Contents

Preface *XVII*
List of Contributors *XIX*

1 Introduction to Plasmas *1*
Hideo Ikegami
1.1 Plasmas *1*
1.1.1 Plasma Characteristics *1*
1.2 Discharge Plasmas *3*
1.2.1 Glow Plasma *3*
1.2.2 Atmospheric Plasmas *4*
References *5*

2 Environmental Application of Nonthermal Plasma *7*
Akira Mizuno
2.1 Introduction *7*
2.2 Generation of Atmospheric Nonthermal Plasma *7*
2.3 Indoor Air Cleaning System Using Plasma and Catalyst Combination *9*
2.4 Diesel Exhaust Cleaning *12*
2.5 Interaction of Atmospheric Plasma with Liquid *14*
2.6 Concluding Remarks *16*
References *16*

3 Atmospheric Plasma Air Pollution Control, Solid Waste, and Water Treatment Technologies: Fundamental and Overview *19*
Jen-Shih Chang
3.1 Introduction *19*
3.1.1 Nonthermal Plasma Air Pollution Control *19*
3.1.2 Thermal Plasma Solid Waste Treatment *20*
3.1.3 Electrohydraulic Water Treatment *21*
3.2 Type of Plasmas *21*
3.3 Plasma Chemistry *23*

3.4 Plasma Reactor *24*
3.4.1 Nonthermal Plasma Reactor *24*
3.4.2 Thermal Plasma Reactors *25*
3.4.3 Electrohydraulic Discharge *26*
3.5 Determination of Plasma Parameters and the Other Phenomena *29*
3.6 Engineering and Economics *30*
3.6.1 Nonthermal Plasma Pollution Control *30*
3.6.2 Thermal Plasma Solid Waste and Water Treatment *32*
3.7 Concluding Remarks *32*
References *34*

4 Optical Diagnostics for High-Pressure Nonthermal Plasma Analysis *37*
Tetsuji Oda and Ryo Ono
4.1 Introduction *37*
4.2 Experimental Examples *38*
4.2.1 Optical Emission Photograph *38*
4.2.2 Optical Emission Spectra *39*
4.2.3 Laser-Induced Fluorescence (LIF) *39*
4.2.3.1 OH Radical *39*
4.2.4 LIF of Atomic Oxygen Radical *41*
4.2.5 LIF of NO Molecule *41*
4.2.6 N_2 (A) LIF in the Plasma *41*
4.2.7 O_2 LIF *43*
4.2.8 Optical Absorption *45*
4.3 Conclusions *47*
References *47*

5 Laser Investigations of Flow Patterns in Electrostatic Precipitators and Nonthermal Plasma Reactors *49*
Jerzy Mizeraczyk, Janusz Podlinski, Anna Niewulis, and Mirosław Dors
5.1 Introduction *49*
5.2 PIV Experimental Setups *50*
5.3 Results–PIV Measurements *51*
5.3.1 3D EHD Flow in Wide ESP with (Transverse) Wire-Plate Electrode System *51*
5.3.2 3D EHD Flow in Wide ESP with (Transverse) Spike-Plate Electrode System *53*
5.3.3 3D EHD Flow in Narrow ESP with Transverse Wire-Plate Electrode System *56*
5.3.4 3D EHD Flow in Narrow ESP with Longitudinal Wire-Plate Electrode System *58*
5.3.5 EHD Flow in Nonthermal Plasma Reactor for Water Treatment *60*
5.4 Conclusions *62*
Acknowledgment *63*
References *63*

6 Water Plasmas for Environmental Application *65*
Takayuki Watanabe
6.1 Introduction *65*
6.2 Water Plasma Generation and Its Characteristics *66*
6.2.1 Water Plasma Generation *66*
6.2.2 Temperature Measurements *68*
6.3 Decomposition of Halogenated Hydrocarbons *69*
6.3.1 Thermodynamic Consideration *70*
6.3.2 Experimental Setups *72*
6.3.3 Experimental Results *73*
6.4 Conclusion *75*
References *76*

7 Chemistry of Organic Pollutants in Atmospheric Plasmas *79*
Ester Marotta, Milko Schiorlin, Massimo Rea, and Cristina Paradisi
7.1 Introduction *79*
7.2 Experimental *80*
7.2.1 Chemicals *80*
7.2.2 Experiments with the Corona Reactor *81*
7.2.3 Analysis of Ions *82*
7.3 Results and Discussion *82*
7.4 Conclusions *90*
Acknowledgments *91*
References *91*

8 Generation and Application of Wide Area Plasma *93*
Noureddine Zouzou, Kazunori Takashima, Akira Mizuno, and Gerard Touchard
8.1 Introduction *93*
8.2 AirFlow Control *93*
8.3 Aerodynamic Plasma Actuators *95*
8.4 Particle Destruction *97*
8.5 Large Sliding Discharge *98*
8.6 Conclusion *103*
References *103*

9 Nonthermal Plasma-based System for Exhaust Treatment under Reduced Atmosphere of Pyrolysis Gases *105*
Marcela Morvová, Viktor Martišovitš, Imrich Morva, Ivan Košinár, Mário Janda, Daniela Kunecová, Nina Kolesárová, Veronika Biskupičová, and Marcela Morvová Jr
9.1 Introduction *105*
9.2 Experimental *106*
9.3 Results *107*
9.4 Conclusions *110*

Acknowledgments *111*
References *111*

10 Pharmaceutical and Biomedical Engineering by Plasma Techniques *113*
Masayuki Kuzuya, Yasushi Sasai, Shin-ichi Kondo, and Yukinori Yamauchi
10.1 Introduction *113*
10.2 Nature of Plasma-Induced Polymer Radicals *114*
10.3 Pharmaceutical Engineering for DDS Preparation by Plasma Techniques *118*
10.3.1 Preparation of Sustained-Release DDS from Plasma-Irradiated DC Tablets *118*
10.3.2 Preparation of Time-Controlled Drug Release System by Plasma Techniques *122*
10.3.3 Preparation of Intragastric FDDS by Plasma Techniques *123*
10.3.4 Patient-Tailored DDS for Large Intestine Targeted-Release Preparations *125*
10.3.5 Preparation of Functionalized Composite Powders Applicable to Matrix-Type DDS *128*
10.4 Biomedical Engineering by Plasma Techniques *129*
10.4.1 Preparation of Clinical Catheter with Durable Surface Lubricity *130*
10.4.2 Improvement of Cell Adhesion by Immobilizing VEMAC on Polymer Surface *131*
10.4.3 Plasma-Assisted Immobilization of Biomolecules onto Polymer Surfaces *132*
10.4.4 Basic Study on Preparation of Functionalized PVA–PAANa Hydrogel for Chemoembolic Agent *135*
10.5 Conclusion *136*
Acknowledgments *137*
References *137*

11 Targeting Dendritic Cells with Carbon Magnetic Nanoparticles Made by Dense-Medium Plasma Technology *141*
Heidi A. Schreiber, Jozsef Prechl, Hongquan Jiang, Alla Zozulya, Zsuzsanna Fabry, Ferencz S. Denes, and Matyas Sandor
References *146*

12 Applications of Pulsed Power and Plasmas to Biosystems and Living Organisms *149*
Hidenori Akiyama, Sunao Katsuki, and Masahiro Akiyama
12.1 Introduction *149*
12.2 Pulsed-Power Source Using Magnetic Pulse Compression System *149*
12.3 Discharge Plasmas by Pulsed Power *151*
12.3.1 Large Volume Discharge Plasmas in Atmospheric Gases *151*
12.3.2 Large Volume Discharge Plasmas in Water *153*
12.4 Action of Pulsed Power and Discharge Plasma to Biosystems *158*
12.4.1 Action of Pulsed Power to Biosystems *158*
12.4.2 Cleaning of Lakes and Dams *160*
12.5 Summary *161*
References *162*

13 Applications of Plasma Polymerization in Biomaterials *165*
David A. Steele and Robert D. Short
13.1 Introduction *165*
13.2 Example 1: Improving Surfaces for Blood Biocompatibility *168*
13.3 Example 2: Foreign Body Response *170*
13.4 Example 3: Extended Wear Contact Lenses *173*
13.5 Example 4: Platform for Immobilizing a Biomolecule *174*
13.6 Example 5: An Improved Surface Plasmon Resonance Biosensor *177*
13.7 Conclusions *178*
References *178*

14 Plasma Sterilization at Normal Atmospheric Pressure *181*
Tetsuya Akitsu, Siti Khadijah Za aba, Hiroshi Ohkawa, Keiko Katayama-Hirayama, Masao Tsuji, Naohiro Shimizu, and Yuichirou Imanishi
14.1 Introduction *181*
14.2 Experimental Schemes *182*
14.2.1 Inductive Energy Storage Pulse-Power Source *182*
14.2.2 Antibacterial Test *184*
14.3 Experimental Result *185*
14.4 Conclusion *188*
Acknowledgments *191*
References *191*

15 Elimination of Pathogenic Biological Residuals by Means of Low-Pressure Inductively Coupled Plasma Discharge *193*
Ondřej Kylián, Hubert Rauscher, Ana Ruiz, Benjamin Denis, Katharina Stapelmann, and François Rossi
15.1 Introduction *193*
15.2 Experimental *194*
15.2.1 Plasma Treatment *194*
15.2.2 Samples Preparation and Evaluation of the Effect of a Plasma Treatment *194*
15.3 Results *196*
15.3.1 Bacterial Spores *196*
15.3.2 Homopolymers of Amino Acids *197*

15.4 Conclusions *197*
Acknowledgments *198*
References *199*

16 Sterilization and Protein Treatment Using Oxygen Radicals Produced by RF Discharge *201*
Nobuya Hayashi and Akira Yonesu
16.1 Introduction *201*
16.2 Experimental Procedure *201*
16.3 Generation of Oxygen Radicals *202*
16.4 Sterilization of Medical Equipments *203*
16.5 Decomposition of Protein's Structure *204*
References *206*

17 Hydrophilicity and Bioactivity of a Polyethylene Terephthalate Surface Modified by Plasma-Initiated Graft Polymerization *207*
Nagahiro Saito, Takahiro Ishizaki, Junko Hieda, Syohei Fujita, and Osamu Takai
17.1 Introduction *207*
17.2 Experimental *208*
17.2.1 Materials *208*
17.2.2 Surface Modification *208*
17.2.3 Surface Characterization *209*
17.2.4 Cell Culture *209*
17.3 Results and Discussion *209*
17.4 Conclusions *218*
References *218*

18 Strategies and Issues on the Plasma Processing of Thin-Film Silicon Solar Cells *221*
Akihisa Matsuda
18.1 Introduction *221*
18.2 Growth Process of a-Si : H and μc-Si : H by PECVD *221*
18.3 Growth of High-Quality a-Si : H *223*
18.4 Concept of Protocrystal a-Si : H (Stable a-Si : H) *226*
18.5 Growth of High-Quality μc-Si : H *228*
18.6 Summary *229*
References *229*

19 Characteristics of VHF Plasma with Large Area *231*
Yoshinobu Kawai, Yoshiaki Takeuchi, Yasuhiro Yamauchi, and Hiromu Takatsuka
19.1 Introduction *231*
19.2 Development of Balanced Power Feeding Method *232*
19.3 Characteristics of VHF Plasma *238*
19.3.1 H_2 Plasma Characteristics *238*
19.3.2 SiH_4/H_2 Plasma Characteristics *241*
19.4 Summary *244*
References *245*

20 Deposition of a-Si : H Films with High Stability against Light Exposure by Reducing Deposition of Nanoparticles Formed in SiH_4 Discharges *247*
Kazunori Koga, Masaharu Shiratani, and Yukio Watanabe
20.1 Introduction *247*
20.2 Formation Mechanism of Nanoparticles in Silane Discharges *248*
20.3 Contribution of Higher Order Silane Molecules and Nanoparticles to SiH_2 Bond Formation in Films *250*
20.4 Effects of Nanoparticles on a-Si : H Qualities *252*
20.5 High Rate Deposition of a-Si : H Films of High Stability against Light Exposure Using Multihollow Discharge Plasma CVD *254*
20.6 Conclusions *256*
Acknowledgments *256*
References *256*

21 Diagnostics and Modeling of SiH_4/H_2 Plasmas for the Deposition of Microcrystalline Silicon: the Case of Dual-Frequency Sources *259*
Eleftherios Amanatides and Dimitrios Mataras
21.1 Introduction *259*
21.2 Experimental *260*
21.3 Model Description *261*
21.4 Results and Discussion *262*
21.5 Conclusions *271*
Acknowledgments *272*
References *272*

22 Introduction to Diamond-Like Carbons *275*
Masaru Hori

23 Diamond-Like Carbon for Applications *277*
John Robertson
23.1 Introduction *277*
23.2 Growth Rates *277*
23.3 Basic Properties *281*
23.4 Stress *284*
23.5 Applications of DLC *286*
23.6 MEMs *291*
23.7 Electronic Applications *292*
23.8 Bioactive Surfaces *294*
23.9 Conclusions *296*

Acknowledgments *297*
References *297*

24 Applications of DLCs to Bioprocessing *301*
Tatsuyuki Nakatani and Yuki Nitta
24.1 Introduction *301*
24.2 High-Tenacity DLC Tin Films for Stents *303*
24.3 Applications of DLC Films to Coronary Drug-Eluting Stent *305*
24.4 DLC Films with Controlled Zeta Potential of Biomaterials *306*
24.5 Characterization of Biomimetic DLC and *In vitro* Biocompatibility Evaluation *308*
24.5.1 Biomimetic DLC and Blood Compatibility *309*
24.5.2 Biomimetic DLC and Cytocompatibility *309*
24.6 Conclusion *312*
Acknowledgments *313*
References *313*

25 Plasma Processing of Nanocrystalline Semiconductive Cubic Boron Nitride Thin Films *315*
Kenji Nose and Toyonobu Yoshida
25.1 Introduction *315*
25.2 Fundamental Properties of cBN *316*
25.2.1 Physical Properties *316*
25.2.2 Electronic Properties *317*
25.2.3 Intrinsic Electronic State *317*
25.2.3.1 Self-Defects *318*
25.2.3.2 Dopants *318*
25.3 Growth of cBN Thin Films *319*
25.3.1 Process and Structure *319*
25.3.1.1 Plasma Processing of cBN Thin Film *319*
25.3.1.2 Initial Layer Growth *320*
25.3.1.3 Nucleation and Growth of Cubic Phase *321*
25.3.2 Approaches to Epitaxial Growth *322*
25.3.2.1 For Direct Growth on Silicon *322*
25.3.2.2 Epitaxy on Diamond *322*
25.4 Doping Processes and Electrical Characterization *323*
25.4.1 In situ Doping Process *323*
25.4.1.1 Doping by Sputtering of Bulk Sources *323*
25.4.1.2 Effects of Doping on Nucleation and Growth *325*
25.4.2 Electrical Properties of Doped cBN Films *327*
25.4.2.1 Silicon-Doped Films *327*
25.4.2.2 Beryllium-Doped Films *328*
25.4.2.3 Zinc-Doped Films *329*
25.4.2.4 Magnesium-Doped Films *331*
25.5 Conclusion *331*
References *332*

26 Fundamentals on Tribology of Plasma-Deposited Diamond-Like Carbon films *335*
Julien Fontaine and Christophe Donnet
26.1 Introduction *335*
26.2 Special Case of DLC Coatings *335*
26.3 Superlubricity of DLC Coatings *336*
26.4 Conclusion *337*
References *337*

27 Diamond-Like Carbon Thin Films Grown in Pulsed-DC Plasmas *339*
Enric Bertran, Miguel Rubio-Roy, Carles Corbella, and José-Luis Andújar
27.1 Introduction *339*
27.2 Experimental Details *340*
27.3 Results and Discussion *342*
27.4 Conclusions *347*
Acknowledgments *347*
References *347*

28 Plasma Deposition of N-TiO_2 Thin Films *349*
Pablo Romero-Gómez, Angel Barranco, José Cotrino, Juan P. Espinós, Francisco Yubero, and Agustín R. González-Elipe
28.1 Introduction *349*
28.2 Experimental Setup and Diagnostic Techniques *350*
28.3 Results and Discussion *351*
Acknowledgments *355*
References *355*

29 Investigation of DLC and Multilayer Coatings Hydrophobic Character for Biomedical Applications *357*
Rodica Vladoiu, Aurelia Mandes, Virginia Dinca, Mirelsa Contulov, Victor Ciupina, Cristian Petric Lungu, and Geavit Musa
29.1 Introduction *357*
29.2 Experimental Setup *358*
29.3 Results and Discussions *360*
29.4 Conclusions *362*
Acknowledgments *363*
References *363*

30 Creation of Novel Electromagnetic and Reactive Media from Microplasmas *365*
Kunihide Tachibana
30.1 Introduction *365*

30.2 Microplasma in Single Use as Plasma Jet *367*
30.3 Microplasma Integration for Large-Area Material Processing *370*
30.4 Microplasma Integration for Electromagnetic Media *372*
30.5 Concluding Remarks and Perspectives *375*
Acknowledgments *375*
References *375*

31 Nanoblock Assembly Using Pulse RF Discharges with Amplitude Modulation *377*
Shinya Iwashita, Hiroshi Miyata, Kazunori Koga, and Masaharu Shiratani
31.1 Introduction *377*
31.2 Formation of Nanoblocks and Their Agglomeration *378*
31.3 Assembly of Nanoblocks in Gas Phase Using Agglomeration *379*
31.4 Conclusions *382*
Acknowledgments *382*
References *383*

32 Thomson Scattering Diagnostics of Discharge Plasmas *385*
Kiichiro Uchino and Kentaro Tomita
32.1 Introduction *385*
32.2 Application to Low-Pressure Plasmas *386*
32.3 Diagnostics of PDP Plasmas *387*
32.3.1 LTS Using a Visible System *387*
32.3.2 Infrared LTS System *388*
32.3.3 Results and Discussion *390*
32.3.3.1 Laser Perturbations *390*
32.3.3.2 Results of LTS Measurements *392*
32.4 Diagnostics of EUV Plasmas *392*
32.4.1 Experiment *394*
32.4.2 Results and Discussions *395*
References *397*

33 Crystallized Nanodust Particles Growth in Low-Pressure Cold Plasmas *399*
Laïfa Boufendi, Marie Christine Jouanny, Marjory Cavarroc, Abdelaziz Mezeghrane, Maxime Mikikian, and Yves Tessier
33.1 Introduction *399*
33.2 Description of the Experimental Setup *400*
33.3 Detection of Nanocrystallites Formation in the Plasma Gas Phase *401*
33.4 Atomic Structure of the Nanocrystallites *402*
33.5 Size and Crystalline Volume Fraction Measurements *404*
33.6 Gas Temperature Effects on Dust Nanoparticle Nucleation and Growth *406*
33.7 Conclusion *407*
References *408*

34 Collection and Removal of Fine Particles in Plasma Chambers *409*
Noriyoshi Sato
34.1 Introduction *409*
34.2 NFP-collector *410*
34.3 Ditch Guidance *414*
34.4 Plate Cleaning *417*
34.5 Effects on Particles Produced in Plasmas *419*
34.6 Conclusions *422*
Acknowledgments *422*
References *422*

Index *425*