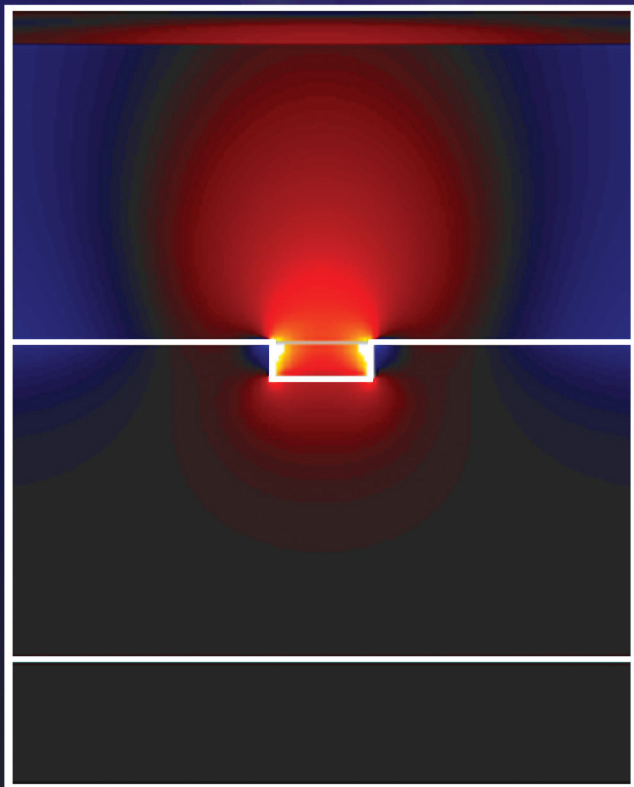

Takeo Nishikawa | Satoshi Fujita

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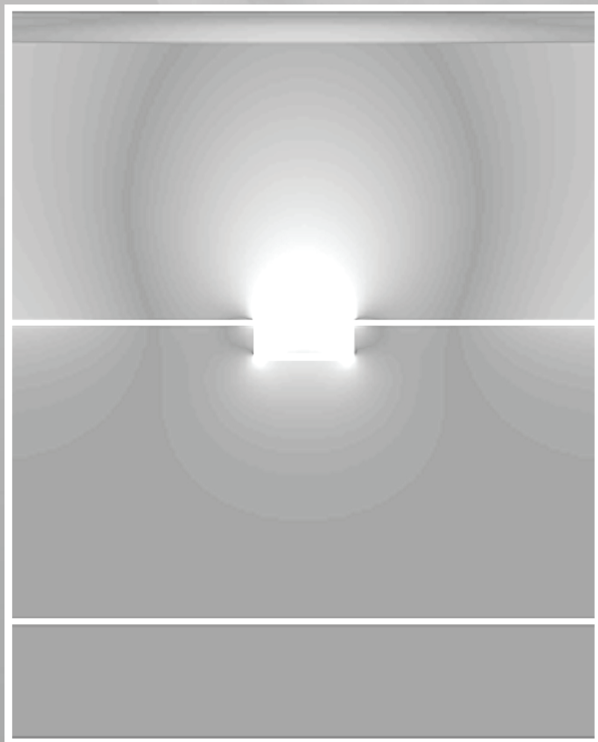
The Fusion of Nanofabrication, Nanophotonics, and Nanobiology



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Contents

Preface	xiii
Acknowledgement	xvii
1. Nanofabrication and Nanoimprint Technology	**1**
1.1 Nanofabrication Technology	1
1.1.1 Photolithography	2
1.1.2 X-Ray Lithography	4
1.1.3 Electron Beam Lithography	4
1.2 Nanoimprint Technology	6
1.2.1 Thermal Nanoimprint	6
1.2.2 UV-Nanoimprint	10
1.2.3 Other Nanoimprint Technologies	13
1.2.3.1 Direct metal imprint	13
1.2.3.2 Soft lithography (microcontact printing)	14
1.2.3.3 Molecular imprint	15
1.3 Key Technologies and Examples of Nanoimprint Technique	16
1.3.1 Master Process	17
1.3.2 Mold	17
1.3.3 Replication and Recent Trends	22
1.4 Applications of Nanoimprint Technology	27
1.4.1 Electron Devices	27
1.4.1.1 Filed emission transistor	27
1.4.1.2 Patterned media	29
1.4.2 Optical Devices	33
1.4.2.1 MLA (microlens array)	33
1.4.2.2 ARS (antireflection structure)	35
1.4.3 Biological Applications	40
1.4.3.1 DNA and protein arrays by micro- and nanocontact printing	41
1.4.3.2 Tissue engineering	42
1.4.3.3 Biomolecular imprinting technology	44

1.4.4 Energy Devices 47
1.4.4.1 Organic solar cells 47
1.4.4.2 Fuel cells 49

2. Nanophotonics and Surface Plasmon Resonance 51
2.1 Nanophotonics 51
2.1.1 Light and Diffraction Limit 53
2.1.2 Nanophotonics and Near-Field Light 54
2.1.3 Scanning Near-Field Optical Microscope 55
2.2 Surface Plasmon Resonance 60
2.2.1 Plasma Oscillation in and around Metal 60
2.2.2 Propagating Surface Plasmon Resonance 61
2.2.3 SPR Theoretical Calculation 67
2.3 Localized Surface Plasmon Resonance 70
2.3.1 Theory of Localized Surface Plasmon Resonance 71
2.3.2 Various Modes of LSPR 72
2.3.2.1 Gold nanorods 72
2.3.2.2 Triangularly shaped nanoparticles by nanosphere lithography 75
2.3.2.3 Closely arranged metal nanoparticles 76
2.4 Applications for Sensors 77
2.4.1 Principle of SPR Sensors 77
2.4.2 SPR Biosensors 79
2.4.2.1 Biacore (GE Healthcare) 81
2.4.2.2 Optoquest Inc. 82
2.4.3 LSPR Biosensors 84
2.4.4 Waveguide SPR Sensors 85
2.5 Other Applications 88
2.5.1 Photovoltaic Device 89
2.5.1.1 Use of LSPR 91
2.5.1.2 Use of attenuated total reflectance type of SPR 91
2.5.1.3 Use of grating type of SPR 92
2.5.2 Nano-photodiode 92
2.5.3 Color Filter 93

3. Nanobiology **95**
3.1 Design of Immobilization Layer for a Surface Plasmon Resonance Biosensor 95
3.1.1 Key Factor 1: Capture Agent 95
3.1.2 Key Factor 2: Surface Chemistry 96
3.1.3 Key Factor 3: Surface Matrix 98
3.2 Improved Antibody Immobilization on an OEG-Mixed SAM 98
3.2.1 Materials and Methods 100
3.2.1.1 Materials 100
3.2.1.2 Preparation of mixed SAM surface 101
3.2.1.3 Preparation and evaluation of antibody-immobilized surface 101
3.2.1.4 Preparation of antibody-immobilized CM5 surface 103
3.2.2 Optimization of Mixing Condition of the Mixed SAMs 103
3.2.3 Coupling Time between anti-AFP and Activated NHS Ester 106
3.2.4 Comparative Analysis with Antibody-Immobilized CM5 Surface 106
3.2.5 Conclusion 110

4. Nanoimprint Biosensor **113**
4.1 Design of Nanoimprint Biosensor 114
4.1.1 Simulation Methods 115
4.1.2 Design Concept 116
4.1.2.1 Simulation model for basic design study 118
4.1.2.2 Basic design of nanostructure and the direction of incident light 119
4.1.3 Design for Nanoimprint Biosensor 123
4.1.3.1 Thickness of metal layer 123
4.1.3.2 Width of nanogap structure 126
4.1.3.3 Depth of nanogap structure 129
4.1.3.4 Matrix relation analysis between depth and width of nanogap structure 131

4.1.3.5 Spatial period of nanogap structure 135
4.1.3.6 The sidewall inclination of nanogap structure 137
4.1.3.7 Summary 139
4.1.4 Optimization of Nanostructures 140
4.1.4.1 Simulation method to verify the sensing depth 140
4.1.4.2 Sensing depth of the nanostructured surface 143
4.1.4.3 Relations between sensing depth and structural parameters 144
4.1.5 Additional Analysis of Nanoimprint Biosensor 154
4.1.5.1 Analysis of sensitivity dependence on the position of sensor surface 154
4.1.5.2 Dispersion analysis of SPR mode 156
4.2 Fabrication of Sensor Device 161
4.2.1 Fabrication Process 162
4.2.2 Fabrication Result 164
4.2.2.1 Device fabricated by photopolymerization 164
4.2.2.2 Device fabricated by injection molding 166
4.2.3 Fabrication of Microchannel 169
4.2.3.1 Design of microchannel 169
4.2.3.2 Microchannel made of PDMS 172
4.2.3.3 Micro- and nanohybrid structure 173
4.2.3.4 Sealing process of cover film 177
4.3 Evaluation of Nanoimprint SPR 179
4.3.1 Basic Evaluation 180
4.3.1.1 Experimental setup 180
4.3.1.2 Basic evaluation of nanoimprint SPR sensor 181
4.3.1.3 Experimental evaluation of sensing depth 185

4.3.1.4 Experimental evaluation of sensing depth II 187
4.3.2 Effect of Structural Parameters 190
4.3.2.1 The effect on the resonant wavelength 190
4.3.2.2 The effect on signal-to-noise ratio 193
4.3.3 Meshy (Two-Dimensional) Groove Pattern 194
4.3.3.1 Concept and principle of meshy groove pattern 194
4.3.3.2 Device fabrication and optical evaluation 195
4.3.3.3 The effect avoidance of polarization defect 197
4.3.4 Pre-Mass Production Test 200

5. Proto-Model Systems for Nanoimprint Biosensor 203
5.1 First Proto-Model for Laboratory Use 204
5.1.1 Optical System 204
5.1.2 Flow Control System 206
5.1.2.1 Single plunger pump 207
5.1.2.2 Electroosmotic flow pump 209
5.1.2.3 Integration to the proto-model 214
5.1.3 System Control Software 217
5.1.3.1 Calculation and storage of the resonant wavelength data 218
5.1.3.2 Control of the motorized linear XY stage 220
5.1.3.3 Flow control system 220
5.2 Second Proto-Model for Portable Use 220
5.2.1 Optical System 221
5.2.2 Flow Control System 222
5.3 Third Proto-Model for Handy Use 222
5.3.1 Optical System 224
5.3.1.1 Selection of light source 225
5.3.1.2 Selection of detector 228
5.3.1.3 Optical system 228

5.3.2 Microflow System 230
5.3.3 Software 231
5.3.4 Demonstration 232
5.3.4.1 Detection of solutions of different refractive indices 232
5.3.4.2 Protein detection 234

6. Applications of Nanoimprint Biosensor 235
6.1 Detection of α-Fetoprotein 235
6.1.1 Preparation of Probe Layer 235
6.1.2 Direct Detection of AFP 237
6.1.3 Signal Amplification by Gold Colloids 238
6.1.3.1 Nonspecific binding evaluation of gold colloid 240
6.1.3.2 Signal amplification by gold colloids 241
6.2 Detection of Single-Stranded DNA 244
6.2.1 Materials and Methods 245
6.2.2 Results and Discussions 246
6.3 Signal Amplification Method by Magnetic Beads 248
6.3.1 Basic Concept 248
6.3.2 Materials and Methods 251
6.3.2.1 Selection of magnetic beads 253
6.3.2.2 Probe immobilization on the magnetic beads 253
6.3.3 System Construction 255
6.3.3.1 Selection of the system conditions 255
6.3.3.2 Construction of the experimental setup 257
6.3.4 Nonspecific Binding of Magnetic Beads on Sensor Surface 259
6.3.4.1 Bare gold surface and purified water dilution 260
6.3.4.2 PEG-coated gold surface and buffer dilution with surface detergent 261
6.3.5 Improvement of Detection Limit 264
6.3.5.1 Preparation of experiment 264

6.3.5.2 Magnetic beads injection after AFP injection 266
6.3.5.3 Injection of pre-mixture solution of AFP and magnetic beads 267
6.4 In-line Monitoring for Purification Process 270
6.4.1 Basic Concept for Chromatography 270
6.4.2 Detection by the Conventional Method (UV Absorption Detection) 271
6.4.2.1 Experimental setup 271
6.4.2.2 Experimental result 272
6.4.3 Detection by Conventional SPR 273
6.4.3.1 Experimental setup 273
6.4.3.2 Experimental result 274
6.4.4 Detection by Nanoimprint LSPR sensor 275
6.4.4.1 Experimental setup 276
6.4.4.2 Experimental result 276
6.4.4.3 Surface regeneration by sheath-flow detergent 276
6.4.5 Future Applications 278

Bibliography **281**

Index 295

Preface

In recent years, the correlation between the health condition of human beings and biological molecules such as nucleic acid and protein, which are major components of the human body, is becoming clearer due to advances in medical technology. Some of these biological molecules called tumor markers are being used as diagnostic indicators in medical tests. In the near future, by detecting the kind, amount, and condition of biological molecules with higher sensitivity and higher accuracy, it would be possible during preventive medical care to remedy and remove a disease before its emergence. Currently, such detection in biological molecules is difficult and costly, and implementing biosensors for the purpose will be greatly helpful in controlling health conditions, reducing medical costs significantly, and improving quality of life of human beings. However, for detecting target molecules with diameter as small as a few to a few tens of nanometers and in low concentration, biosensors with extremely high sensitivity are required. Furthermore, the sensing system should also be compact and popular priced to make its usage widespread.

We have been working to achieve these technically challenging issues by utilizing “nanotechnology” that has been keenly focused upon in this decade. In the conventional biosensing system, the detecting system has a dimension larger than millimeter scale while that of the target molecule is in nanometer scale. Therefore, many additional functions and elements are necessary to compensate the error factors derived from the difference in the detection scale in this system. This results in an increase in the apparatus size and consequently high cost. In our method, the target molecules are detected by a sensor device in which nanopatterns are formed by nanofabrication technology. The nanopatterns are made to interfere with light incident on a nanoscale on the basis of nanophotonics principle and thus ambient minute changes are detected. In this method, since the dimensions of the detection system and the target molecules are in the same order, superfluous noise factors can be eliminated and a high signal-to-noise ratio can be realized. The size of the biosensor system can be as small as a palm in this technology. To achieve high sensitivity, we have also developed a biological probe layer on the sensor surface and it plays the most important part in the procedure which is to capture the target molecules in a specific way. In this biosensor, many different kinds of technologies are included, which have been presented in the book. We feel that fusion of the state-of-the-art technologies with nanofabrication, nanophotonics, and nanobiology fields will be the key to realize new biosensors to satisfy detection demands of the next decade.

In Chapter 1, nanofabrication technologies, especially the nanoimprint technology that can realize mass production of the devices with nanoscale patterns on it, are introduced. Although these technologies have been applied to various applications, such as recording medium, much smaller-scale patterns are necessary to use them for the detection of biological molecules. In addition, a high process throughput is also required to achieve low-cost sensor devices. Examples of basic technologies and applications are also introduced in this chapter.

In Chapter 2, behavior of light in nanoscale is described. In regions smaller than its wavelength (several hundred nanometers), light exhibits "wave" nature. As one of its interesting phenomena, it can resonate with free electrons in a metal. This phenomenon is called "surface plasmon resonance" and is applied to detect the change in ambient resonant condition. However, the resonant interaction of light with free electrons, which is confined in the nanoscale metal structure, has not been analyzed in detailed so far and is being keenly focused upon in recent years.

In Chapter 3, recent trends in biotechnology to develop a surface membrane that can be used on a sensor to capture target biomolecules is introduced. To realize a highly sensitive biosensor, the construction of a probe layer on the basis of an oligo(ethylene glycol)-mixed self-assembled monolayer is very significant. Our developments to achieve a probe layer with high sensitivity and high specificity are also included in this chapter.

In Chapter 4, we introduce the nanoimprint biosensor which we have proposed. As mentioned above, detailed analysis of resonance between light and the nanopatterned metal has not been conducted yet. In this chapter, results of the design, fabrication, and evaluation of the sensor device using nanoimprint technology are presented along with a description of the optimization of nanopatterns for the nanoimprint biosensor.

In Chapter 5, proto-type systems for the nanoimprint biosensors are presented. We have constructed three different types of the proto-models. The first one is for laboratory use, the second for on-site use, and the third for portable use. We have developed a palm-sized biosensor system especially for portable use.

In Chapter 6, applications of nanoimprint biosensors are presented. Detection results of biological molecules using a fabricated sensor are reported. The chapter discusses in detail the use of gold nanoparticles and magnetic beads with nanoimprint biosensors to achieve higher sensitivity, although such systems are still being developed. Besides their use in medical care, application concepts of nanoimprint biosensors in other fields are also introduced in this chapter.

The technologies and concepts of nanoimprint biosensors to detect small molecules can be applied to a wide range of fields such as environmental sensing, food analysis, security check, as well as medical care and healthcare in the future. We hope that this book proves helpful for researchers working on this concept and can thus contribute to improve human life.

Takeo Nishikawa
Satoshi Fujita

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