Resistive switching phenomena in stacks of binary transition metal oxides grown by atomic layer deposition

Hehe Zhang
Resistive switching phenomena in stacks of binary transition metal oxides grown by atomic layer deposition

Hehe Zhang
Contents

Abstract i
Kurzfassung iii
Acknowledgements v
1 Introduction 1
  1.1 State of the art 2
  1.2 Scope of this work 3
2 Fundamentals 5
  2.1 Emerging memories 5
  2.2 Integration of ReRAM cells 6
  2.3 Principle of the VCM-type ReRAM 11
  2.4 Electronic transport mechanisms 14
    2.4.1 Tunneling 14
    2.4.2 Thermionic emission 16
    2.4.3 Poole-Frenkel emission 18
    2.4.4 Hopping conduction 19
    2.4.5 Ohmic conduction 20
    2.4.6 Summary for the transport mechanisms 20
  2.5 Properties of the Materials 21
    2.5.1 Titanium dioxide 21
    2.5.2 Aluminium oxide 24
3 Experimental methods 27
  3.1 Thermal atomic layer deposition (ALD) 27
    3.1.1 Overview and principle of ALD 27
    3.1.2 Typical precursors for ALD of Al₂O₃ and TiO₂ 31
    3.1.3 Technical parameters of liquid injection thermal ALD 31
  3.2 Structural characterization methods 34
    3.2.1 X-ray reflectivity 34
7.2.2 HRS in the Pt/4.8 nm Al₂O₃/Ti device ............................ 107
7.2.3 HRS in the Pt/3 nm Al₂O₃/3 nm TiO₂/Ti device .................. 109
7.2.4 HRS in the Pt/3 nm TiO₂/3 nm Al₂O₃/Ti device ................. 111
7.2.5 Summary for HRS ................................................. 113
7.3 Conduction behavior in the low resistance state ................. 115
  7.3.1 LRS in single-layer devices .................................. 115
  7.3.2 LRS in bilayer devices ....................................... 117
7.4 Summary and discussion .............................................. 118

8 Eightwise resistive switching in TiO₂-based nano-structures 121
  8.1 Characteristic phenomena in 8w BRS devices ................... 122
    8.1.1 Coexistence of c8w and 8w BRS ............................ 122
    8.1.2 Transition from different 8w states to c8w BRS ........... 123
    8.1.3 Stability of 8w resistance states in Pt/TiO₂/Ti devices .... 124
    8.1.4 Multilevel states in 8w BRS ............................... 126
    8.1.5 Interface effect in Pt/(Al₂O₃)/TiO₂/Ti devices ........... 130
    8.1.6 Interface effect in Pt/TiO₂/Al₂O₃/TE device ............. 131
  8.2 Electronic transport in 8w BRS devices ........................ 132
    8.2.1 Temperature related I(V) behavior in 8w states ........ 132
    8.2.2 Electronic conduction behavior in the 8w BRS states .. 134
  8.3 Summary and discussion .......................................... 143

9 Final summary and outlook .............................................. 149

Appendix A Temperature related I(V) analysis for the initial state 153
  A.1 Pt/3 nm Al₂O₃/3 nm TiO₂/Ti device ............................ 153
  A.2 Pt/3 nm TiO₂/3 nm Al₂O₃/Ti device ............................ 155

Appendix B Rₜh and Wₐ optimization ................................. 157

Appendix C Thickness analysis on TiO₂ films grown by FlexAL ALD 159

Appendix D List of Symbols ............................................ 161

Abbreviation .............................................................. 164

Bibliography .............................................................. 169
Resistive switching phenomena in stacks of binary transition metal oxides grown by atomic layer deposition

Hehe Zhang

Diagram showing the resistive switching behavior with voltage and current.