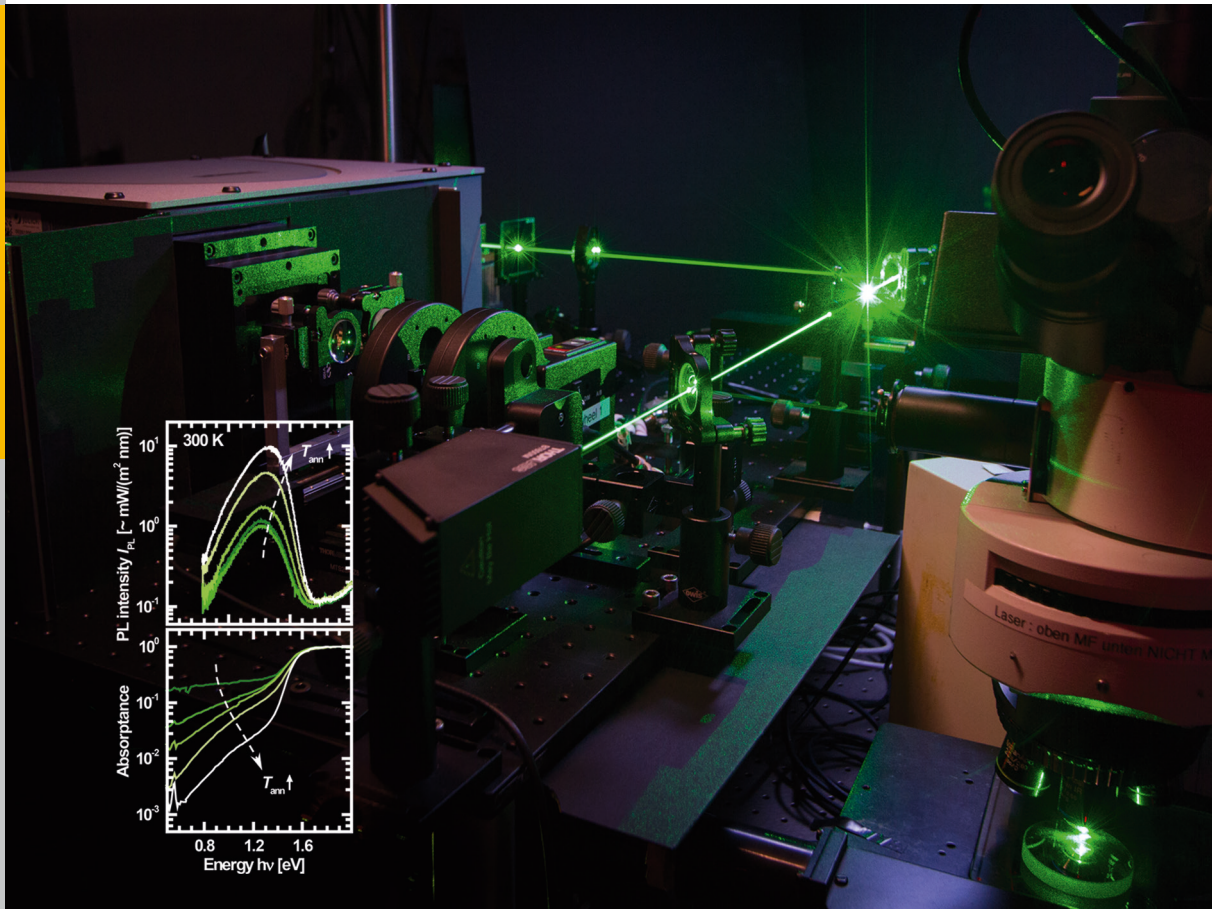


Characterization & Modification of Copper and Iron Oxide Nanoparticles for Application as Absorber Material in Silicon based Thin Film Solar Cells

Maurice René Nuys



Energie & Umwelt/
Energy & Environment
Band/ Volume 291
ISBN 978-3-95806-096-8

Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research
Photovoltaics (IEK-5)

Characterization & Modification of Copper and Iron Oxide Nanoparticles for Application as Absorber Material in Silicon based Thin Film Solar Cells

Maurice René Nuys

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

Band / Volume 291

ISSN 1866-1793

ISBN 978-3-95806-096-8

Contents

1	Introduction	1
2	Fundamentals and characterization methods	5
2.1	Raman spectroscopy	5
2.2	Photoluminescence	7
2.2.1	Electronic structure of semiconductors	7
2.2.2	Generation & recombination processes	8
2.3	Photothermal deflection spectroscopy	11
2.4	X-ray diffraction (XRD)	13
2.5	Transmission electron microscopy (TEM)	13
2.6	Scanning electron microscopy (SEM)	14
2.7	Raman and PL setup	14
2.7.1	Experimental details and data evaluation	16
2.7.1.1	Raman measurements	16
2.7.1.2	PL measurements	16
2.7.1.3	Raw data evaluation	17
3	Material properties	19
3.1	The physics of copper oxide	19
3.1.1	History of cuprite	20
3.1.1.1	Cuprite band structure	21
3.1.1.2	Absorption coefficient of cuprite	22
3.1.1.3	Non-stoichiometry of cuprite	23
3.1.1.4	Photoluminescence of cuprite	24
3.1.1.5	Raman modes of cuprite	26
3.1.2	Tenorite and paramelaconite	28
3.1.2.1	Absorption coefficient of tenorite and paramelaconite	28
3.1.2.2	Luminescence of tenorite	29
3.1.2.3	Raman modes of tenorite and paramelaconite	29
3.2	The physics of iron oxides	31
3.2.1	Structure and magnetism of Hematite, maghemite, and magnetite	31
3.2.2	Electronic structure of the hematite and maghemite	32
3.2.3	Absorption coefficient of hematite and maghemite	35
3.2.4	Luminescence of hematite and maghemite	37

3.2.5	Raman modes of hematite, maghemite, magnetite, and wustite	40
4	Characterization & modification of copper oxide nanoparticles	43
4.1	Summary of the related diploma theses	43
4.2	Pre-examination of tenorite nanoparticles by TEM	47
4.3	Oven annealing of tenorite nanoparticles	49
4.3.1	Structural modification	49
4.3.1.1	Raman spectroscopy	49
4.3.1.2	XRD	51
4.3.2	PL and PDS before phase transition	52
4.3.3	PL and PDS after phase transition towards cuprite	55
4.4	Annealing at 1000 °C in nitrogen atmosphere	57
4.5	Discussion - modification of copper oxide nanoparticles	59
4.5.1	Structural modification	59
4.5.2	Opto-electronic properties of tenorite nanoparticles	63
4.5.2.1	Shift of the emission peak	65
4.5.2.2	Defect structure in the tenorite nanoparticles	66
4.5.3	Opto-electronic properties of cuprite nanoparticles	70
4.5.3.1	PL of cuprite - comparison to literature	71
4.5.3.2	Influence of laser irradiation	73
4.5.4	Summary - characterization & modification of copper oxide nanoparticles	73
5	Characterization & modification of iron oxide nanoparticles	75
5.1	Summary of the related diploma thesis	76
5.2	Pre-examination of maghemite nanoparticles by TEM	78
5.3	Oven annealing of iron oxide nanoparticles	78
5.3.1	Untreated maghemite nanoparticles and nanoparticles annealed at 300 °C	80
5.3.2	Annealing of maghemite nanoparticles at 450 °C and 550 °C	81
5.3.3	Annealing of maghemite nanoparticles at 750 °C and 900 °C	83
5.4	Characterization of hematite nanoparticles from the DWI	84
5.4.1	TEM pre-examination of the hematite nanoparticles from the DWI	85
5.4.2	Raman, PL, and PDS measurements of the hematite nanoparticles from the DWI	85
5.5	Discussion - modification of iron oxide nanoparticles	88
5.5.1	Oven annealing of maghemite nanoparticles	88
5.5.2	Absorption of maghemite and hematite	96
5.5.3	PL in the band gap region	98
5.5.4	Raman spectra measured with different excitation wavelengths	103
5.5.5	Comparison different kind of hematite nanoparticles	104

6 Summary & Outlook	107
Literaturverzeichnis	121

**Energie & Umwelt /
Energy & Environment
Band/ Volume 291
ISBN 978-3-95806-096-8**

