

Contents

Preface	
R.W.Crompton (Australian National University)	v

OVERVIEW

Invited Paper:	
CHARACTERISTICS AND CONTROL OF PROCESSING PLASMAS	
FOR SEMICONDUCTOR DEVICE MANUFACTURING	
R. Itatani (Kyoto University)	1
1. INTRODUCTION	1
2. SUBJECTS OF REACTIVE PLASMAS	2
3. UNDERSTANDING REACTIVE PLASMAS	3
3.1 RF Plasmas of Parallel Plate Electrodes	3
3.2 ECR Plasmas	5
4. CONTROL METHODS OF REACTIVE PLASMAS	6
4.1 Control of Electron Temperature	6
4.2 Control of Reactions through Difference of Relaxation Time	6
4.3 Control by Hybrid Plasmas	6
5. CONCLUDING REMARK	7
References	7

NEW ASPECT OF COLLISION CROSS SECTIONS

ELECTRON COLLISION CROSS SECTIONS OF ATOMS AND	
MOLECULES	
M. Hayashi (Nagoya Institute of Technology)	9
1. INTRODUCTION	9
2. DEFINITION OF CROSS SECTIONS	10
3. EXPERIMENTAL METHODS	11
4. CROSS SECTION DATA BY BEAM EXPERIMENTS	14
4.1 Rare Gases	14
4.1.1 Kr	14
4.1.2 Other Rare Gases	21
4.2 CO ₂	21
4.3 CH ₄ and C ₂ H ₆	27
5. CONCLUSIONS	30

References	30
THE BEHAVIOUR OF LOW ENERGY ELECTRONS IN WATER VAPOUR	
M.T. Elford (Australian National University)	34
1. INTRODUCTION	34
2. ATTACHMENT AND IONIZATION OF ELECTRONS IN WATER VAPOUR	35
2.1 Attachment and Negative Ion Reactions	35
2.2 Ionization	37
3. MEASUREMENTS OF D_T/μ IN WATER VAPOUR	38
3.1 Available Data	38
3.1.1 Measurements below 30 Td	38
3.1.2 Measurements at $E/N > 30$ Td	39
4. THE DRIFT VELOCITY OF ELECTRONS IN WATER VAPOR	40
4.1 Measurements of Cheung and Elford	41
5. THE COEFFICIENT ND_L	42
6. THE ROLE OF WATER DIMERS	42
7. CROSS SECTIONS AND CALCULATIONS OF TRANSPORT COEFFICIENTS	44
7.1 The Momentum Transfer Cross Section, σ_m	44
7.2 Cross Sections for Rotational Excitation	46
7.3 Cross Sections for Vibrational Excitation	47
7.4 Cross Sections for Attachment and Ionization	47
7.5 Cross Sections for Electronic Excitation	47
7.6 Comparisons of Measured and Calculated Values of v_{dr} , D_T/μ , and D_L/μ	47
8. CONCLUSION	49
References	49
DEEXCITATION OF EXCITED RARE GAS ATOMS IN METASTABLE AND RESONANCE STATES AS STUDIED BY THE PULSE RADIOLYSIS METHOD	
M. Ukai and Y. Hatano (Tokyo Institute of Technology)	51
1. INTRODUCTION	51
2. EXPERIMENTAL	53
3. DEEXCITATION OF $He(2^3S)$	55
4. DEEXCITATION OF $He(2^1P)$	60
5. STATE DEPENDENCE OF THE DEEXCITATION OF $He(2^3S, 2^1S, 2^1P)$	67
6. CONCLUSIONS	69
References	70
MEASUREMENT OF THREE BODY ION-ELECTRON RECOMBINATION RATE CONSTANTS IN RARE GASES AT MODERATE PRESSURES	
R.Cooper, M.Burgers, R.Bhave, R.Van Sonsbeek, K.Caulfield (Univ. of Melbourne) and J. Lowke (CSIRO)	73

1. INTRODUCTION	73
2. THEORY	76
2.1 Noyes	77
2.2 Theoretical Models for Electron-Ion Recombination	77
2.2.1 Thomson	77
2.2.2 Bates	78
2.2.3 Pitaevskii	78
2.2.4 Bates and Khare	78
3. EXPERIMENTAL	80
3.1 Preparation of Gas Samples	80
3.2 Pulsed Electron Beam Source	80
3.3 Microwave Conductivity Studies	80
3.3.1 Microwave source and detection	81
3.4 Operation at Low and High Temperatures	82
4. ANALYSIS OF DATA	82
4.1 Calculation of Cell Constant	83
4.2 Calculation of Electron Mobility, μ_e	83
5. RESULTS AND DISCUSSION	85
5.1 Nature of the Positive Ion	85
References	87

ELECTRON SWARM TRANSPORT -Theoretical Aspect-

EIGENVALUE PROBLEMS IN GASEOUS ELECTRONICS THEORY	
R.E. Robson (James Cook University)	89
1. INTRODUCTION	89
2. FORMULATION OF THE EIGENVALUE PROBLEM	91
2.1 Formal Solution of Boltzmann's Equation	91
2.2 Boundary Conditions	92
2.3 Isotropic Source	93
2.4 Decomposition in Phase Space	93
2.5 Spectral Theorems	95
3. ANALYSIS OF EXPERIMENTS	97
3.1 Expression for Density	97
3.2 Time of Flight Experiment	98
3.3 Cavalleri Experiment	99
3.4 Steady State Townsend Experiment	99
4. DISCUSSION	100
References	101

BOLTZMANN EQUATION ANALYSIS OF POSITION AND TIME DEPENDENT VELOCITY DISTRIBUTION OF ELECTRONS

N.Ikuta, S.Nakajima, Y.Seki and T.Okamoto (Tokushima University) 102

1. INTRODUCTION	102
2. THEORY	103
3. RESULTS OF POSITION AND TIME DEPENDENT ANALYSIS FOR A DC FIELD	106
3.1 Cross Sections and Other Data for the Calculations	106

3.2	Variation of $f(x, v, t)$	107
3.3	Variations of the Local Transport Coefficients	108
3.4	Transport Coefficients Defined in Velocity Space	110
3.5	Variation of Transport Coefficients	111
4.	RESULTS OF THE TIME DEPENDENT ANALYSIS FOR RF FIELDS	112
4.1	Cross Sections and Other Data for the Calculations	112
4.2	Velocity Distributions	114
4.3	Periodical Variation of Transport Coefficients	114
4.4	Fourier Analysis	120
5.	CONCLUSION	124
	References	125
HIGHER-ORDER TRANSPORT PROCESSES IN ELECTRON SWARMS		
	H.A. Blevin and L.J. Kelly (Flinders Univ. of South Australia)	127
1.	INTRODUCTION	127
2.	MONTE CARLO SIMULATION	128
2.1	Electron Concentration	129
2.2	Excitation Rates	133
2.3	The Cathode Boundary	136
3.	EXPERIMENTAL RESULTS FOR EXCITATION RATES	141
4.	THE STEADY-STATE TOWNSEND DISCHARGE	141
5.	CONCLUSIONS	142
	References	143
ELECTRON SWARM PARAMETERS IN SiH_4/H_2 MIXTURES		
	N. Sato (Iwate Univ.) and H. Tagashira (Hokkaido Univ.)	144
1.	INTRODUCTION	144
2.	THE SIMULATION METHODE	145
2.1	Tracking of the Electron Motion	145
2.2	Cross Sections	146
2.3	The Sampling Method	147
3.	RESULTS AND DISCUSSION	148
3.1	The Ionization Coefficient of the Mixture in DC Fields	148
3.2	Synergism of the Swarm Parameters	150
3.3	Non-Equilibrium Region of the Electron Swarm in DC Fields	152
3.4	Swarm Parameters in RF Fields	153
4.	CONCLUSION	158
	References	159
ELECTRON SWARM TRANSPORT -Experimental Aspect-		
SOME INVESTIGATIONS OF ELECTRON AND ION SWARMS IN LOW CURRENT ELECTRICAL DISCHARGES		
	J. Fletcher (Flinders Univ. of South Australia)	160
1.	INTRODUCTION	160

2.	EXPERIMENTAL DATA ANALYSIS	161
3.	METHODS OF INVESTIGATION	162
3.1	The Integrated Voltage Pulse Method	163
3.2	The Photon Flux Technique	164
4.	RESULTS	165
4.1	Nitrogen	165
4.2	The Atomic Gases	169
5.	CONCLUSIONS	175
	References	176
RECENT ELECTRON SWARM STUDIES USING RARE GAS/MOLECULAR GAS MIXTURES		
	Y. Nakamura (Keio University)	178
1.	INTRODUCTION	178
2.	ELECTRON SWARM STUDIES USING MIXTURES BEFORE 1985	179
2.1	Inelastic Collision Cross Section for Metal Atoms	179
2.1.1	Drift velocity in Cs-Ar mixtures and excitation cross section for Cs atom	180
2.1.2	Ionization coefficient in Cs-Ar mixtures and excitation cross section for Cs atom	181
2.1.3	Electron drift velocity and ionization coefficient in Na-Ar mixtures and excitation cross section for Na atom	181
2.2	Vibrational Excitation Cross Sections for Molecular Gases	183
3.	RECENT SWARM STUDIES IN MIXTURES	185
3.1	Molecular Gas/Rare Gas Mixtures (Case 1: Momentum Transfer Cross Section for Krypton Atom)	185
3.2	Molecular Gas/Rare Gas Mixtures (Case 2: Inelastic Collision Cross Sections for Plasma Processing Gases)	186
3.2.1	SiH_4	188
3.2.2	CH_4	191
3.2.3	CF_4	194
3.3	Advantages of Using Gas Mixtures in Swarm Studies	196
4.	CONCLUSIONS	197
	References	198
MEASUREMENT OF THE MOBILITY OF EXCITED STATE IONS IN A DISCHARGE PLASMA BY USING A TUNABLE DIODE LASER		
	T. Sakurai and H. Hori (Yamanashi University)	201
1.	INTRODUCTION	201
2.	MOBILITY OF IONS IN A PLASMA	202
3.	EXPERIMENTAL ARRANGEMENT	204
4.	RESULTS AND DISCUSSION	206
4.1	Ca^+	206
4.2	Cd^+	209
5.	CONCLUSION	211
	References	212

LASER-INDUCED OPTOGALVANIC STUDIES OF SWARM PHENOMENA

S.C. Haydon and M.P. Fewell (University of New England)	213
1. INTRODUCTION	213
2. LASER-INDUCED PERTURBATION-BASIC CONCEPTS . .	214
3. SPATIAL AND TEMPORAL IONIZATION GROWTH	215
4. THE ROLE OF NEUTRAL EXCITED PARTICLES	217
4.1 Spatial Effects	217
4.2 Temporal Effects	219
5. EXPERIMENTAL PROCEDURES	221
5.1 Spatial Measurements	221
5.2 Temporal Measurements	222
6. PULSED AND CW LASER DIAGNOSTIC TECHNIQUES . .	222
6.1 Pulsed-Laser Experiments	223
6.2 CW Laser Experiments	224
7. MULTIMODE AND SINGLE-MODE INTERACTIONS	225
8. RATE-EQUATION ANALYSIS	226
9. EXPERIMENTAL OBSERVATIONS	228
9.1 Pulsed Investigations	228
9.2 CW Investigations	230
9.2.1 Multimode observations	233
9.2.2 Single mode observations	233
10. SUMMARY AND CONCLUSIONS	234
References	235

RECENT ADVANCES IN PROCESSING RF PLASMAS

RF ELECTRON SWARM TRANSPORT AND RELATED RF GLOW DISCHARGE PROPERTIES T. Makabe (Keio University)	236
1. INTRODUCTION	236
2. RF SWARM THEORY	237
2.1 Semiquantitative Theory	238
2.2 Expansion Procedure	240
2.3 Direct Numerical Procedure	249
3. EXPERIMENTAL RF SWARM TRANSPORT	254
4. MODELING OF RF PLASMAS	257
4.1 Governing Equations	258
4.1.1 Local field approximation model	258
4.1.2 Thermal model	259
4.1.3 Relaxation continuum model	259
4.2 General View of an RF Plasma	261
4.3 Influence of Driving Frequency	263
4.4 Effect of Electrode Asymmetry	264
4.5 Influence of Negative Ions	265
4.6 Reactive Dissociative RF Plasma in CH ₄	267
4.7 Space-Time Evolution of the Deposited Surface	269
References	270

RADICAL KINETICS IN AN RF-DISCHARGE SILANE PLASMA FOR THE CHEMICAL VAPOR DEPOSITION OF a-Si:H FILM

K.Tachibana (Kyoto Inst.Technol.), A.Yuuki and Y.Matsui (Mitsubishi Electric Co.)	273
1. INTRODUCTION	273
2. MEASUREMENTS OF RADICALS IN THE GAS PHASE . .	275
2.1 Spatial Profiles of Emissions	275
2.2 Measurement of Si and SiH by LIF	276
2.3 Measurement of SiH ₂ by ICLAS	278
3. CALCULATION BY A PLASMA CHEMISTRY MODEL	282
4. RADICAL FLUX AND FILM DEPOSITION	283
4.1 Estimation of Radical Fluxes	283
4.2 Deposition Rate and Trench Coverage	286
4.3 Characteristics of Deposited a-Si:H Film	289
References	291

SWARM ANALYSIS OF PHENOMENA IN WEAKLY IONIZED GASES

T. Dote (Fukui Inst. Technol.) and M. Shimada (Osaka Kyoiku Univ.)	294
1. QUASI-NEUTRAL THEORY OF THE POSITIVE COLUMN OF A GLOW DISCHARGE	295
1.1 Basis	295
1.2 Expressions at the Central Axis	296
1.3 Diffusion Cooling for Positive Ions	297
1.4 Theory of the Electron Temperature	298
1.5 Determination of Other Parameters	299
2. TRANSITION FROM FREE TO AMBIPOLAR DIFFUSION OF CHARGED PARTICLES	299
2.1 Basic Equations	299
2.2 Transition Theory of the Diffusion	300
2.3 Characteristics of the Diffusion-Transition	302
3. QUASI-NEUTRAL CONDITION IN WEAKLY IONIZED GASES	302
3.1 Significance of the Problem	302
3.2 Calculating Procedure	303
3.3 Characteristics of the Space Charge Density Ratio - Quasi-Neutral Condition -	304
3.4 Physical Meaning of Non-Quasi-Neutrality	304
4. Non-Quasi-Neutral Theory of the Positive Column	305
4.1 Summary of Theory	305
4.2 Representative Characteristics	305
5. CONCLUDING REMARKS	306
References	307

APPLICATION

PLASMA ETCHING OF SEMICONDUCTORS

M.W.Austin (Royal Melbourne Inst. of Technol.), J.S. Williams, M.A. Jarnyk, A.J. Perry, R.W. Boswell, G. Palmer and J.A. Davies (Australian National Univ.)	314
---	-----

1. INTRODUCTION	314
2. OVERVIEW OF DRY ETCHING METHODS	315
2.1 Non-Reactive Plasma Etching	315
2.2 Reactive Plasma Etching	315
2.3 Control of Etching Parameters	315
2.3.a Selectivity	315
2.3.b Etch rate	315
2.3.c Anisotropy	317
2.3.d End-point determination	317
3. SOME KEY ISSUES IN ETCHING OF SEMICONDUCTORS	317
3.1 Silicon	317
3.1.a Etch rate and uniformity	317
3.1.b Substrate damage	317
3.2 III-V Compound Semiconductors	318
3.2.a Selectivity	318
3.2.b Substrate damage	318
3.2.c Contamination	319
4. RECENT EXPERIMENTS AT ANU	319
4.1 Experimental Considerations	319
4.2 Silicon Damage Studies	321
4.3 III-V Compound Semiconductor Studies	321
5. CONCLUSIONS	322
References	322
ION/PLASMA-ASSISTED DEPOSITION STUDIES FOR ADVANCED MATERIAL PROCESSING	
K. Miyake (Hitachi Ltd.)	324
1. INTRODUCTION	324
2. ION BEAM DEPOSITION	325
3. PLASMA STREAM TRANSPORT METHOD	328
3.a Plasma Oxidation of Silicon Surfaces	330
3.b High-Tc Superconductor Film Formation by Plasma Stream Assisted Reactive Evaporation	333
4. A MODEL PLASMA EXPERIMENT PROPOSED FOR FURTHER INVESTIGATION	335
5. CONCLUSION	337
References	337
CORONA DISCHARGE MEASUREMENTS USING LASER OPTICS	
G.A. Woolsey (University of New England)	339
1. INTRODUCTION	339
2. INTERFEROMETRY	340
3. SCHLIEREN ANALYSIS	344
4. LASER DOPPLER FLOW ANALYSIS	350
5. OPTICAL FIBER SENSING	352
References	355
Index	358