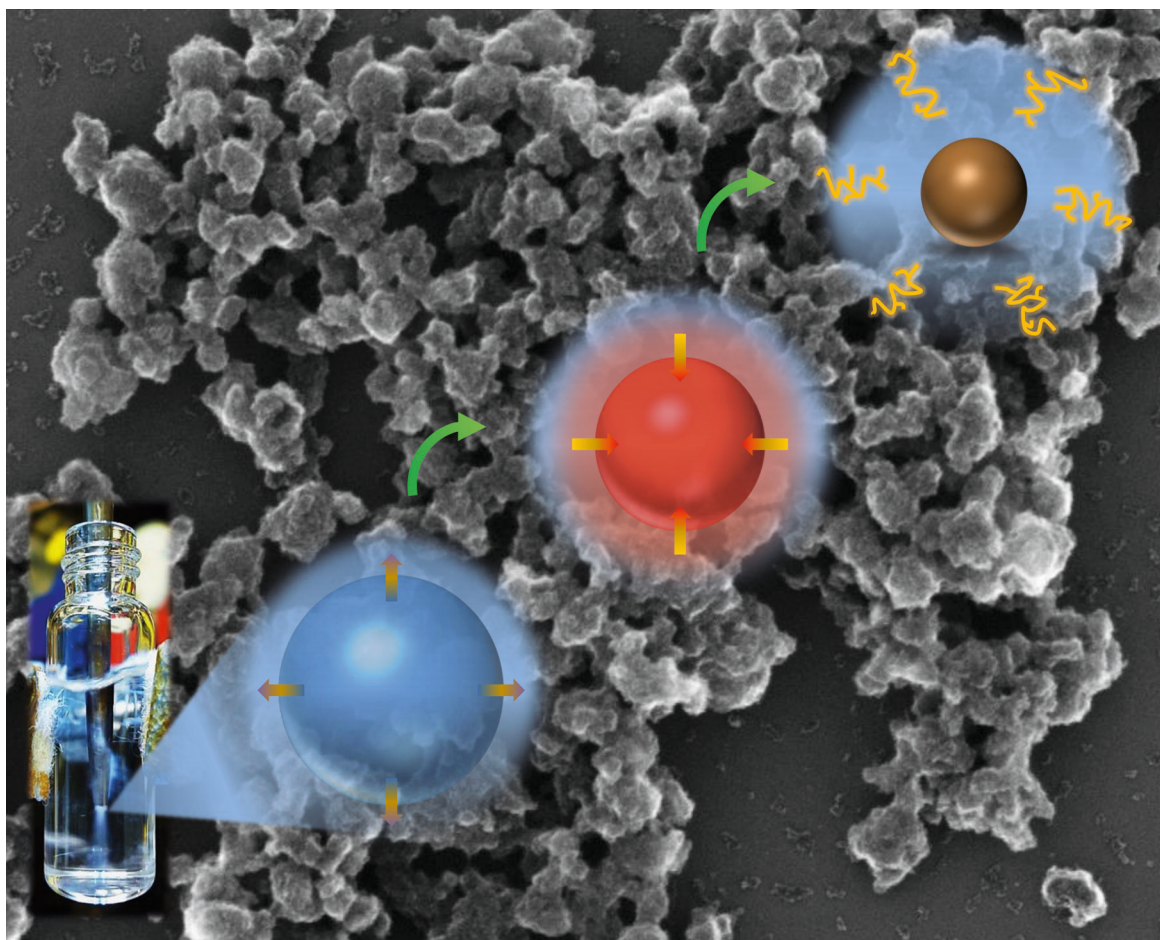




Sonochemical Synthesis of Silicon Hydride Polymers and Silicon Nanoparticles from Liquid Silanes

Andrew Paolo Cádiz Bedini

Energie & Umwelt / Energy & Environment

Band / Volume 423

ISBN 978-3-95806-329-7

Forschungszentrum Jülich GmbH
Institut für Energie- und Klimaforschung
IEK-5 Photovoltaik

Sonochemical Synthesis of Silicon Hydride Polymers and Silicon Nanoparticles from Liquid Silanes

Andrew Paolo Cádiz Bedini

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

Band / Volume 423

ISSN 1866-1793

ISBN 978-3-95806-329-7

Contents

Abstract	i
Kurzfassung	iii
1 Introduction	1
2 Fundamentals	7
2.1 Silicon Hydrides	7
2.2 Solution-Processed Silicon Hydride Polymer Inks	9
2.2.1 Monomers and Polymerisation Techniques	11
2.2.2 Solution-Processed Thin Film Deposition Methods	13
2.3 Hydrogenated Amorphous Silicon	15
2.3.1 Microstructure Factor	16
2.3.2 Estimation of Hydrogen Content	17
2.3.3 Optoelectronic Applications	18
2.4 Ultrasound and Sonochemistry	19
2.5 Silicon Nanoparticle Synthesis	21
2.6 Characterisation Techniques	23
2.6.1 Characterisation of the Silicon Polymer - Silicon Nanoparticle Composite Ink	23
2.6.2 Characterisation of Thin Films and Optoelectronic Devices .	25
2.6.3 Surface Passivation Layers	27
3 Experimental	29
3.1 Materials	29
3.2 Ink Preparation	30

Contents

3.3	Thin Film Deposition	32
3.3.1	Spin Coating	32
3.3.2	Atmospheric Pressure Chemical Vapour Deposition of Thin-Films	32
3.3.3	Plasma Enhanced Chemical Vapour Deposition of Thin-Films	34
3.4	Hot-Wire Atomic Hydrogen Treatment	34
3.5	Optical Characterisation Techniques	35
3.5.1	UV-Vis Optical Transmission Measurements	35
3.5.2	Optical Microscopy	35
3.5.3	Electron Microscopy	35
3.6	Fourier Transform Infrared Spectroscopy	36
3.7	Raman Spectroscopy	37
3.8	Photothermal Deflection Spectroscopy	37
3.9	Gas Chromatography-Mass Spectrometry	38
3.10	Nuclear Magnetic Resonance	38
3.11	Size Exclusion Chromatography	39
3.12	Electrical Conductivity Measurements	41
3.13	Optoelectronic Device Characterisation	42
3.13.1	Photovoltaic Cell Contacting and JV Curve Acquisition	42
3.13.2	Characterisation of Surface Passivation Layers	42
4	Results	43
4.1	Synthesis of Polysilane Inks from Trisilane	43
4.1.1	Ultraviolet Irradiation of Untreated Trisilane Solutions	43
4.1.2	Ultrasonic Irradiation of Trisilane Solutions	44
4.1.3	Irradiation of Sonicated Trisilane Solutions with UV Light	50
4.1.4	UV-Vis Transmission Measurements	52
4.1.5	Gas Chromatography-Mass Spectrometry	54
4.1.6	Nuclear Magnetic Resonance	57
4.1.7	Pyrolytic Treatment of Trisilane Solutions	59
4.1.8	Preparation of p-Type Inks using Decaborane and Trisilane	60
4.1.9	Summary of Polysilane Ink Synthesis from Trisilane Precursor	61

4.2	Synthesis of Polysilane Inks from Cyclopentasilane	63
4.2.1	On The Non-“Macrothermal” Nature of the Sonolytic Treatment	64
4.2.2	Polymer Growth via Sonication using Cyclopentasilane as Precursor	70
4.2.3	Summary of Polysilane Ink Synthesis using Cyclopentasilane Precursor	72
4.3	Synthesis of Silicon Nanoparticles from Trisilane	73
4.3.1	Formation Mechanism	73
4.3.2	Analysis of the Silicon Nanoparticles via Electron Microscopy Techniques	75
4.3.3	Analysis of the Silicon Nanoparticles via Infrared Spectroscopy	78
4.3.4	Raman Spectroscopy	83
4.3.5	X-Ray Photoelectron Spectroscopy	85
4.3.6	Summary of Silicon Nanoparticle Synthesis	87
4.4	Thin Films Deposition, Growth, and Conversion	89
4.4.1	Spin-Coated Silicon Hydride Polymer Films	89
4.4.2	Formation of Hydrogenated Amorphous Silicon via Pyrolytic Conversion	90
4.4.3	Films Grown via Atmospheric Pressure Chemical Vapour Deposition using Trisilane	95
4.4.4	Summary of Film Deposition, Growth and Conversion	98
4.5	Thin Film Post-Treatment and Characterisation	99
4.5.1	Hydrogen Radical Treatment via Hot-Wire	99
4.5.2	Passivated Films from Inks Prepared from Cyclopentasilane	101
4.5.3	Passivated Films from Inks Prepared from Trisilane	105
4.5.4	Summary of Film Post-Treatment and Characterisation	119
4.6	Optoelectronic Applications	122
4.6.1	Photovoltaic Devices	122
4.6.2	Passivation Layers	123
4.6.3	Summary of Optoelectronic Applications	125
5	Summary and Outlook	127
	Summary	127

Contents

Outlook	130
Acknowledgements	I
Bibliography	III

Energie & Umwelt / Energy & Environment
Band / Volume 423
ISBN 978-3-95806-329-7