

# Content

Acknowledgement .....	IV
Abstract .....	VII
Kurzfassung.....	IX
Explanation of the contribution to the publications .....	XI
Preface .....	XIX
<b>1 Introduction.....</b>	<b>1</b>
<b>1.1 Heterogeneous Catalysis.....</b>	<b>1</b>
<b>1.2 Atomic Layer Deposition.....</b>	<b>5</b>
1.2.1 Fundamentals.....	6
1.2.2 ALD for heterogeneous catalysts.....	13
1.2.3 Processes on particulate systems.....	16
<b>1.3 Objective and Outline.....</b>	<b>20</b>
<b>1.4 Substrates and ALD processes for Showcase Studies .....</b>	<b>22</b>
1.4.1 Proof-of-concept study: V <sub>2</sub> O <sub>5</sub> with phosphorus ALD .....	22
1.4.2 Validation of ALD setup: Mesoporous SiO <sub>2</sub> with Al <sub>2</sub> O <sub>3</sub> ALD .....	25
<b>1.5 References .....</b>	<b>27</b>
<b>2 Enhancing of catalytic properties of vanadia <i>via</i> surface doping with phosphorous using Atomic Layer Deposition .....</b>	<b>33</b>
<b>2.1 Abstract.....</b>	<b>33</b>
<b>2.2 Introduction.....</b>	<b>34</b>
<b>2.3 Experimental .....</b>	<b>36</b>
2.3.1 Chemicals .....	36
2.3.2 Catalyst synthesis .....	36
2.3.3 Characterization.....	38
2.3.4 Catalytic testing.....	39

2.4	<b>Results and Discussion .....</b>	<b>40</b>
2.4.1	V <sub>2</sub> O <sub>5</sub> Reference characterization .....	40
2.4.2	Phosphorus Atomic Layer Deposition.....	41
2.4.3	Phosphorus doped V <sub>2</sub> O <sub>5</sub> samples characterization.....	42
2.4.4	Selective oxidation of n-butane .....	47
2.5	<b>Summary and Conclusion .....</b>	<b>51</b>
2.6	<b>References .....</b>	<b>52</b>
<b>3</b>	<b>Atomic Layer Deposition on porous powders with <i>in situ</i></b>	
	<b>gravimetric monitoring in a modular fixed bed reactor setup</b>	<b>55</b>
3.1	<b>Abstract.....</b>	<b>55</b>
3.2	<b>Introduction.....</b>	<b>56</b>
3.3	<b>Setup Design .....</b>	<b>58</b>
3.3.1	Dosing Unit .....	59
3.3.2	Reactor Unit.....	64
3.3.3	Downstream Unit .....	67
3.3.4	Safety.....	68
3.4	<b>Experimental Section.....</b>	<b>69</b>
3.4.1	Chemicals .....	70
3.4.2	AlO <sub>x</sub> ALD Experimental.....	70
3.5	<b>Results and Discussion .....</b>	<b>71</b>
3.6	<b>Summary and Conclusion .....</b>	<b>78</b>
3.7	<b>References .....</b>	<b>79</b>
<b>4</b>	<b>Investigating the trimethylaluminium/water ALD process</b>	
	<b>on mesoporous silica by <i>in situ</i> gravimetric monitoring.....</b>	<b>83</b>
4.1	<b>Abstract.....</b>	<b>83</b>
4.2	<b>Introduction.....</b>	<b>84</b>
4.3	<b>Experimental Section.....</b>	<b>86</b>
4.3.1	Chemicals .....	86
4.3.2	AlO <sub>x</sub> ALD Experimental.....	87

4.3.3	Characterization Methods .....	88
<b>4.4</b>	<b>Results and Discussion .....</b>	<b>89</b>
4.4.1	Influence of Cycle Number .....	90
4.4.2	Influence of Substrate Temperature.....	99
4.4.3	Scale Up in Fixed Bed.....	103
<b>4.5</b>	<b>Conclusion .....</b>	<b>105</b>
<b>4.6</b>	<b>Supplemental Material .....</b>	<b>106</b>
<b>4.7</b>	<b>References .....</b>	<b>109</b>
<b>5</b>	<b>Summary &amp; Final Conclusions.....</b>	<b>111</b>
<b>6</b>	<b>Appendices.....</b>	<b>116</b>
6.1	List of Abbreviations.....	116
6.2	List of Figures .....	117