

Contents

Acknowledgements — V

Preface — VII

About the Author — XIII

1 Bendable, Stretchable, and Adaptive Optics — 1

- 1.1 Introduction — 1
- 1.2 Illustrations of Elastomeric Optical Elements — 5
 - 1.2.1 Adaptive Mirrors — 5
 - 1.2.2 Stretchable Diffraction Gratings — 7
 - 1.2.3 Variable Focus Lenses — 10
- 1.3 Elastomeric Micro-optical Lens Arrays — 13
- 1.4 Flexible Optical Sheets — 14
- 1.5 Roadmap for This Book — 18
- References — 20

2 Light and Optical Waveguides — 23

- 2.1 Light and the Electromagnetic Spectrum — 23
- 2.2 The Wave–Particle Duality of Light — 29
- 2.3 Common Sources of Light — 32
 - 2.3.1 Solar Radiation — 34
 - 2.3.2 Laser Light — 36
- 2.4 Light Transmission, Reflection, and Absorption — 39
 - 2.4.1 Light Transmission Through a Solid Medium — 40
 - 2.4.2 Surface Reflectivity — 41
 - 2.4.3 Light Absorption — 43
- 2.5 Impact of Dimensional Scale on Optical Design — 47
 - 2.5.1 Generic Scaling Parameter s — 47
 - 2.5.2 Scaling in Optics — 48
- 2.6 Optical Waveguides — 52
 - 2.6.1 Total Internal Reflection in Waveguides — 54
 - 2.6.2 Light Loss in Optical Waveguides — 58
- 2.7 Final Comments — 60
- References — 61

3 Optically Transparent Polymers and Elastomers — 63

- 3.1 Introduction — 63
- 3.2 Material Properties of Optical Polymers — 64
 - 3.2.1 Light Transmittance Properties — 65

3.2.2	Thermal and Water Absorption Properties —	68
3.2.3	Coatings on Polymer Optical Components —	68
3.3	Optically Transparent Elastomer: Polydimethylsiloxane (PDMS) —	69
3.3.1	Optical Dispersion and Refractive Index —	69
3.3.2	Optical Damping Coefficient —	70
3.3.3	Mechanical Characterization of Elastomer Stretchability —	71
3.4	Rheological Considerations of Optically Transparent Elastomers —	73
3.4.1	Liquid Elastomer Viscosity —	73
3.4.2	Rate of Material Hardening —	74
3.4.3	Spin-Coating Liquid Elastomers on Substrates —	74
3.5	Modifying the Refractive Index of Elastomer Material —	74
3.5.1	Effect of Pre-polymer Mixing Ratios and Curing Parameters —	75
3.5.2	Modifying the Refractive Index with Nanoparticles —	75
3.5.3	Impact of Deep Ultraviolet Irradiation —	76
3.6	Final Comments —	77
	References —	79
4	Fabrication of Elastomeric Optical Devices —	81
4.1	Introduction —	81
4.2	Fabrication of Monolithic Single-Layer Polymer Devices —	81
4.2.1	Micromould Masters for Replicating Optical Devices —	82
4.2.2	Common Micromoulding Processes —	85
4.3	Fabrication of Curved Relief Structures —	90
4.4	Creating Optically Transparent Elastomeric Layers —	91
4.4.1	Removing Trapped Bubbles by Degassing —	92
4.4.2	Surface Treatments and Demoulding —	94
4.4.3	Assembling Multiple Elastomeric Layers —	95
4.5	Constructing Large-Area Multiple-Layered Thin Optical Devices —	96
4.5.1	Build-by-Layers Fabrication Method —	96
4.5.2	Fabrication of a Large Area Illuminator —	99
4.6	Final Comments —	102
	References —	104
5	Strain-Tunable Elastomeric Optics —	108
5.1	Introduction —	108
5.2	Optical Devices with Deformable Surfaces —	108
5.2.1	Elastomeric Force Sensor —	109
5.2.2	Thermally Activated Elastomeric Light Valve —	112
5.2.3	Elastomeric Fresnel Lens —	113

5.3	Focus-Tunable Elastomeric Lens — 115
5.4	Elastomeric Microlens Light Diffuser Array — 119
5.5	Strain Effects on Elastomeric Microlens Array — 121
5.6	Tunable Microlens Array for Compound Eye Cameras — 127
5.7	Final Comments — 131
	References — 131
6	Diffusers and Illuminators — 134
6.1	Introduction — 134
6.2	Operating Principles of Edge-Lit Diffusers and Panels — 135
6.3	Diffuser Micro-optical Structures (MOSs) — 138
6.3.1	Single and Multiple Micro-optical Structures — 139
6.3.2	Arrays of Micro-optical Structures — 142
6.3.3	Sequential Optimization of MOS Depth — 147
6.4	Elastomeric Light Guide Plate Diffuser — 150
6.5	Final Comments — 154
	References — 155
7	Concentrators and Collectors — 158
7.1	Introduction — 158
7.2	Coupled Microlens–MOS Configuration — 160
7.3	Planar Micro-optical Solar Concentrator — 163
7.3.1	Geometric Concentration Ratio — 164
7.3.2	Efficiency of Waveguide Coupling — 166
7.4	Planar Waveguide Solar Concentrator (PWSC) — 168
7.4.1	Optical Efficiency of Concentrator — 169
7.4.2	Impact of Waveguide Coupling — 172
7.4.3	Role of Concentrator Acceptance Angle — 174
7.5	PDMS Waveguide as a Light Concentrator — 175
7.6	Final Comments — 177
	References — 179
8	Mechanically Flexible Elastomeric Optical Sheets — 182
8.1	Introduction — 182
8.2	Multifunctional Elastomer Optical Sheets — 184
8.3	Design Parameters for a Concentrator–Transmitter–Diffuser Optical Sheet — 187
8.3.1	Concentrator–Transmitter Design — 189
8.3.2	Diffuser Design — 190
8.4	Selecting Appropriate Optical Sheet Parameters — 192
8.5	Evaluating the Performance of a Flat ($\beta = 0$) Elastomeric Optical Sheet — 197

8.5.1	Impact of Concentrator–Transmitter Parameters on Sheet Performance —	198
8.5.2	Impact of Diffuser Parameters on Sheet Performance —	201
8.6	Performance of Curved ($\beta > 0$) Elastomeric Optical Sheets —	205
8.6.1	Impact of Bending on Optical Sheet Performance —	206
8.6.2	Deformation of Concentrator–Transmitter Optical Microstructures —	208
8.6.3	Deformation of Diffuser Optical Microstructures —	211
8.7	Final Comments —	214
	References —	215
9	Perspectives on Elastomeric Optics —	217
9.1	A Short Retrospective on Bendable, Stretchable, and Adaptive Optics —	217
9.2	Developing a Sustainable Technology – Optical Bioelastomers —	220
9.3	Final Thoughts —	225
	References —	226
	Index —	229