
Contents

Introduction	xi
1 Types of experimental complex plasmas	1
<i>Vladimir E. Fortov, Alexey G. Khrapak, Vladimir I. Molotkov, Gregor E. Morfill, Oleg F. Petrov, Hubertus M. Thomas, Olga S. Vaulina, Sergey V. Vladimirov</i>	
1.1 Complex plasmas in rf discharges	3
1.1.1 The GEC-RF-Reference Cell	4
1.1.2 Symmetrically driven rf discharge for microgravity experiments	10
1.1.3 Complex plasmas in inductively coupled discharges	15
1.2 Complex plasmas in dc discharges	17
1.2.1 Ground-based experiments	17
1.2.2 Microgravity experiments	31
1.3 Thermal complex plasmas	36
1.3.1 Source of thermal plasma with macroparticles	37
1.3.2 Plasma diagnostics	38
1.3.3 Particle diagnostics	38
1.3.4 Spatially ordered structures in thermal plasmas	40
1.4 Other types of complex plasmas	41
1.4.1 Complex plasmas at cryogenic temperatures	41
1.4.2 Experiments with complex plasma induced by UV-radiation	45
1.4.3 Nuclear-induced and track complex plasmas	49
1.4.4 Particle structures in a dc discharge in the presence of magnetic fields	53
1.4.5 “Small” dust structures: Coulomb or Yukawa clusters and balls	58
1.4.6 Complex plasmas with non-spherical particles	65
1.5 Formation and growth of dust particles	73
2 Basic plasma-particle interactions	99
<i>Sergey A. Khrapak and Alexey V. Ivlev</i>	
2.1 Charging of particles in complex plasmas	99
2.1.1 Charging in collisionless plasmas	100
2.1.2 Effect of plasma collisionality on the particle charging	111
2.1.3 Experimental determination of the particle charge	118
2.1.4 Emission processes	123

2.1.5	Quasineutrality of complex plasmas	125
2.1.6	Fluctuations of the particle charge	125
2.2	Electric potential distribution around a particle	127
2.2.1	Isotropic plasmas	127
2.2.2	Anisotropic plasmas	133
2.3	Interparticle interactions	136
2.3.1	Isotropic plasmas	136
2.3.2	Anisotropic plasmas	138
2.3.3	Experiments	139
2.4	Momentum exchange	141
2.4.1	Momentum transfer cross section	141
2.4.2	Momentum exchange rates	147
2.4.3	Momentum exchange diagram	149
2.5	Forces on particles	153
2.5.1	Ion drag force	153
2.5.2	Other forces	166
2.6	Particle surface temperature	168
3	Particle dynamics	185
<i>Alexey V. Ivlev</i>		
3.1	Vertical oscillations in an rf sheath	185
3.2	Non-Hamiltonian dynamics	186
3.2.1	Role of variable charges	186
3.2.2	Role of plasma wakes	191
3.3	Kinetics of ensembles with variable charges	193
4	Waves and instabilities	199
<i>Alexey V. Ivlev and Sergey A. Khrapak</i>		
4.1	Wave excitation technique	200
4.2	Waves in ideal (gaseous) complex plasmas	201
4.2.1	Major wave modes	202
4.2.2	Damping and instabilities	205
4.3	Waves in strongly coupled (liquid) complex plasmas	210
4.3.1	Longitudinal waves	212
4.3.2	Transverse waves	213
4.4	Waves in plasma crystals	214
4.4.1	One-dimensional strings	214
4.4.2	Two-dimensional triangular lattice	215
4.4.3	Three-dimensional plasma crystals	220
4.4.4	Instabilities in plasma crystals	221
4.5	Nonlinear waves	222
4.5.1	Ion solitons and shocks	222
4.5.2	Dust solitons and shocks	223
4.5.3	Mach cones	227

5 Kinetic studies of fluids and solids with complex plasmas	239
<i>Alexey V. Ivlev, Gregor E. Morfill, and Sergey A. Khrapak</i>	
5.1 Phase diagram of complex plasma	240
5.2 Strongly coupled fluids	244
5.2.1 Atomistic dynamics in fluids	245
5.2.2 Kinetics of stable shear flows	249
5.2.3 Kinetics of heat transport	252
5.2.4 Hydrodynamics at the discreteness limit	255
5.2.5 Confined fluids	261
5.2.6 Electrorheological fluids	263
5.3 Solids	268
5.3.1 Atomistic dynamics in crystals	268
5.3.2 Scalings in 2D crystallization	270
5.3.3 Dynamics of dislocations	274
5.3.4 3D crystallization	276
6 Dusty plasmas in the solar system	291
<i>Mihály Horányi, Ove Havnes, Gregor E. Morfill</i>	
6.1 Introduction	291
6.2 Noctilucent clouds	291
6.3 Planetary rings	296
6.3.1 Simplified dynamics	296
6.3.2 Saturn's E-ring	299
6.3.3 Spokes	302
6.4 Lunar surface	306
6.4.1 Imaging	307
6.4.2 Plasma and electric field measurements	309
6.4.3 Dust measurements	312
6.4.4 The lunar dust environment	314
6.5 Summary	315
7 Numerical simulation of complex plasmas	325
<i>Olga S. Vaulina and Boris A. Klumov</i>	
7.1 Molecular dynamics simulations of complex plasmas: Basic concepts	325
7.1.1 Methods of simulation of the dynamics of dust particles	325
7.1.2 Equations of motion of dust particles	326
7.2 Numerical simulation of spatial correlations between dust particles	329
7.2.1 Pair and three-particle correlation functions	329
7.2.2 Pair correlation functions and phase states of the particle subsystems	334
7.3 Transport properties of complex plasma: Numerical study	337
7.3.1 Transport of particles in non-ideal media	337
7.3.2 Diffusivity	339
7.3.3 Viscosity	344

7.4	Complex plasmas in narrow channels	347
7.4.1	2D complex plasmas in narrow channels	347
7.4.2	3D complex plasmas in narrow channels	351
7.5	Crystallization waves in complex plasmas	357
7.5.1	Local order analysis of 3D data	362
7.6	On the role of dust in cometary plasma	367
7.7	Electronegative complex plasmas	375
8	Diagnostics of complex plasma	385
	<i>Oleg F. Petrov and Olga S. Vaulina</i>	
8.1	Introduction	385
8.2	Light scattering and absorption measurements	385
8.2.1	Mie theory	386
8.2.2	Determination of the size, concentration, and refractive index of particles	388
8.3	Spectral methods of determination of particle parameters	392
8.3.1	Particle temperature	392
8.3.2	The spectrometric method of the particle size and refractive index determination	396
8.3.3	Simultaneous determination of the particle size, refractive index, and temperature	396
8.3.4	The effect of particles on the determination of the concentration of alkali metal atoms and the gas temperature	397
9	Applications	401
	<i>Vladimir E. Fortov, Alexey G. Khrapak, Sergey V. Vladimirov</i>	
9.1	Technological and industrial aspects	401
9.2	Dust in fusion reactors	404
9.3	Nuclear photovoltaic electric battery	407
Index		413

