



Unveiling the relaxation dynamics of Ag/HfO₂ based diffusive memristors for use in neuromorphic computing

Solomon Amsalu Chekol

Information
 Band / Volume 101
 ISBN 978-3-95806-729-5

Forschungszentrum Jülich GmbH
Peter Grünberg Institut (PGI)
Elektronische Materialien (PGI-7)

Unveiling the relaxation dynamics of Ag/HfO₂ based diffusive memristors for use in neuromorphic computing

Solomon Amsalu Chekol

Schriften des Forschungszentrums Jülich
Reihe Information / Information

Band / Volume 101

ISSN 1866-1777

ISBN 978-3-95806-729-5

Contents

1	Introduction	1
2	Fundamentals	7
2.1	Fundamentals of Memristive Devices	7
2.2	Principle of Electrochemical Metallization (ECM) Cells	9
2.3	Charge Carrier Transport Mechanisms and SET Kinetics of ECM Cells	14
2.4	Diffusive Memristors	17
2.5	Material Properties	22
2.5.1	Metals	22
2.5.2	Oxides	23
3	Experimental methods	25
3.1	Thin Film Deposition	25
3.1.1	Atomic Layer Deposition (ALD)	25
3.1.2	Physical Vapor Deposition (PVD)	31
3.2	Thin Film Analysis	35
3.3	Device Fabrication	36
3.3.1	Crossbar Devices	36
3.3.2	Nano Plug Devices	38
3.3.3	Samples Used in This Work	39
3.4	Electrical Measurements	40
4	Threshold Switching in Diffusive Memristors	45
4.1	Threshold Switching in Ag/HfO ₂ /Pt Cells	45
4.1.1	Initial Forming Behavior	45
4.1.2	Threshold Switching	48
4.1.3	Device Scalability	56
4.1.4	Influence of the Sweep Rate on Threshold Voltage	57
4.1.5	Influence of Counter Electrode on Device Performance	60
4.2	Threshold Switching in Ag/SiO ₂ /Pt Cell	67
4.2.1	Initial Forming Behavior	67
4.2.2	Threshold Switching	68
4.3	Comparison and Summary	69

5	SET Kinetics of Diffusive Memristors	71
5.1	SET Kinetics of HfO ₂ -based Diffusive Memristor	71
5.1.1	Impact of Voltage on the SET Kinetics	72
5.1.2	Impact of a Series Resistor on the SET Kinetics	75
5.1.3	Influence of Counter Electrode on the SET Kinetics	80
5.2	SET Kinetics of SiO ₂ -based Diffusive Memristor	84
5.3	Comparison and Summary	86
6	Relaxation Behavior of Diffusive Memristors	89
6.1	Relaxation Dynamics of HfO ₂ -based Cells	89
6.1.1	Impact of Programming Scheme on Relaxation Behavior	89
6.1.2	Origin of the Relaxation Time Dependence on Programming Pulse Width	91
6.1.3	Impact of Series Resistor on the Relaxation Dynamics	93
6.1.4	Impact of Sweep Rate on the Relaxation Dynamics	100
6.2	Relaxation Dynamics of Ag/SiO ₂ -based Cells	105
6.2.1	Impact of Programming Scheme on Relaxation Behavior	105
6.3	Comparison and Summary	106
7	Correlation between the SET Kinetics and Relaxation Behavior	109
7.1	Interdependence of SET and Relaxation Processes	109
7.2	Filament Evolution During SET Process and Relaxation Behavior	111
7.3	Series Resistor and its Implications in Device Operation	116
8	Applications of Diffusive Memristors	119
8.1	Design Rule of Diffusive Memristors for Emerging Applications	119
8.2	Diffusive Memristors as Synaptic Emulators	121
8.3	Diffusive Memristors as Artificial Neuronal Elements	124
9	Summary and Outlook	129
	Appendix A Numerical and Analytical JART ECM Models	133
	Appendix B Device Fabrication Protocols	135
B.1	Micro-crossbar structure fabrication AZ 5214E resist	135
B.2	Micro-crossbar structure fabrication AZ MIR 701 and AZ nLOF 2020 resists	137
B.3	Nanoplug structure fabrication	139
	List of Abbreviations	141
	List of Publications	159
	Bibliography	161

Information

Band / Volume 101

ISBN 978-3-95806-729-5

Mitglied der Helmholtz-Gemeinschaft

