



Universiteit  
Leiden  
The Netherlands

## Resistive switching in mixed conductors : Ag<sub>2</sub>S as a model system

Morales Masis, M.

### Citation

Morales Masis, M. (2012, January 12). *Resistive switching in mixed conductors : Ag<sub>2</sub>S as a model system*. Casimir PhD Series. Retrieved from <https://hdl.handle.net/1887/18364>

Version: Not Applicable (or Unknown)

License: [Leiden University Non-exclusive license](#)

Downloaded from: <https://hdl.handle.net/1887/18364>

**Note:** To cite this publication please use the final published version (if applicable).

RESISTIVE SWITCHING IN MIXED CONDUCTORS

$\text{Ag}_2\text{S}$  as a model system



RESISTIVE SWITCHING IN MIXED CONDUCTORS  
Ag<sub>2</sub>S as a model system

**Proefschrift**

ter verkrijging van  
de graad van Doctor aan de Universiteit Leiden,  
op gezag van Rector Magnificus prof. mr. P. F. van der Heijden,  
volgens besluit van het College voor Promoties  
te verdedigen op donderdag 12 januari 2012  
klokke 10:00 uur

door

MONICA MORALES MASIS

geboren te Cartago, Costa Rica  
in 1982

## Promotiecommissie

Promotor: Prof. dr. J. M. van Ruitenbeek

Overige leden: Prof. dr. E. R. Eliel

Prof. dr. H. D. Wiemhöfer Universität Münster

Prof. dr. ir. H.J.W. Zandvliet Universiteit Twente

Prof. dr. J. Aarts

Dr. ir. S. J. van der Molen

Dr. A. I. Yanson

ISBN: 978-90-8593-115-7

Casimir PhD series, Delft-Leiden 2012-2



This work is part of the research program of the Foundation for Fundamental Research on Matter (FOM), which is part of the Netherlands Organization for Scientific Research (NWO).

**Cover:** design by Monica Morales Masis

*A mis padres*



# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Introduction and Motivation . . . . .	2
1.2	Resistance Switching in Chalcogenides . . . . .	3
1.3	$\text{Ag}_2\text{S}$ as the model system to study conductance switching effects	12
1.4	Concepts and phenomenological transport equations of mixed conductors . . . . .	16
1.5	Conclusion . . . . .	19
<b>2</b>	<b><math>\text{Ag}_2\text{S}</math>: Fabrication and Characterization Techniques</b>	<b>21</b>
2.1	Introduction . . . . .	22
2.2	Sulfurization of Silver Thin Films . . . . .	23
2.3	Reactive Sputtering of $\text{Ag}_2\text{S}$ thin films . . . . .	30
2.4	Fabrication of in-plane electrodes and $\text{Ag}_2\text{S}$ deposition issues . . . . .	32
2.5	Conclusions . . . . .	35
<b>3</b>	<b>Conductance switching in <math>\text{Ag}_2\text{S}</math> devices fabricated by sulphurization</b>	<b>37</b>
3.1	Introduction . . . . .	38
3.2	Measurement setup . . . . .	38
3.3	Electrical conductivity . . . . .	39
3.4	Electrical Switching . . . . .	40
3.5	Conclusion . . . . .	47
<b>4</b>	<b>Towards a Quantitative Description of Solid Electrolyte Conductance Switches</b>	<b>49</b>
4.1	Introduction . . . . .	50
4.2	Measurement setup . . . . .	51
4.3	Results . . . . .	51
4.4	Theory . . . . .	53

## Contents

---

4.5 Discussion . . . . .	59
4.6 Conclusion . . . . .	64
4.7 Appendix . . . . .	65
<b>5 Bulk and Surface Nucleation Processes in Ag<sub>2</sub>S Conductance Switches</b>	<b>67</b>
5.1 Introduction . . . . .	68
5.2 Experimental procedure . . . . .	68
5.3 Conditions for vacuum tunneling on Ag <sub>2</sub> S . . . . .	69
5.4 Nucleation and Conductance Switching . . . . .	70
5.5 Topography scans . . . . .	76
5.6 Discussion . . . . .	78
5.7 Conclusion . . . . .	83
<b>6 Observing “Quantized” Conductance Steps in Silver Sulfide: Two Parallel Resistive Switching Mechanisms</b>	<b>85</b>
6.1 Introduction . . . . .	86
6.2 Experimental details . . . . .	86
6.3 Results . . . . .	87
6.4 Discussion . . . . .	93
6.5 Conclusion . . . . .	96
<b>7 Discussion and Outlook</b>	<b>97</b>
7.1 Introduction . . . . .	98
7.2 Ag <sub>2</sub> S as a model material to study conductance switching . . . . .	98
7.3 Ag <sub>2</sub> S as a material for resistive memories . . . . .	99
7.4 Challenges for the future of conductive bridge memories . . . . .	99
7.5 Conclusion . . . . .	101
<b>Appendix A</b>	<b>103</b>
<b>Bibliography</b>	<b>105</b>
<b>Summary</b>	<b>111</b>
<b>Samenvatting voor de leek</b>	<b>115</b>
<b>Acknowledgments</b>	<b>121</b>
<b>Curriculum vitae</b>	<b>123</b>