# Table of Contents

**Chapter 1 Introduction to MEMS**

1.1 Introduction  
1.2 Commercial Applications of MEMS  
1.3 MEMS Markets  
1.4 Top 30 MEMS Suppliers  
1.5 Introduction to MEMS Packaging  
1.6 MEMS Packaging Patents Since 2001  
1.6.1 US MEMS Packaging Patents  
1.6.2 Japan MEMS Packaging Patents  
1.6.3 Worldwide MEMS Packaging Patents  
1.7 References

**Chapter 2 Advanced MEMS Packaging**

2.1 Introduction  
2.2 Advanced IC Packaging  
2.2.1 Moore’s Law vs. More Than Moore  
2.2.2 3D IC Integration and WLP  
2.2.3 Low-Cost Solder Microbumps for 3D IC SiP  
2.2.4 Thermal Management of 3D IC SiP with TSV  
2.3 Advanced MEMS Packaging  
2.3.1 3D MEMS WLP – Designs and Materials  
2.3.2 3D MEMS WLP – Processes  
2.4 References

**Chapter 3 Enabling Technologies for Advanced MEMS Packaging**

3.1 Introduction  
3.2 TSV for MEMS Packaging  
3.2.1 Via formations  
3.2.2 Dielectric Isolation Layer (SiO2) Deposition  
3.2.3 Barrier/Adhesion and Seed Metal Layer Deposition  
3.2.4 Via Filling  
3.2.5 Cu polishing by Chemical/Mechanical polish (CMP)  
3.2.6 Fabrication of ASIC Wafer with TSV  
3.2.7 Fabrication of Cap Wafer with TSV and Cavity  
3.3 Piezoresistive Stress Sensors for MEMS Packaging  
3.3.1 Design and Fabrication of Piezoresistive Stress Sensors  
3.3.2 Calibration of Stress Sensors  
3.3.3 Stresses in Wafers After Mounting on a Dicing Tape  
3.3.4 Stresses in Wafers After Thinning (Back-Grinding)  
3.4 MEMS Wafer Thinning and Thin-Wafer Handling  
3.4.1 3M Wafer Support System  
3.4.2 EV Group’s Temporary Bonding and DeBonding System  
3.4.3 A Simple Support-Wafer Method for Thin Wafer Handling  
3.5 Low-Temperature Bonding for MEMS Packaging  
3.5.1 How Does Low Temperature Bonding with Solders Work?  
3.5.2 Low Temperature C2C Bonding  
3.5.3 Low Temperature C2W Bonding  
3.5.4 Low Temperature W2W Bonding  
3.6 MEMS Wafer Dicing  
3.6.1 Fundamentals of Stealth Dicing (SD) Technology  
3.6.2 Dicing of SOI Wafers  
3.6.3 Dicing of Silicon-on-Silicon Wafers  
3.6.4 Dicing of Silicon-on-Glass Wafers  
3.7 RoHS Compliant MEMS Packaging  
3.7.1 EU RoHS  
3.7.2 What is the Definition of X-free, e.g., Pb-free?  
3.7.3 What is a Homogeneous Material?  
3.7.4 What is the TAC?  
3.7.5 How a Law is Published in EU RoHS?  
3.7.6 EU RoHS Exemptions  
3.7.7 Current Status of RoHS Compliance in the Electronics Industry  
3.7.8 Lead-Free Solder Joint Reliability of MEMS Packages
Chapter 4 Advanced MEMS Wafer Level Packaging

4.1 Introduction
4.2 Micromachining, Wafer Bonding Technologies and Interconnects
4.2.1 Thin Film Technologies
4.2.2 Bulk Micromachining Technologies
4.2.3 Conventional Wafer Bonding Technologies for Packaging
4.2.4 Plasma Assisted Wafer Bonding Technology
4.2.5 Electrical Interconnects
4.2.6 Solder Based Intermediate Layer Wafer Bonding Technology
4.3 Wafer Level Encapsulation
4.3.1 High Temperature Encapsulation Process
4.3.2 Low Temperature Encapsulation Process
4.4 Wafer Level Chip Capping and MCM Technologies
4.5 Wafer Level MEMS Packaging Based on Low Temperature Solders – Case Study
4.5.1 Case study – In/Ag system of non-eutectic composition
4.5.2 Case study – Eutectic InSn solder for Cu/Ni/Au based metallization
4.6 Summary and Future Outlooks
4.7 References

Chapter 5 Optical MEMS Packaging - Communications

5.1 Introduction
5.2 Actuation Mechanisms and Integrated Micromachining Processes
5.2.1 Electrostatic Actuation
5.2.2 Thermal Actuation
5.2.3 Magnetic Actuation
5.2.4 Piezoelectric Actuation
5.2.5 Integrated Micromachining Processes
5.3 Optical Switches
5.3.1 Small Scale Optical Switches
5.3.2 Large Scale Optical Switches
5.4 Variable Optical Attenuators
5.4.1 Early Development Works
5.4.2 Surface Micromachined VOAs
5.4.3 DRIE Derived Planar VOAs Using Electrostatic Actuators
5.4.4 DRIE Derived Planar VOAs Using Electrothermal (Thermal) Actuators
5.4.5 3-D VOAs
5.4.6 VOAs Using Various Mechanisms
5.5 Packaging, Testing and Reliability Issues
5.5.1 Manufacturability and Self-assembly
5.5.2 Case Study – VOAs
5.5.3 Case Study – Optical Switches
5.6 Summary and Future Outlooks
5.7 References

Chapter 6 Optical MEMS Packaging - Bubble Switch

6.1 Introduction
6.2 3D Optical MEMS Packaging
6.3 Boundary Value Problem
6.3.1 Geometry
6.3.2 Materials
6.3.3 Loading Conditions
6.4 Nonlinear Analyses of the 3D Photonic Switch
6.4.1 Creep Hysteresis Loops
6.4.2 Deflections
6.4.3 Shear Stress Time-History
6.4.4 Shear Creep Strain Time-History
6.4.5 Creep Strain Energy Density Range
6.5 Isothermal Fatigue Tests and Results
6.5.1 Sample Preparation
6.5.2 Test Set-Up and Procedures
6.5.3 Test Results
6.6 Thermal-Fatigue Life Prediction of the Sealing Ring
6.7 Summary
6.8 Appendix A: Package Deflection by Twyman-Green Interferometry Method
6.8.1 Sample Preparation
6.8.2 Test Setup and Procedure
6.8.3 Temperature Conditions
6.8.4 Measurement Results
6.9 Appendix B: Package Deflection by Finite Element Method
6.10 Appendix C: Finite Element Modeling of the Bolt
6.11.1 Description of Bolted Model
6.11.2 Responses of Bolted Photonic Switch
Chapter 7 Bolometer MEMS Packaging

7.1 Introduction
7.2 Bolometer chip
7.3 Thermal optimization
7.3.1 Final temperature stability testing
7.4 Structural optimization of package
7.5 Vacuum packaging of Bolometer
7.5.1 Ge Window
7.6 Getter attachment and activation
7.7 Outgassing study in a Vacuum package
7.8 Testing set up for Bolometer
7.9 Image testing
7.10 References

Chapter 8: Bio MEMS Packaging

8.1 Introduction
8.2 BioMEMS chip
8.3 Micro fluidic components
8.3.1 Micro fluidic cartridge
8.3.2 Biocompatible polymeric materials
8.4 Microfluidic Packaging
8.4.1 Polymer microfabrication techniques
8.4.2 Replication technologies
8.4.3 Overview of existing DNA and RNA extractor bio-cartridges
8.5 Fabrication of PDMS layers
8.6 Assembly of PDMS microfluidic packages
8.6.1 Microfluidic package with out reservoirs
8.6.2 Development of Reservoir and Valve
8.7 Self contained Micro fluidic cartridge
8.7.1 Micro fluidic package with self contained reservoirs
8.7.2 Reservoir design for controlled fluid flow
8.7.3 Pin valve design
8.7.4 Fluid Flow control Mechanism
8.8 Fabrication
8.8.1 Substrate fabrication
8.8.2 Material selection for the reservoir membrane
8.9 Permeability of material
8.10 Thermo Compression Bonding
8.10.1 Bonding of PMMA to PMMA for Channel layer
8.10.2 Polypropylene to PMMA for Reservoir and channel layer
8.10.3 Tensile Test
8.11 Microfluidic Package Testing
8.11.1 Fluidic testing
8.11.2 Biological Testing on bio-sample
8.12 Sample Preparation and Set Up
8.12.1 Pre treatment of the cartridge
8.12.2 DNA Extraction
8.12.3 PCR amplification
8.13 References

Chapter 9 Bio Sensor MEMS Packaging

9.1 Introduction
9.1.1 Review of Optical Coherence Tomography
9.2 Biosensor packaging
9.2.1 Upper Substrate
9.2.2 Single Mode Optical Fiber and Graded Index Lens
9.2.3 Lower Substrate
9.2.4 Micro Mirror
9.3 The Package
9.3.1 The Configuration of the Probe
9.3.2 Optical Properties and Theories
9.3.3 Evaluations of Parameters
9.4 Optical Simulation
9.4.1 Optical model of the Probe
9.4.2 Effect of Mirror Curvature to Coupling Efficiency
9.4.3 Effect of Lateral Tilt in Flat Micro Mirror on a Curved Sample
9.4.4 Effect of Vertical Tilt in Flat Micro Mirror on a Curved Sample
9.4.5 Effect of Vertical Tilt in Flat Micro Mirror on a Flat Sample
9.5 Assembly of Optical probe
9.5.1 Fabrication of SiOB
9.5.2 Probe Assembly
9.5.3 Probe Housing