Contents

1 Research Background and Motivation ........................................ 1
  1.1 General Concept of Anodic Porous Alumina ....................... 1
  1.2 Various Applications of Anodic Porous Alumina ............... 2
    1.2.1 Applications in Photonic Crystals ....................... 2
    1.2.2 Applications in Energy Storage and Conversion ....... 3
    1.2.3 Applications in Bio-devices ......................... 4
    1.2.4 Applications in Electronic/Magnetic Devices ......... 5
  1.3 Formation Mechanisms of Anodic Porous Alumina ............. 6
  1.4 Fabrication Methods for Self-ordered Anodic
      Porous Alumina ........................................... 10
    1.4.1 Mild Anodization and Hard Anodization ............... 10
    1.4.2 Anodization with Prepatterns on Aluminum
          Substrate .............................................. 11
    1.4.3 Anodic Porous Alumina Formed on Aluminum
          Grains with Different Crystallographic
          Orientations ........................................... 12
    1.4.4 Other Anodization Methods .......................... 13
  1.5 Objectives and Flow of the Present Research ............... 13
References .......................................................... 15

Part I  Modelling, Numerical Simulation, and Experimental
Verification of Self-ordering in Anodic Porous Alumina

2 Establishment of a Kinetics Model ....................................... 23
  2.1 Introduction .................................................. 23
  2.2 Electric Potential Distribution Within Anodic
      Porous Alumina ........................................... 23
Part III Electro-Chemo-Mechanical Actuations of Anodic Porous Alumina

8 Charge-Induced Reversible Bending in Anodic Porous Alumina–Aluminum Composites
  8.1 Introduction ............................................. 129
  8.2 Direct Observation of the Reversible Bending by Optical Microscope. ....................... 130
  8.3 Detection of the Reversible Bending by In Situ Nanoindentation ......................... 133
  8.4 Discussion of the Reversible Bending ........................................... 137
  8.5 Summary ............................................. 140
  References ............................................. 140

9 Chemomechanical Softening During In Situ Nanoindentation of Anodic Porous Alumina with Anodization Processing ............................................. 143
  9.1 Introduction ............................................. 143
  9.2 Experimental Method ............................................. 144
    9.2.1 Electrochemical Cell Setup. ....................... 144
    9.2.2 In Situ and Ex Situ Nanoindentation ............... 145
    9.2.3 Drift Correction Method for Nanoindentation ........ 145
    9.2.4 In Situ and Ex Situ Microindentation ............. 147
    9.2.5 Electron Microscopic Characterization ............. 148
  9.3 Softening During In Situ Nanoindentation ............................................. 148
  9.4 Possible Explanations of the In Situ Softening ............................................. 153
    9.4.1 Electric-Field Assisted Softening of the Oxide .......... 153
    9.4.2 Enhancement of Electrochemical Reactions at the Metal/Oxide Interface ............... 154
    9.4.3 Enhancement of Dislocation Activities in Aluminum Substrate ....................... 154
  9.5 TEM Examination of Deformation of Oxide and Aluminum Substrate .................... 155
  9.6 Enhancement of Electrochemical Reactions at the Metal/Oxide Interface by High Electric-Field and Stresses ............................................. 157
  9.7 Summary ............................................. 159
  References ............................................. 160
10 Conclusions and Future Work ........................................ 161
  10.1 Conclusions .................................................. 161
  10.2 Future Work ................................................ 164
    10.2.1 Modeling and Numerical Simulation ................. 164
    10.2.2 Fabrication ........................................... 165
    10.2.3 Actuation ............................................ 165
References ......................................................... 166

Appendix I: Calculation Program for Pore Channel Growth
  in Anodic Porous Alumina ................................. 167

Appendix II: Calculation Program for Evaluation
  of Self-ordering in Anodic Porous Alumina ............. 229
2015, XVII, 278 p. 70 illus., 49 illus. in color., Hardcover ISBN: 978-3-662-47267-5