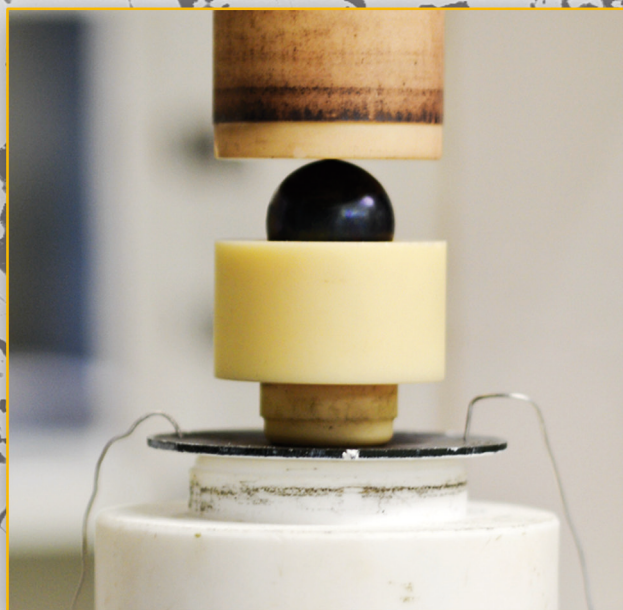


Mechanical and Thermochemical Properties of Nano-structured Membranes for Gas Separation in Fossil-fired Power Plants

Jizu Zhang



Energie & Umwelt /
Energy & Environment
Band/ Volume 311
ISBN 978-3-95806-126-2

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

Mechanical and Thermochemical Properties of Nano-structured Membranes for Gas Separation in Fossil-fired Power Plants

Jizu Zhang

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

Band / Volume 311

ISSN 1866-1793

ISBN 978-3-95806-126-2

Contents

1	Introduction	1
2	Scope of work.....	3
3	Fundamentals.....	5
3.1	CO ₂ capture and storage technologies (CCS).....	5
3.1.1	Pre- combustion process	5
3.1.2	Oxyfuel process	6
3.1.3	Post-combustion process	8
3.2	Membrane technology for gas separation	9
3.2.1	Membranes	9
3.2.2	Requirements for membranes	10
3.2.3	Characteristics	12
3.2.4	Mechanism of gas separation and transport.....	12
3.3	Porous membranes	16
3.3.1	Structure of porous membrane.....	16
3.3.2	Porous silica membranes	18
3.3.3	Porous silica membranes modified with amino-group	18
3.3.4	Synthesis of porous silica membranes	19
3.3.5	Degradation of silica membrane with water vapour.....	23
4	Literature review of investigated materials' properties	25
4.1	Substrate.....	25
4.1.1	Ceramic substrate – porous α -Al ₂ O ₃	25
4.1.2	Metallic substrate – porous ITM (Intermediate temperature metal).....	27
4.2	Membrane	28
4.2.1	Porous silica membrane.....	28
4.2.2	Amino-modified silica membrane	29
5	Materials and experimental methods.....	31
5.1	Characterization of membranes with different substrates	31
5.1.1	Membranes with Atech substrate	31
5.1.2	Membranes with IEK-1 substrate	32
5.1.3	Membranes with metallic ITM substrate	33
5.1.4	Mercury porosimetry	34
5.2	Determination of membrane permeability	35
5.2.1	Setup of single gas permeation tests	35
5.2.2	Set-up of mixed gas permeation tests	35

5.2.3	Performance of permeation measurements.....	41
5.3	Thermal stability evaluation.....	42
5.4	Determination of mechanical properties	44
5.4.1	Ring-on-ring bending test.....	44
5.4.2	Acoustic emission test	47
5.4.3	Indentation test	49
5.5	Microstructure identification.....	50
5.5.1	Scanning electron microscopy (SEM)	50
5.5.2	Infrared spectroscopy	51
6	Results and discussion.....	53
6.1	Characterization of membranes with different substrates	53
6.1.1	SiO ₂ -membrane with ceramic Atech substrate	53
6.1.2	SiO ₂ -membrane with ceramic IEK-1 substrate.....	53
6.1.3	SiO ₂ -membrane with metallic ITM substrate	54
6.1.4	Porosity of Atech substrate and IEK-1 substrate	55
6.2	Mechanical properties	56
6.2.1	Mechanical properties of porous ceramic substrates	56
6.2.2	Mechanical properties of porous metallic substrate	70
6.3	Permeability	79
6.3.1	SiO ₂ -membrane on ceramic Atech substrate	79
6.3.2	SiO ₂ -membrane with ceramic IEK-1 substrate.....	81
6.3.3	Amino-modified SiO ₂ -membrane on ceramic IEK-1 substrate	91
6.3.4	Permeability of SiO ₂ -membrane on porous metal substrates	98
6.4	Thermochemical stability	101
6.4.1	SiO ₂ -membrane with ceramic Atech substrate and ceramic IEK-1 substrate.	101
6.4.2	Amino-modified SiO ₂ -membrane with ceramic IEK-1 substrate.....	104
7	Conclusions	109
	References	111
	Symbol index.....	123
	Figure index.....	127
	Table index	131
	Acknowledgements	133

Energie & Umwelt /
Energy & Environment
Band / Volume 311
ISBN 978-3-95806-126-2

