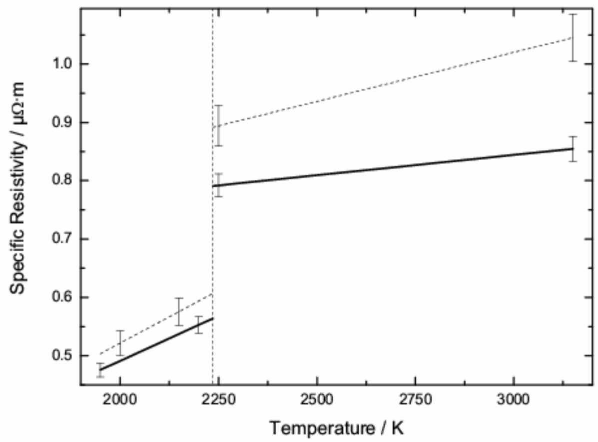


Figure 41: Specific resistivity of rhodium as a function of temperature. Dashed line: values including volume expansion.

Weitere Daten

Thermophysical properties obtained by pulse-heating

- Enthalpy $$H(t) = \frac{1}{m} \cdot \int I(t) \cdot U(t) \cdot dt \,,$$
- Resistivity $$\rho_{el,\ uncorr}(t) = \frac{U(t) \cdot \pi \cdot r^2}{I(t) \cdot \ell} \,,$$
- Thermal conductivity $$\lambda(T) = \frac{L \cdot T}{\rho_{el,corr}(T)} \,,$$
- Thermal diffusivity $$a(T) = \frac{\lambda(T)}{c_p(T) \cdot \rho_d(T)}$$

Book Review in High Temp. – High Press.

Reviewed by I. Egry

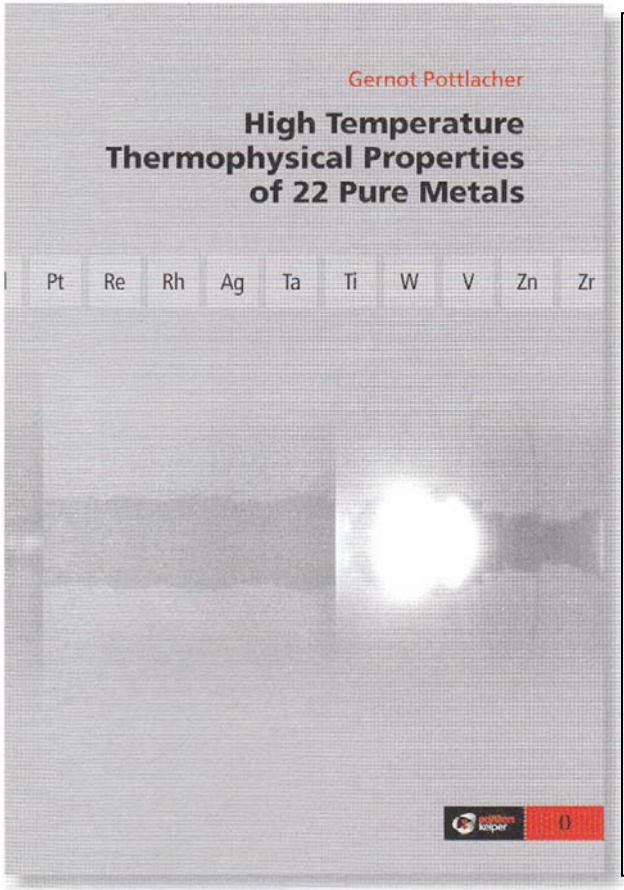
There are not many groups worldwide engaged in measuring high temperature thermophysical properties; G. Pottlacher's group at the university of Graz is one of them. His group has worked on the high temperature properties of metals for about 30 years, and this book is a compilation of the results obtained. The method employed throughout is fast pulse heating, also known as the "exploding wire" technique. In addition to delivering data in the solid phase, this method provides also access to the liquid phase, thanks to fast data acquisition. It is possible to measure thermal expansion, enthalpy, heat capacity and electrical resistivity of the solid and liquid metal as function of temperature until the molten wire collapses. This technique is suitable for metals with high melting points and, consequently, the 22 metals investigated are mainly transition, noble and rare-earth metals, namely (in alphabetical order) Co, Cu, Au, Hf, In, Ir, Fe, Pb, Mo, Ni, Nb, Pd, Pt, Re, Rh, Ag, Ta, Ti, W, V, Zn and Zr.

Book Review, continued

The book contains a short introduction, explaining how the data were obtained, and one section for each metal considered. Each section starts with a basic survey, including the metal's history, its common uses, its relevance in daily life, safety and health aspects. The second part is devoted to the measured data. These are presented in graphical form with indicative error bars. In addition, recommended values are provided as polynomial fits. From the data, additional thermophysical properties like thermal conductivity and thermal diffusivity can be derived. A comprehensive bibliography, quoting the original publications from which the data were extracted, is also given.

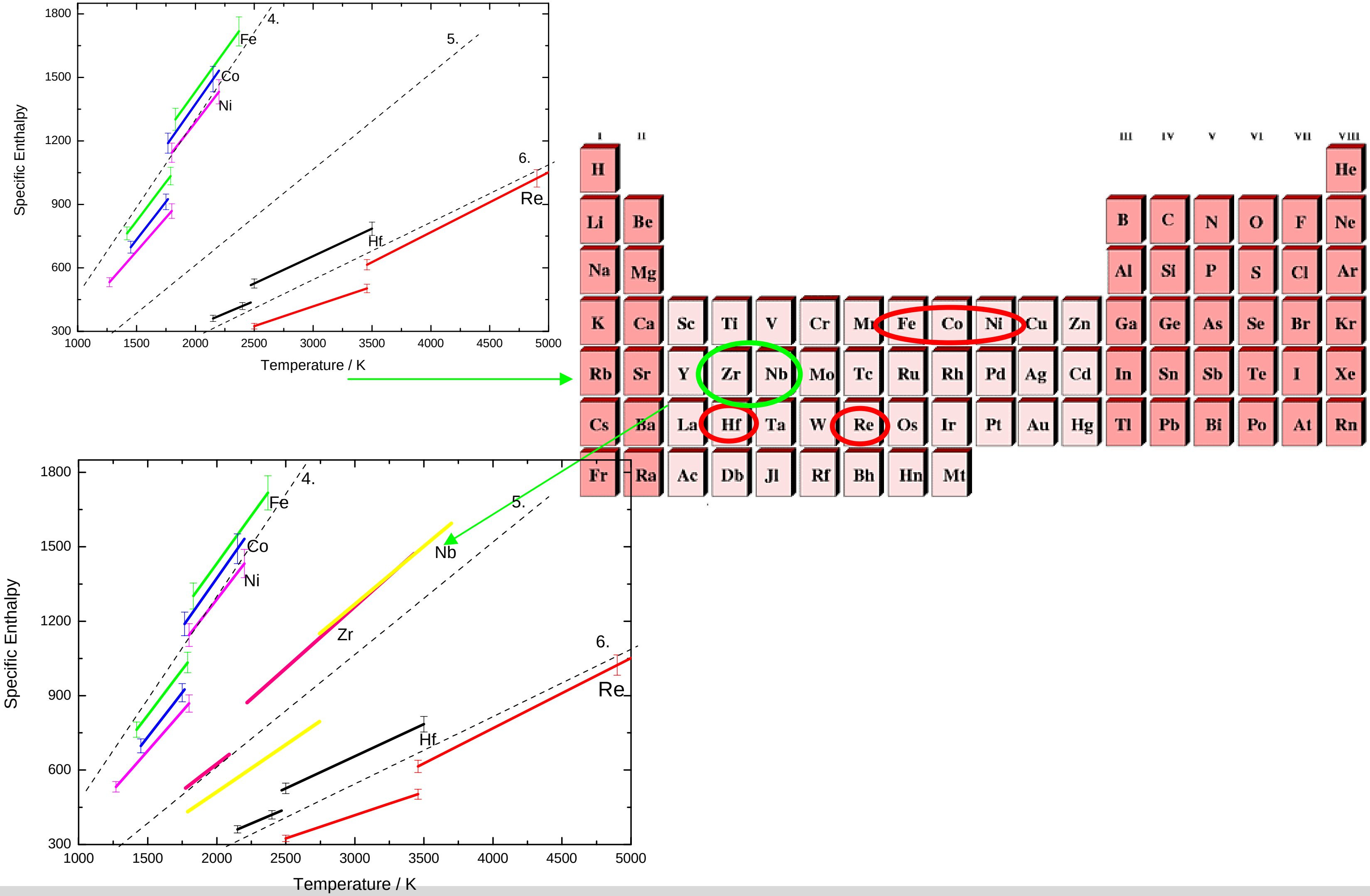
Everybody who works in the area of high temperature thermophysical properties will find this book a useful compilation. It represents state-of-the-art results, based on the author's expert knowledge. It is the strength of the book that it contains only data measured by the author's group, therefore allowing cross comparisons between the elements without having to deal with potential systematic differences. It is a valuable complement to existing collections on thermophysical properties of (liquid) metals, published in books or scattered in journal publications or review papers.

Datenbücher sind nicht gerade billig



480.- €

Ergebnisse spezifische Enthalpie



Mehr davon im Sommer bei der

19th European Conference on Thermophysical Properties

August 28 - September 1, 2011, Thessaloniki, Greece
"Nicolaos Germanos" Conference Center, HELEXPO

Subsecond Thermophysics Workgroup staff during the years

Professor Dr. H. Jäger
Dr. R. Gallob
Dr. E. Kaschnitz
Dipl.-Ing. W. Neff
Dipl.-Ing. S. Melnitzky
Dr. W. Obendrauf
Dipl.-Ing. G. Nußbaumer
Dr. W. Maichen
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M. Phil. Shahid Mehmood
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