WP12-MAT-01-HHFM-02-02/KIT

→ *(ii) Structural Materials Development*

Development of a Reduced Activation (austenitic) Stainless Steel (RASS)

- WP12
- Reporting period: **February 2012 - January 2013**
- Investigators:
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- KIT - IAM

MOTIVATION

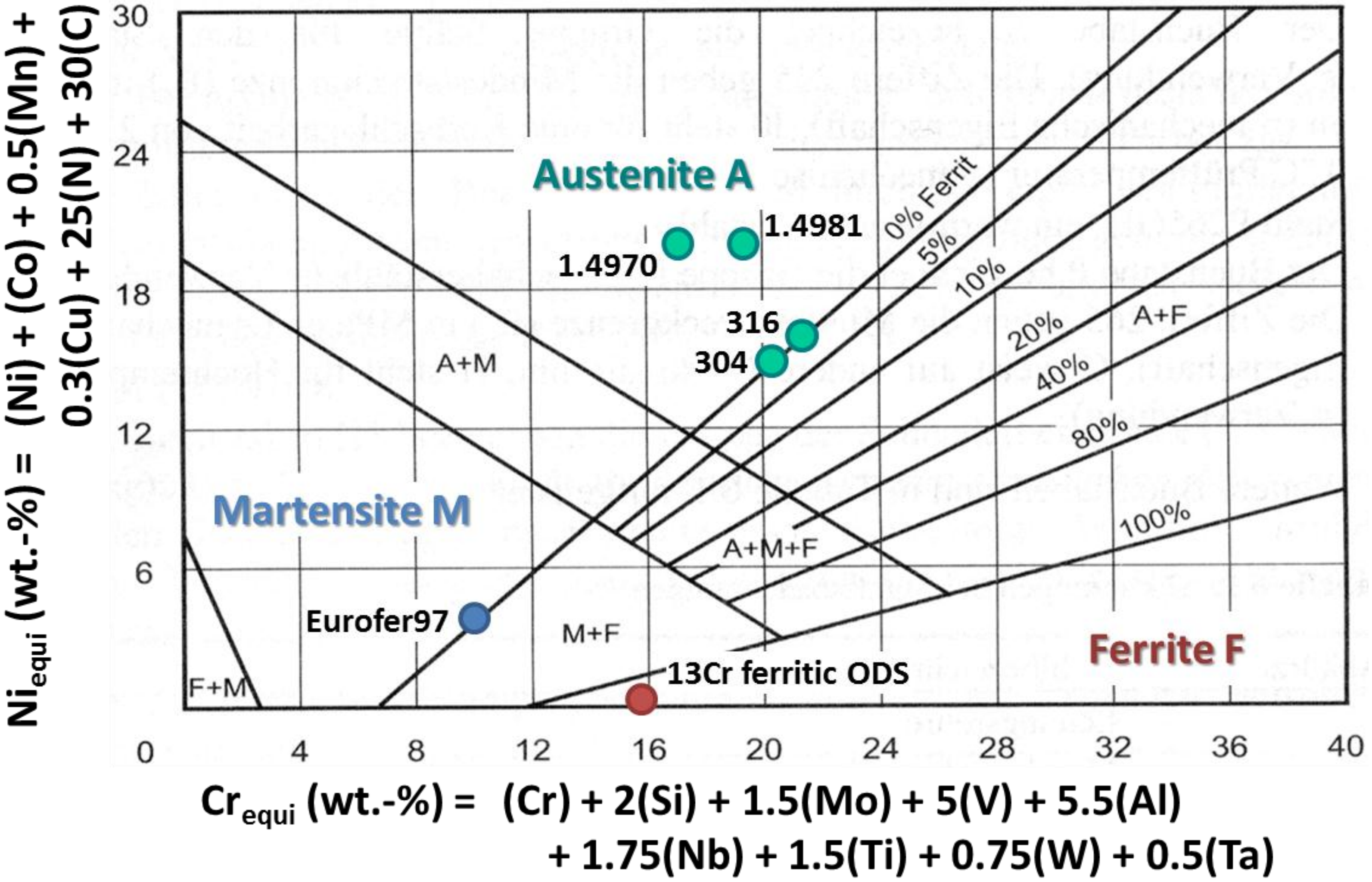
- Water cooled divertor development (5-10 MW/m²)
- There is an operating window for austenitic SS
- Goal: Reduced Activation Stainless Steel (RASS) with properties comparable to 316 but with better irradiation resistance

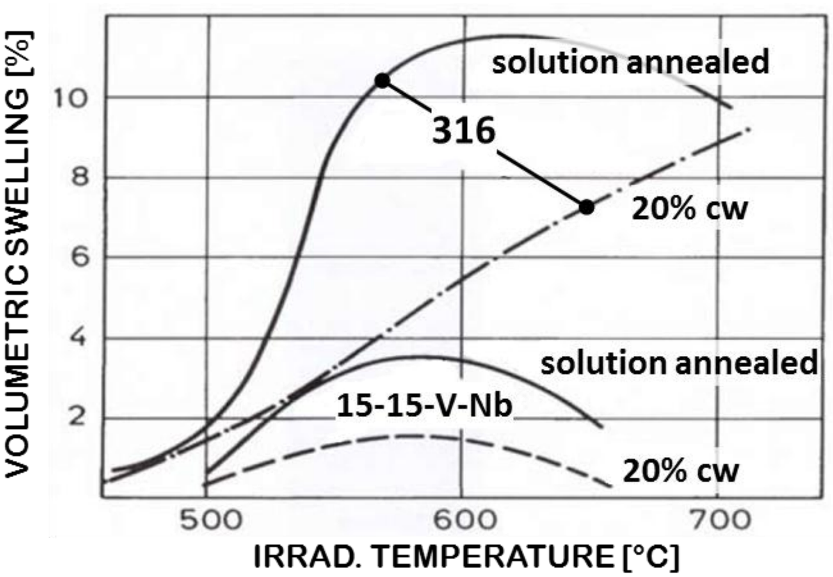
INVESTIGATION

- Study of Fast Breeder claddings
- Preliminary Activation Calculations
- Basic Characterisation and PM Studies

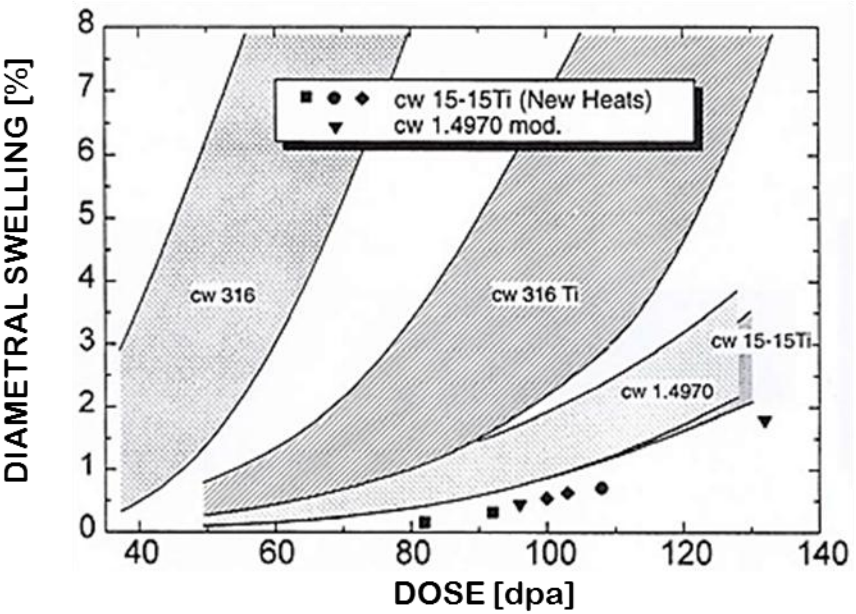
Schaeffler Diagram (chrome and nickel equivalents)

The phase points of typical steels for nuclear applications are indicated in the diagram.





Swelling of austenitic steels depending on irradion temperature during ion irradiation (**40 dpa, 10 appm He**). Swelling is clearly reduced in cold-worked (cw) compared to solution annealed steels. The steel 15-15-V-Nb (1.4988) steel belongs to the same steel class as 1.4970 or 1.4981.



Swelling of austenitic steels depending on dose during fast neutron irradiation at **500 °C**. All steels have been cold-worked (cw) prior to irradiation.
Source: H.-J. Bergmann, W. Dietz, K. Ehrlich, G. Mühling, M. Schirra, FZKA 6864, ISSN 0947-8620, 2003.

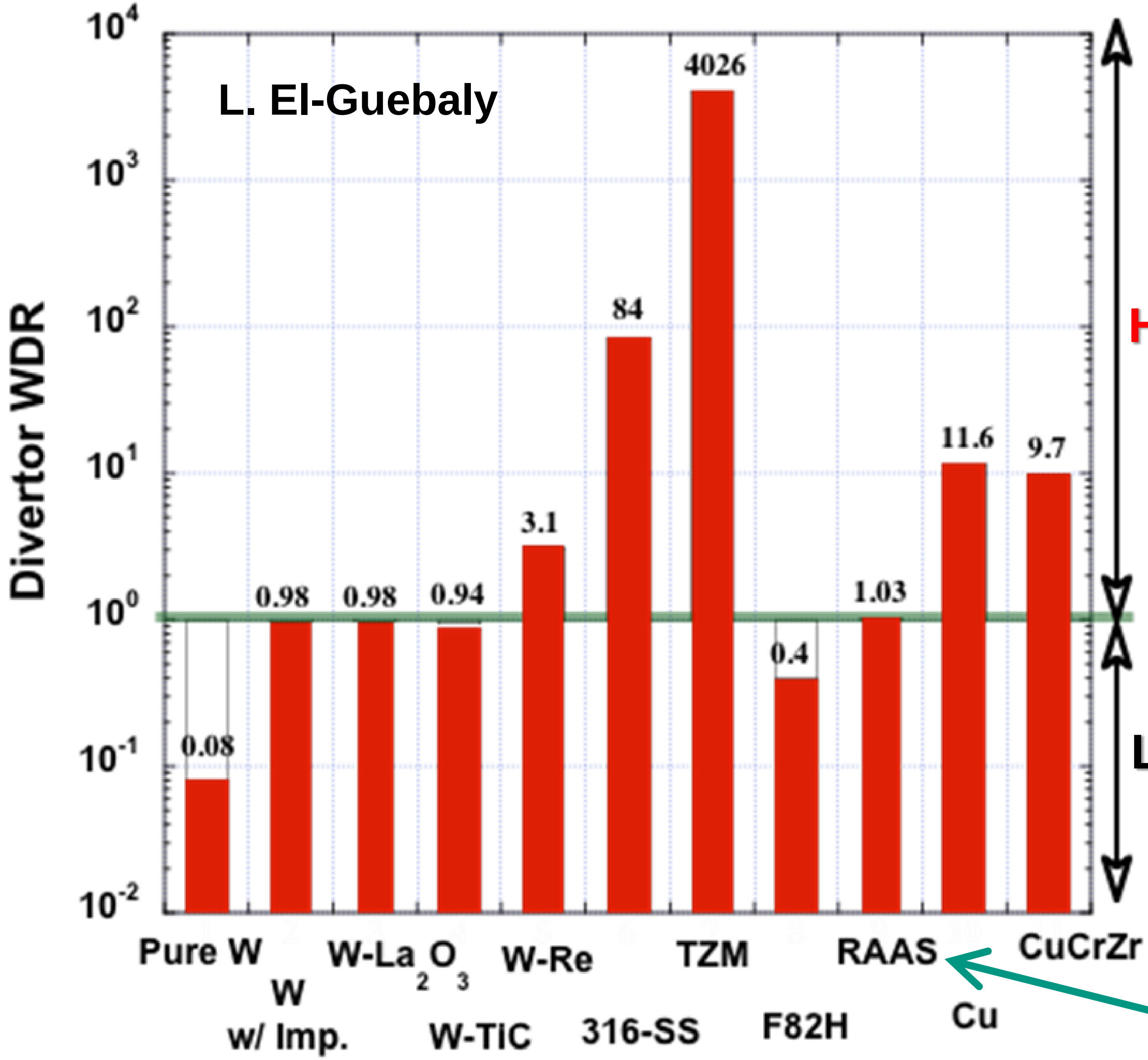
Ductility of 316L(N) Steel after Neutron Irradiation

Irrad. Dose	**Irradiation Temperature**					
	60 °C	**80 °C**	**200 °C**	**225 °C**	**325 °C**	**400 °C**
unirrad.	0.5	0.4	0.33	0.31	0.3	0.32
5 dpa	0.35	0.22	0.18	0.08	0.09	0.14
7 dpa	0.3		0.13		0	0.05
10 dpa	0.28		0.11	0.05	0	0.04
15 dpa	0.26		0.08		0	0.03

Uniform elongation (i.e. strain to necking) before and after neutron irradiation of 316L(N) steels. Parameters are irradiation temperature and neutron dose (details are given in [1, 2]).

[1] J.P. Robertson, I. Ioka, A.F. Rowcliffe, M.L. Grossbeck and S. Jitsukawa, Temperature dependence of deformation behavior of type 316 stainless steel after low temperature neutron irradiation, ASTM STP (1997) 1325.

[2] P.H. Dubuisson, J.L. Seran, P. Soulat, Irradiation Embrittlement of Reactor Internal Materials, in “Effect of Irradiation on Water Reactor Internals,” Study Contract COSU CT94-074, Vol.3, June 1997, p.15.

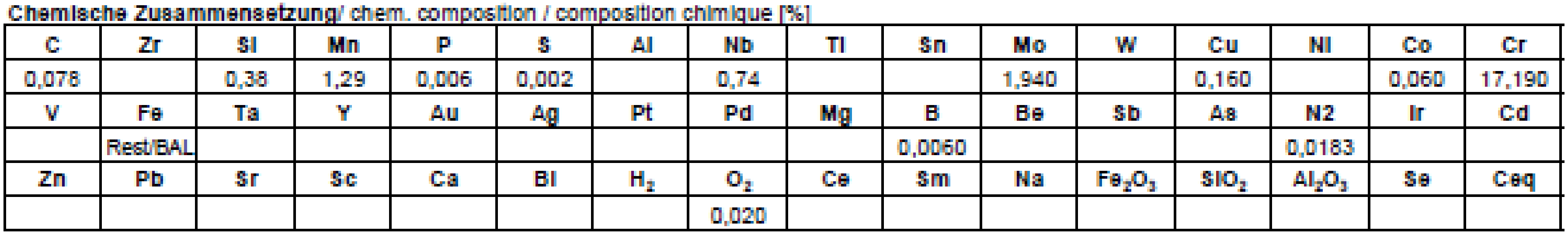


High Level Waste

Low Level Waste

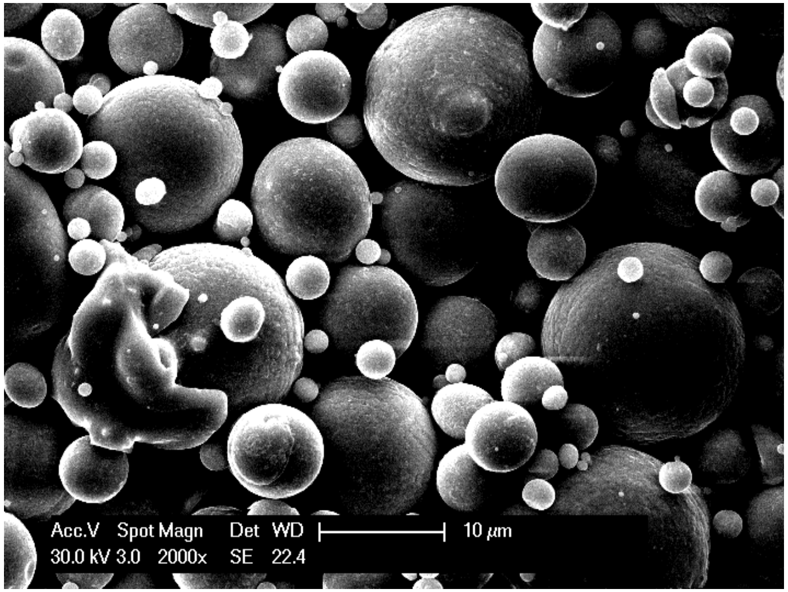
Reduced Activation 1.4970

Base Material: 1.4981 Rod (40 mm, forged)

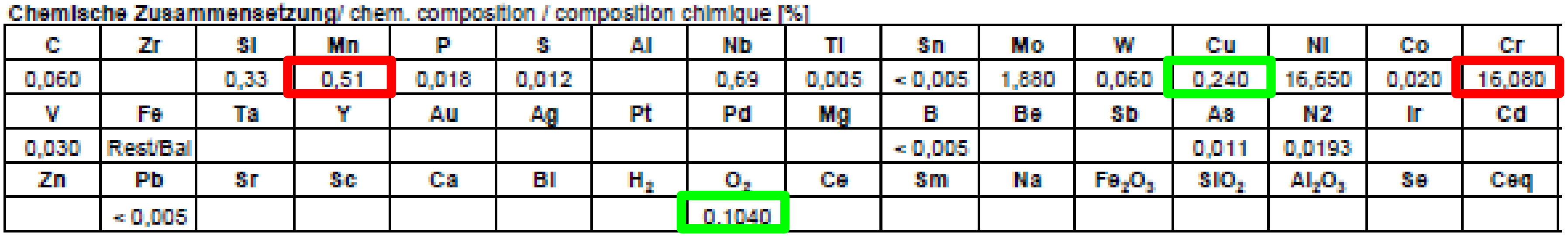


Chemische Zusammensetzung/ chem. composition / composition chimique [%]

C	Zr	Si	Mn	P	S	Al	Nb	Ti	Sn	Mo	W	Cu	Ni	Co	Cr
0,078		0,38	1,29	0,006	0,002		0,74			1,940		0,160		0,060	17,190
V	Fe	Ta	Y	Au	Ag	Pt	Pd	Mg	B	Be	Sb	As	N2	Ir	Cd
	Rest/BAL								0,0060				0,0183		
Zn	Pb	Sr	Sc	Ca	Bi	H_2	O_2	Ce	Sm	Na	Fe_2O_3	SiO_2	Al_2O_3	Se	Ceq
							0,020								

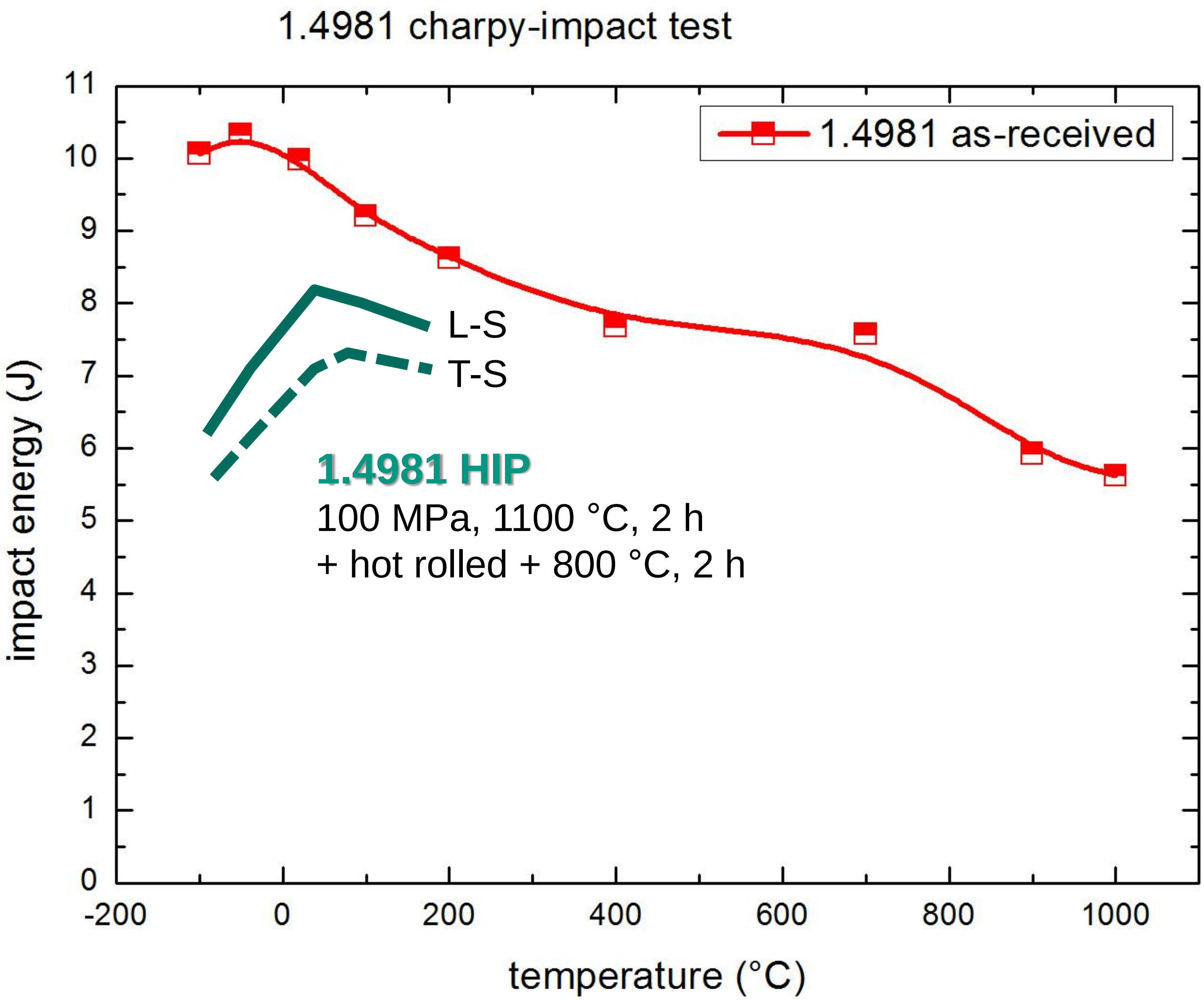


Powder Production by Atomisation (Nanoval)



Chemische Zusammensetzung/ chem. composition / composition chimique [%]

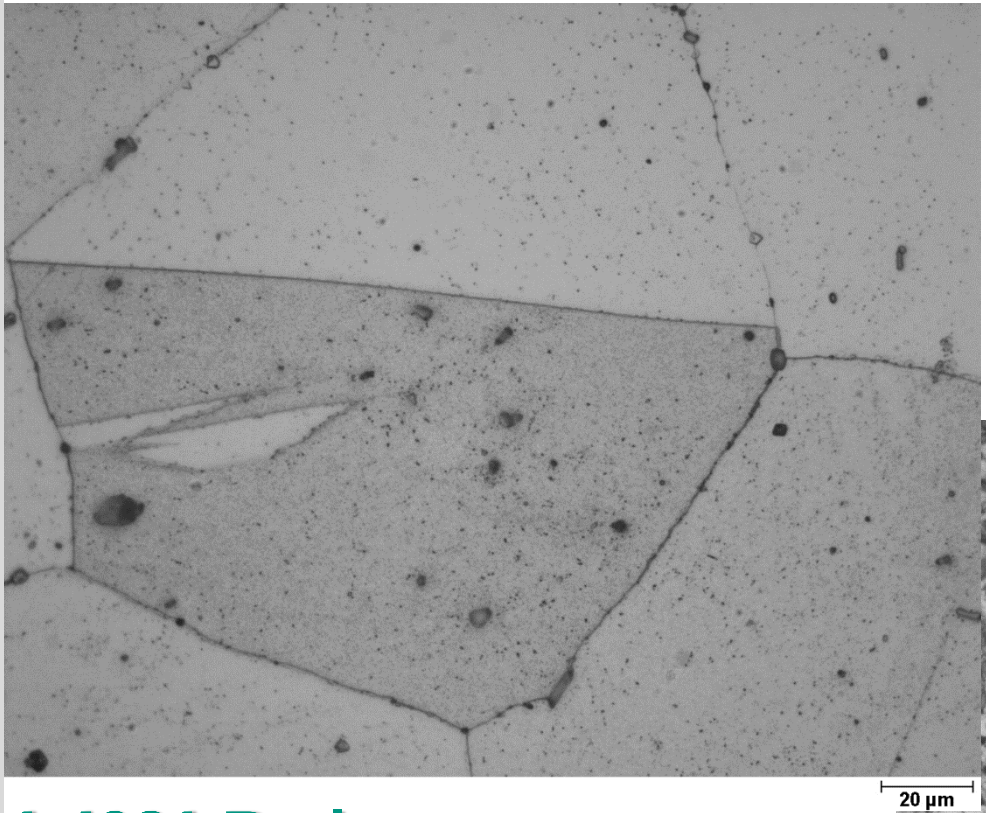
C	Zr	Si	Mn	P	S	Al	Nb	Ti	Sn	Mo	W	Cu	Ni	Co	Cr
0,060		0,33	0,51	0,018	0,012		0,69	0,005	< 0,005	1,880	0,060	0,240	16,650	0,020	16,080
V	Fe	Ta	Y	Au	Ag	Pt	Pd	Mg	B	Be	Sb	As	N2	Ir	Cd
0,030	Rest/Bal								< 0,005			0,011	0,0193		
Zn	Pb	Sr	Sc	Ca	Bi	H_2	O_2	Ce	Sm	Na	Fe_2O_3	SiO_2	Al_2O_3	Se	Ceq
	< 0,005						0.1040								



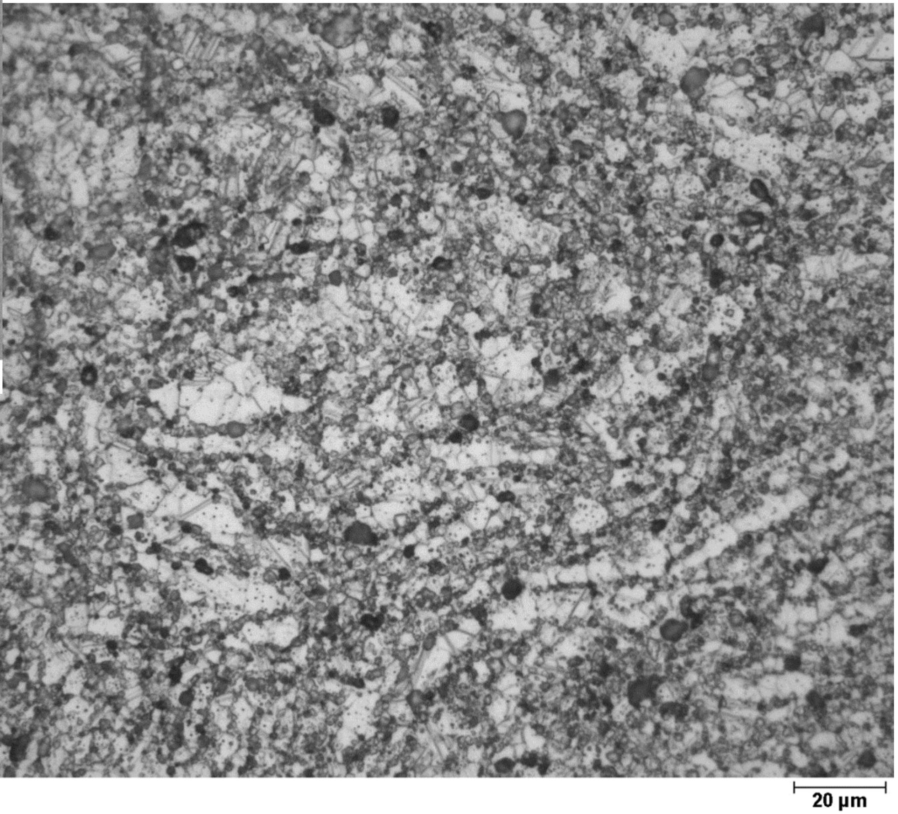
1.4981 HIP

100 MPa, 1100 °C, 2 h
+ hot rolled + 800 °C, 2 h

1.4981-ODS
mixed with ZrO_2
+ HIP @ 1100 °C, 2 h



1.4981 Rod
1070 °C, 1 h



Conclusions and Assessment

- RASS is feasible – Main concern: short term activity
- Swelling is no concern for RASS under DEMO WC divertor conditions
- Ductility is the limiting factor for WC application – Max. dose: ~5 dpa
- PM processing is easily applicable to this material

Since Ti stabilization becomes ineffective at lower irradiation temperatures, and since Eurofer/F82H-type steels perform better at temperatures above 350 °C, it seems to be unnecessary to follow the Ti stabilizing concept for RASS. Therefore, future activities could be restricted to investigate RASS with simple chemical compositions, that is, Fe-Cr-Ni-Mn-W plus variations or minor contents of other elements (C, Si, N).

Many thanks to all involved in this task!