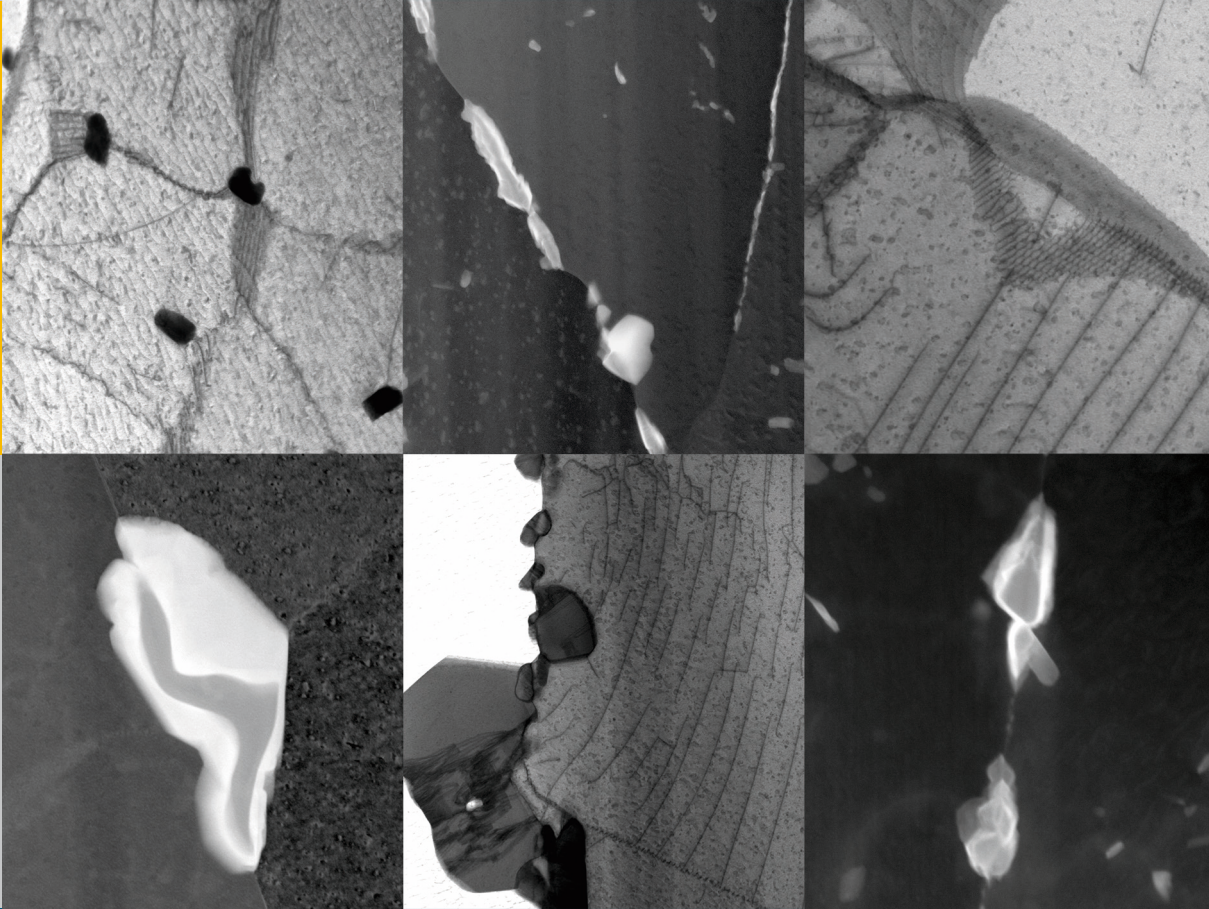


Microstructure Evolution of Laves Phase Strengthened Ferritic Steels for High Temperature Applications

Jennifer Katharina Lopez Barrilao



Member of the Helmholtz Association

Energie & Umwelt/
Energy & Environment
Band/ Volume 375
ISBN 978-3-95806-231-3

Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research (IEK)
Microstructure and Properties of Materials (IEK-2)

Microstructure Evolution of Laves Phase Strengthened Ferritic Steels for High Temperature Applications

Jennifer Katharina Lopez Barrilao

Schriften des Forschungszentrums Jülich
Reihe Energie & Umwelt / Energy & Environment

Band / Volume 375

ISSN 1866-1793

ISBN 978-3-95806-231-3

Contents

1	Introduction	1
1.1	Background and Motivation	1
1.2	Outline	3
2	Scientific Background	5
2.1	State of the art 9-12% Cr steels	5
2.2	Crofer [®] 22 APU and Crofer [®] 22 H	7
2.3	Strengthening Particles	8
2.3.1	Carbide and Nitride	8
2.3.2	Laves Phase	9
2.3.3	σ -Phase	10
2.3.4	Z-Phase	11
2.4	Crystallographic Defects	12
2.4.1	0-dimensional Lattice Defects	12
2.4.2	1-dimensional Lattice Defects	14
2.4.3	2-dimensional Lattice Defects	16
2.5	Ageing Processes in Solids	20
2.5.1	Diffusion	20
2.5.2	Precipitation	20
2.5.3	Structural Ageing	22
2.6	Phase Diagrams	27
2.7	Mechanical Properties	27
2.8	Transmission Electron Microscopy (TEM)	29
2.8.1	Fundamental Principles	29
2.8.2	Architecture	30

2.8.3	Imaging	32
2.8.4	General Sample Preparation	34
2.9	Scanning Electron Microscopy (SEM)	37
3	Experimental	39
3.1	Materials and Production	39
3.2	Annealing Experiments and Sample Preparation	39
3.3	Microstructural Analysis	41
3.3.1	HR-FESEM and Image Analysis	41
3.3.2	STEM	44
3.4	Thermodynamic Modelling of Phase Diagrams	44
4	Results and Discussion	45
4.1	Previous Studies	45
4.2	Selection of Sample Preparation	47
4.3	Thermodynamic Modelling and Verification by Electron Microscopy Examination	48
4.3.1	Thermodynamic Modelling	48
4.3.2	STEM Examination at 600 °C and 650 °C	50
4.3.3	Chemical Composition at 600 °C and 650 °C	60
4.3.4	Examination of Phase Structure	70
4.4	Particle Evolution at 600 °C and 650 °C	73
4.4.1	Particle Diameter Evolution	76
4.4.2	Evolution of Particle Size Distribution	77
4.5	Summary and Conclusion: Particle Verification and Evolution	86
4.6	Microstructure Evolution at 650 °C	87
4.6.1	Sub-Grain Structure Evolution	87
4.6.2	Particle-Free Zone Evolution	87
4.7	Summary and Conclusion: Microstructure Evolution	98
5	Overall Conclusion and Outlook	101

A Appendix:	
Thermodynamic Modelling and Verification by Electron Microscopy Examination	103
A.1 STEM Examination at 600 °C and 650 °C	103
A.2 Phase Distinction	105
A.2.1 EDX measurement	105
A.2.2 Diffraction measurement	107
B Particle Evolution	109
C Microstructure Evolution	111
C.1 Particle-Free Zone Evolution	111
Bibliography	115
List of Figures	125
List of Tables	131

**Energie & Umwelt /
Energy & Environment
Band / Volume 375
ISBN 978-3-95806-231-3**

