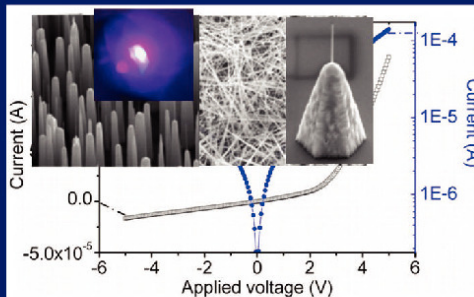




Augustine Che Mofor (Autor)  
**Fabrication and Characterisation of Device Quality  
ZnO Nanostructures**

Augustine Che Mofor

Fabrication and Characterisation of Device  
Quality ZnO Nanostructures



Cuvillier Verlag Göttingen

<https://cuvillier.de/de/shop/publications/1770>

Copyright:  
Cuvillier Verlag, Inhaberin Annette Jentsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,  
Germany  
Telefon: +49 (0)551 54724-0, E-Mail: [info@cuvillier.de](mailto:info@cuvillier.de), Website: <https://cuvillier.de>

# Table of contents

<b>1. Introduction and motivation .....</b>	<b>5</b>
<b>2. ZnO as a semiconductor and nanomaterial.....</b>	<b>8</b>
2.1 Properties of ZnO .....	8
2.1.1 Crystal and band structure of ZnO .....	8
2.1.2 Other physical properties of ZnO.....	10
2.1.3 ZnO-based ternary semiconductors.....	11
2.2 Substrates for ZnO growth .....	12
2.2.1 Commonly used substrates.....	13
2.2.2 Employed substrates and their quality .....	14
2.3 ZnO and Nanophysics .....	15
2.3.1 Nanostructures and physics.....	15
2.3.2 Some ZnO nanostructures .....	17
2.4 Fabrication approaches for ZnO nanostructures .....	18
2.4.1 Top-down approach.....	18
2.4.2 Bottom-up approach.....	20
2.5 Potential application areas for ZnO nanorods .....	22
<b>3. Employed fabrication and characterisation methods .....</b>	<b>24</b>
3.1 The Vapour transport growth method .....	24
3.1.1 Principle of vapour transport growth .....	24
3.1.2 The vapour transport growth set-up .....	26
3.1.3 Growth procedure and possibilities.....	29
3.2 Other growth methods involved in this work.....	30
3.2.1 Molecular beam epitaxy .....	31
3.2.2 Metal-organic vapour phase epitaxy .....	32
3.3 Employed characterisation methods.....	34
3.3.1 Scanning Electron Microscopy .....	34
3.3.2 X-Ray Diffractometry .....	35
3.3.3 Transmission Electron Microscopy.....	37
3.3.4 Photo- and Cathodoluminescence spectroscopy .....	39
3.3.5 I-V and C-V measurements.....	41
<b>4. Vapour transport growth and characterisation of ZnO nanorods.....</b>	<b>43</b>
4.1 Growth fundamentals and mechanism .....	43

4.1.1	Crystal growth from the vapour phase .....	43
4.1.2	Mechanism and model for nanostructure growth.....	44
4.2	Vapour transport growth of ZnO-based nanorods.....	47
4.2.1	Catalyst-assisted growth on Si .....	47
4.2.2	Catalyst-free ZnO nanorods on Al <sub>2</sub> O <sub>3</sub> and 6H-SiC.....	49
4.2.3	Influence of temperature on nanorod growth.....	51
4.2.4	Effect of pressure on nanorod growth .....	53
4.2.5	Effect of growth time on nanorod morphology.....	54
4.2.6	Growth on off-axis 4H-SiC: influence on growth parameters .....	55
4.2.7	Suggestion for selective-area growth on SiC .....	57
4.2.8	Special structure: from ZnO hexagonal pyramid to nanowhisker.....	58
4.3	Structural analysis on ZnO nanorods .....	59
4.3.1	X-ray diffractometry investigations .....	59
4.3.2	Transmission electron microscopy analysis.....	62
4.4	Optical properties of ZnO nanorods.....	63
4.4.1	Photoluminescence from ZnO nanorods .....	63
4.4.2	Cathodoluminescence analysis.....	68
4.5	Electrical property measurement on ZnO nanorods.....	70
<b>5.</b>	<b>ZnO nanorods for magnetoelectronics .....</b>	<b>73</b>
5.1	Magnetism and semiconductors .....	74
5.1.1	Magnetism phenomena .....	74
5.1.2	Magnetism in semiconductors.....	76
5.2	Employed magnetic property measurement systems .....	77
5.2.1	SQUID magnetometer.....	77
5.2.2	Magnetic force microscopy .....	79
5.3	Transition metal-doped ZnO .....	80
5.3.1	State of research in ZnTMO.....	80
5.3.1.1	Mn-doped ZnO .....	81
5.3.1.2	Fabrication and characterisation of V-doped ZnO .....	86
5.3.2	MOVPE-grown ZnO:V nanorods .....	88
5.3.3	Possible application areas for ferromagnetic ZnO nanorods .....	91
<b>6.</b>	<b>Some ZnO nanorod-based device structures .....</b>	<b>93</b>
6.1	ZnO nanorod-based p-n heterojunction.....	93
6.1.1	n-ZnO nanorods on p-4H-SiC epilayers.....	94

6.1.2 Ohmic contacts on p-SiC and n-ZnO nanorods .....	95
6.1.3 Characterisation of n-ZnO/p-SiC heterojunctions.....	97
6.2 Quantum confinement in ZnO nanorods.....	99
6.2.1 The ZnO/Zn <sub>x</sub> Mg <sub>1-x</sub> O heterostructure system .....	101
6.2.2 Growth of ZnO/ZnMgO single <i>nano</i> quantum wells .....	102
6.2.2.1 Quantum confinement .....	102
6.2.2.3 Characterisation of <i>nano</i> quantum well samples.....	104
<b>7. Summary.....</b>	<b>107</b>
<b>8. List of references .....</b>	<b>110</b>
<b>9. Publications and conference contributions .....</b>	<b>121</b>
Acknowledgement.....	127
Biography .....	128