

Integration of Redox-Based Resistive Switching Memory Devices

Florian Lentz

Forschungszentrum Jülich GmbH
Peter Grünberg Institute (PGI)
Electronic Materials (PGI-7)

Integration of Redox-Based Resistive Switching Memory Devices

Florian Lentz

Schriften des Forschungszentrums Jülich
Reihe Information / Information

Band / Volume 41

ISSN 1866-1777

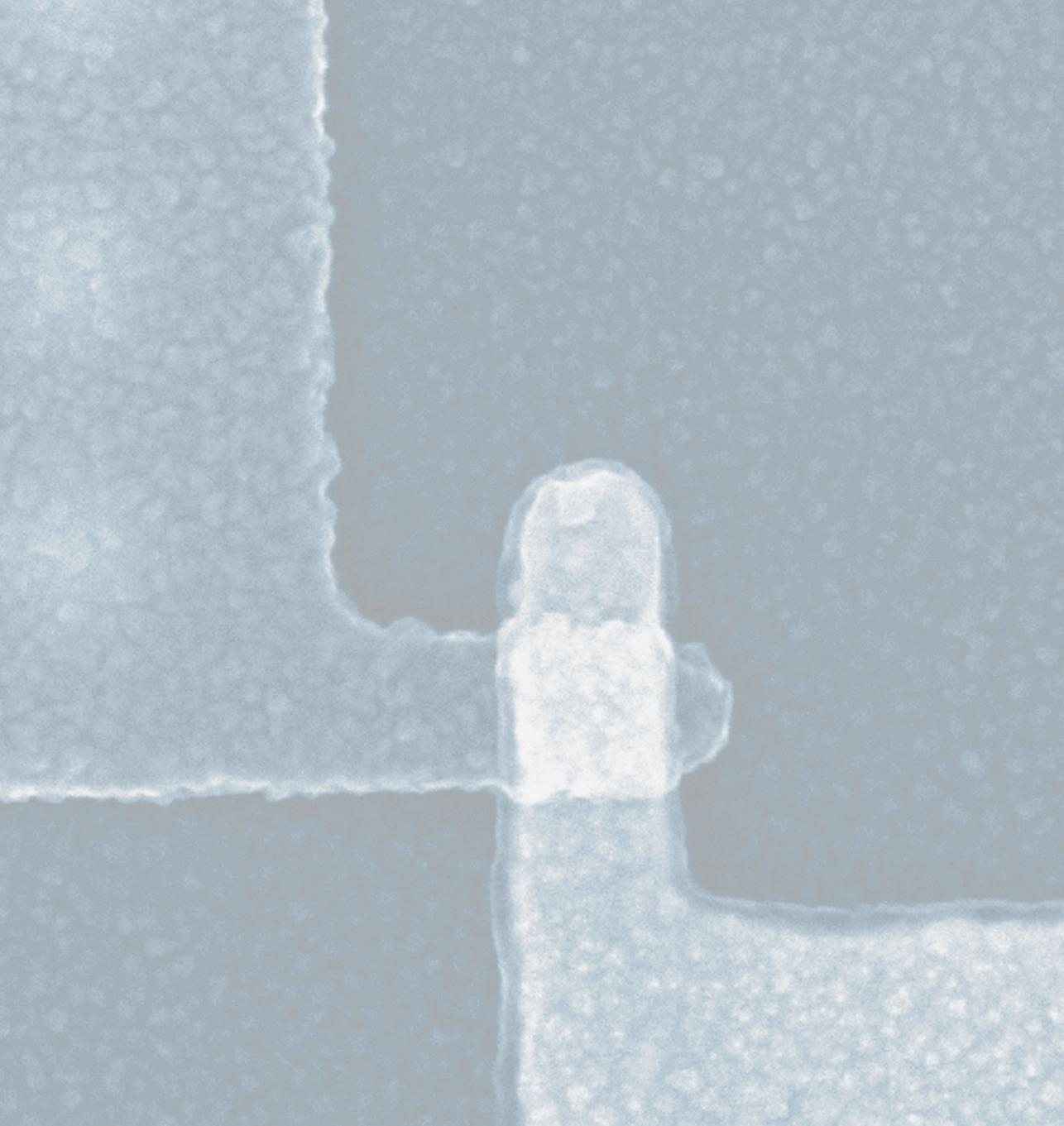
ISBN 978-3-95806-019-7

Contents

1	Introduction	1
1.1	Scope of this work	2
2	Redox-Based Resistive Switching RAM	3
2.1	Mechanisms and Materials	3
2.1.1	Electrochemical Metallization Memory	6
2.1.2	Valence Change Memory	8
2.2	ReRAM Crossbar-Array Integration	9
3	Fabrication of ReRAM Devices	15
3.1	Equipment and Experimental Methods	15
3.1.1	Thin Film Deposition Techniques	15
3.1.1.1	Sputter Deposition	15
3.1.1.2	Thermal Evaporation	17
3.1.2	Lithography Methods	19
3.1.2.1	Optical Lithography	19
3.1.2.2	Electron Beam Lithography	22
3.1.2.3	Nanoimprint Lithography	27
3.1.3	Etching	30
3.1.3.1	Wet Etching	30
3.1.3.2	Dry Etching	31
3.1.4	Physical Characterization Methods	33
3.1.4.1	Scanning Electron Microscopy	33
3.1.4.2	Surface Profilometry	35
3.1.5	Electrical Characterization Setup	36
3.1.5.1	Automated Quasi-Static IV-Characterization .	36

3.1.5.2	Voltage Pulse Measurement Setup	37
3.2	Nano-Crossbar Device Fabrication	41
3.2.1	Development of the Imprint Mold	41
3.2.1.1	Mask Design	49
3.2.2	Pattern Transfer	51
3.2.2.1	UV-Nanoimprint Process	51
3.2.2.2	Development of the Etch-Proceses	54
3.2.2.3	Electrical Characteristics of the Nano-Electrodes	60
3.2.3	Top Electrode Patterning	63
3.3	Integration of ReRAM Devices with MOSFETs	66
3.3.1	Mask Layout	67
3.3.2	Development of the Process Flow	69
3.3.2.1	Oxide Deposition	69
3.3.2.2	Top Electrode Patterning by E-Beam Lithography	71
4	Electromotive Force in ReRAM Devices	77
4.1	Theory	77
4.2	EMF in ECM Systems	78
4.3	Impact of the EMF on ReRAM Devices	82
5	Electrical Characterization of Nano-Crossbar Memory Elements	85
5.1	TiO ₂ Based Nano-Crossbar ReRAM	85
5.1.1	Electroforming Characteristics	86
5.1.1.1	TiO ₂ Layer Thickness Dependence	88
5.1.1.2	Impact of the External Series Resistance	89
5.1.1.3	Influence of the Top Electrode Layer Material .	91
5.1.1.4	Electroforming at Elevated Temperature	94
5.1.2	Transient Pulse Characterization	95
5.2	WO ₃ Based Nano-Crossbar ReRAM	99
5.2.1	Electroforming Characteristics	99
6	Electrical Characterization of Integrated ReRAM Devices	103
6.1	MOSFET Characterization	103
6.2	TiO ₂ based ReRAM in 1T-1R configuration	105

6.2.1	Quasi-static Electrical Characterization of Integrated ReRAM	105
6.2.2	Electroforming Characteristics of TiO ₂ based ReRAM in 1T-1R Configuration	106
6.2.2.1	Impact of the Current Compliance	106
6.2.2.2	Impact of the Cell Size and the Oxide Layer Thickness	109
6.2.3	SET and RESET Characteristics	112
6.2.3.1	Variability in the Resistive Switching Charac- teristics	114
6.2.4	AC Nonlinearity of the Integrated 1T-1R Devices	118
6.2.5	Ultra Low Current Switching in TiO ₂ Based ReRAM	122
6.2.5.1	Quasi-static Electrical Characterization	122
6.2.5.2	AC Characterization	125
6.3	WO ₃ based ReRAM in 1T-1R configuration	129
6.3.1	Electroforming Behavior	129
6.3.2	Variability in the SET and RESET Characteristics	130
6.4	Issues Regarding 1T-1R Characterization	133
7	Conclusion and Outlook	135
7.1	Technology Improvements	135
7.2	Electromotive Force in ReRAM	136
7.3	TiO ₂ and WO ₃ based Nano-Crossbar Structures	136
7.4	ReRAM Elements in 1T-1R Configuration	137
7.5	Outlook	137



**Information/Information
Band / Volume 41
ISBN 978-3-95806-019-7**

