

SCATTERING METHODS IN COMPLEX FLUIDS

Summarising recent research on the physics of complex liquids, this in-depth analysis examines the topic of complex liquids from a modern perspective, addressing experimental, computational and theoretical aspects of the field.

Selecting only the most interesting contemporary developments in this rich field of research, the authors present multiple examples including aggregation, gel formation and glass transition, in systems undergoing percolation, at criticality, or in supercooled states. Connecting experiments and simulation with key theoretical principles, and covering numerous systems including micelles, microemulsions, biological systems and cement pastes, this unique text is an invaluable resource for graduate students and researchers looking to explore and understand the expanding field of complex fluids.

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SCATTERING METHODS IN COMPLEX FLUIDS

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Contents

<i>List of illustrations</i>	<i>page</i> ix
<i>Preface</i>	xv
Part I Scattering and liquids	1
1 Scattering techniques for the liquid state	3
1.1 Introduction	3
1.2 Module – Small angle neutron scattering	28
2 Statistical mechanics of the liquid state	48
2.1 Pair correlations and structure factors in liquids	49
2.2 The Ornstein–Zernike equation and its approximate solutions	66
2.3 Theories of macroion solutions	80
3 Aggregation and cluster formation	88
3.1 Introduction	88
3.2 Module – Reaction controlled aggregation of colloidal particles	92
3.3 Module – Diffusion controlled irreversible aggregation and supramolecular ordering	101
3.4 Module – Percolation in microemulsions	109
3.5 Module – Critical supramolecular systems	114
Part II Structural arrest	125
4 The theory of slow dynamics in supercooled colloidal solutions	127
4.1 Introduction	127
4.2 Module – The mode-coupling theory of supercooled liquids	131
4.3 Module – MCT for repulsive and attractive glasses	139
4.4 Module – Clustering in systems with competing interactions	151

vi	<i>Contents</i>	
5	Experiments on structural arrest	157
5.1	Introduction	157
5.2	Module – Experiments on the glass transition in PMMA	158
5.3	Module – Copolymer solutions and higher-order singularities	160
5.4	Module – The glass–glass transition	166
6	Models of gel-forming colloids	179
6.1	Introduction	179
6.2	Module – Limited valence models	182
6.3	Module – Patchy colloids and Wertheim theory	184
6.4	Module – Gel-forming colloids and network glass formers	194
Part III	Water	209
7	Dynamic crossover phenomena in confined water	211
7.1	Introductory remarks on confined water	211
7.2	Module – Model for water’s single-particle dynamics–relaxing cage model (RCM)	224
7.3	Module – Dynamic crossover in hydration water of biomaterials	228
7.4	Module – Dynamic crossover in hydration water of cement pastes	249
7.5	Module – Dynamic crossover in confined water and its relation to the second critical point of water	252
7.6	Module – Density measurement of confined water in MCM-41S	258
8	Dynamic crossover phenomena in other glass-forming liquids	274
8.1	Introduction	274
8.2	Absence of structural arrest at T_g	281
8.3	Fractional Stokes–Einstein relation	283
9	Inelastic neutron scattering in water	286
9.1	Introduction to Q -dependent density of states $G_S(Q, \omega)$ of water	286
9.2	Density of state measurements of water: a plausible evidence for the existence of a liquid–liquid phase transition in low-temperature water	293
9.3	Measuring boson peak as a means to explore the existence of the liquid–liquid transition in deeply cooled confined water	301

	<i>Contents</i>	vii
10	Introduction to high-resolution inelastic X-ray scattering spectroscopy	309
10.1	Comparison of inelastic neutron scattering and inelastic X-ray scattering techniques	309
10.2	Module – Theory of inelastic X-ray scattering from monoatomic liquids	324
10.3	Module – Finite Q collective modes in bio-macromolecular assemblies	336
	<i>References</i>	359
	<i>Index</i>	379

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Sow-Hsin Chen & Piero Tartaglia
Frontmatter
[More information](#)

Illustrations

1.1	Schematic diagram of scattering geometry	<i>page</i> 4
1.2	Ranges covered in the scattering experiment	5
1.3	Reduced half-widths	24
1.4	Incoherent neutron quasi-elastic scattering	25
1.5	Time-domain experiment completed with photon-correlation technique	26
1.6	Reduced line width of quasi-elastic light-scattering spectra from a binary liquid mixture	27
1.7	Neutron diffraction geometry	29
1.8	SANS intensity distributions in BSA	44
1.9	Absolute scattering intensity	45
1.10	Protein/SDS complex in an aqueous buffer solution	46
2.1	Geometry used to prove Eq. (2.32c)	59
2.2	A hard sphere of potential $u(r)$	60
2.3	Schematic diagrams showing the relative positions of particles 1, 2 and 3	67
2.4	Percus–Yevick structure factor $S(Q)$	80
2.5	Comparison between MSA and HNC	84
2.6	SANS intensity distributions for protein solutions	86
2.7	Structure factor extracted from GOCM fitting	86
3.1	Temperature dependence of the fraction of bonds at equilibrium	98
3.2	Cluster size distribution	99
3.3	Time dependence of the fraction of bonds during reversible aggregation	100
3.4	Scaled intensity at different times during the aggregation process in the non-scaling regime	107
3.5	Scaled intensity at different times during the aggregation process in the scaling regime	107
3.6	Phase diagram of the AOT/water/decane system	111
3.7	Scaled conductivity as a function of the distance from the percolation line	112
3.8	Measured squared correlation function at two temperatures	115

x	<i>List of illustrations</i>	
3.9	Structure factor according to Coniglio–Klein Ising model	118
3.10	Squared correlation function showing deviations from exponential behaviour	121
3.11	Measured scaled line width of the AOT/water/decane system	123
4.1	PMMA colloidal fluids, crystal and glass	128
4.2	PMMA phase diagram	129
4.3	Density correlators in a supercooled liquid	136
4.4	Density correlators of the extended MCT	139
4.5	Phase diagram of colloidal particles	141
4.6	MCT phase diagram of the square-well system	142
4.7	Colloid with hard-sphere and short-range attractive interactions	144
4.8	Mean square displacement near the A_4 singularity	147
4.9	Decay of the density fluctuations close to a higher-order singularity	147
4.10	Fitting parameters close to a higher-order singularity	148
4.11	Elastic shear modulus across the glass–glass transition region	150
4.12	Ground state energy for connected clusters in systems with long-range interactions	153
4.13	Evolution of $S(q)$ on cooling	154
4.14	$F(q, t)$ and stretched exponentials	155
5.1	Hard spheres close to the glass transition	161
5.2	Non-ergodicity parameter of hard-sphere colloidal glass	162
5.3	Phase diagram of Pluronic	163
5.4	Intermediate scattering function in the glass region	164
5.5	Experiments on A_3	165
5.6	Scaling time of the von Schweidler law	166
5.7	ISF of the L64/D ₂ O micellar system	169
5.8	Shear viscosity of the L64/D ₂ O micellar system	170
5.9	Phase diagram of the L64/D ₂ O micellar system	171
5.10	SANS intensity distribution in the L64/D ₂ O micellar system	173
5.11	Scaling plots of SANS intensities	174
5.12	Intermediate scattering function in attractive colloids	176
5.13	Phase diagrams of the L64/D ₂ O micellar system	177
6.1	Phase diagram of a short-range square-well binary system	180
6.2	Kinetic phase diagram of aqueous lysozyme solutions	181
6.3	Phase diagram of the limited valence model	183
6.4	Arrhenius plot for the diffusivity for the $n_{max} = 4$ model	184
6.5	Patchy colloids with different number of sticky spots	185
6.6	Order parameter distributions of patchy colloids	188
6.7	Comparison between theoretical and numerical results for patchy particles	189
6.8	Spinodal curves for the patchy particles models	189

List of illustrations

xi

6.9	Temperature and volume fraction dependence of the bond probability	191
6.10	Cluster size distribution	192
6.11	Number of finite-size clusters	193
6.12	Phase diagram of the 2–3 mixture	194
6.13	Phase diagram of network-forming limited valency systems	196
6.14	PMW model	197
6.15	Mean square displacement in PMW	198
6.16	Three-dimensional view of the PMS molecular model of silica	199
6.17	Radial distribution functions for Si–Si, O–O and Si–O	200
6.18	Temperature dependence of the diffusion coefficient of Si particles	200
6.19	Model for a single DNA strand	202
6.20	Gas–liquid spinodal line and iso-diffusivity line for models of patchy particles	204
6.21	Phase diagrams and iso-diffusivity lines of the BKS model for silica, and the ST2 and the SPC/E models for water	205
7.1	Phase diagram of supercooled water	212
7.2	Radial density profile of water confined in pores	214
7.3	Self-intermediate scattering function of water oxygen atoms confined in pores	215
7.4	QENS spectra from water under strong confinement in pores	216
7.5	Temperature dependence of the average translational relaxation time of water under strong confinement in pores	217
7.6	Average translational relaxation times of water under strong confinement in pores at elevated pressures	219
7.7	Temperature dependence of the collective relaxation time of heavy water under confinement in pores	220
7.8	Arrhenius plot of the inverse self-diffusion coefficient of water under strong confinement	221
7.9	$D\tau_T/T$ as a function of temperature	222
7.10	Average translational relaxation time of water confined in a double-walled carbon nanotube	223
7.11	Arrhenius plot of the viscosity of the glass former α -phenyl-o-cresol	224
7.12	Rotational intermediate scattering function $F_R(Q, t)$ at three different Q values	228
7.13	Comparison of MSDs measured for the protein and its hydration water	231
7.14	Reduced plot of pressure dependence of MSD of protein and its hydration water	232
7.15	The difference neutron spectra between the H ₂ O hydrated and the D ₂ O hydrated DNA samples	233
7.16	Example of the RCM analysis for lysozyme hydration water	234
7.17	Extracted relaxation time at six different pressures	235

xii	<i>List of illustrations</i>	
7.18	Pressure dependence of the measured FSC temperature	237
7.19	RNA and DNA hydration water and the dynamic transition temperature	238
7.20	Temperature dependence of the MSD of hydrogen atoms in both the biopolymer and its hydration water	239
7.21	Water proton incoherent self-intermediate scattering functions and average translational relaxation time	241
7.22	Arrhenius plot of the mean relaxation time τ	244
7.23	Arrhenius plot of the mean characteristic relaxation time $\langle \tau \rangle$	246
7.24	Microstructure and porosity in C-S-H gel	249
7.25	Water under confinement in aged cement paste	252
7.26	Average D ₂ O density inside pores measured by the SANS method	261
7.27	Density vs. temperature curves at ambient pressure for water and ice	262
7.28	Hypothesised phase diagrams of water in the presence of a first-order liquid-liquid phase transition	264
7.29	Neutron diffraction intensities	265
7.30	Density profiles of confined D ₂ O in a hydrophilic substrate	266
7.31	Profiles of $I(Q_0)$	268
7.32	Phase diagram of deeply cooled confined D ₂ O	269
7.33	Q scan intensity distribution and expected average density of confined D ₂ O	271
7.34	Average H ₂ O density confined in MCM-41-S-24 compared with water and ice	272
7.35	Thermal expansion coefficient of H ₂ O confined in MCM-41-S-15 and MCM-41-S-24 compared with Mallamace's calculation	272
7.36	Latest result of the density hysteresis measurement of D ₂ O	273
8.1	o-Terphenyl dynamic crossover phenomenon	275
8.2	An example of the calculated values of the configurational entropy and specific heat	277
8.3	Evidence of the dynamic crossover phenomenon in the Arrhenius plot of the viscosity of four different glass-forming liquids	278
8.4	Heat capacity peak of supercooled water confined within pores of silica gel	279
8.5	Molecular dynamics simulations of bulk TIP4P-Ew water	280
8.6	Relaxation time and viscosity calculated from the eMCT	282
8.7	Photon correlation spectroscopy measurement	283
8.8	Scaled representation of the fractional SER and DSE	285
9.1	Proton density of states for bulk water	289
9.2	Density of states for water	290
9.3	Constant Q density of states in supercooled water	291
9.4	Q -dependent proton density of states	292
9.5	Water P - T phase diagram	296

	<i>List of illustrations</i>	xiii
9.6	Q -averaged DOSs of hydrogen	296
9.7	Comparison between the Q -averaged DOSs of hydrogen atoms $g_H(\omega)$ at three measured pressures within the energy range $E = 10\text{--}140$ meV	298
9.8	Comparison between the Q -averaged DOSs of hydrogen atoms $g_H(\omega)$ at two measured pressures within the energy range $E = 2\text{--}27$ meV	299
9.9	Comparison between the Q -averaged DOSs of hydrogen atoms $g_H(\omega)$ at three measured pressures within the energy range $E = 330\text{--}600$ meV	300
9.10	Inelastic neutron scattering spectra of confined water	304
9.11	$T_B(P)$ in the (P, T) plane	305
9.12	Proposed phase diagram of the liquid–liquid phase transition line	306
9.13	Measured spectra of the confined H_2O	306
9.14	Illustration of capillary rise	307
9.15	The fitted curves of the measured spectra	308
10.1	Inelastic X-ray scattering beamline ID16BL21 at ESRF	318
10.2	Resolution function of the X-ray scattering beamline	320
10.3	IXS spectra of H_2O	323
10.4	Fitting parameters from IXS spectra	324
10.5	Dispersion curve of H_2O	325
10.6	IXS spectra of fully hydrated DLPC	339
10.7	High-frequency sound dispersion and damping of fully hydrated DLPC	340
10.8	Calculated and measured structure factor	341
10.9	Relaxation rate of the central peak of the dynamic structure factor	342
10.10	Fittings of IXS spectra with GTEE theory	344
10.11	Structure factors in calf-thymus	345
10.12	Longitudinal-acoustic-phonon-dispersion relation in ZnCl_2	346
10.13	Longitudinal-acoustic-phonon-dispersion relation in spermidine	347
10.14	Phonon-dispersion relation of calf-thymus in H_2O	348
10.15	Comparison of the phonon-dispersion relation of two samples	349
10.16	Phonon damping and the phonon frequency of DNA samples	350
10.17	IXS spectra for denatured lysozyme	352
10.18	Dispersion relations of the phonon-like excitations	353
10.19	Phonon energy softening and phonon population enhancement in α -Chymotrypsinogen A	355
10.20	Dispersion relations of the excitations in lysozyme and amino acids	356
10.21	Phonon energy softening of a lysozyme molecule	357

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Sow-Hsin Chen & Piero Tartaglia
Frontmatter
[More information](#)

Preface

The central theme of this book is ‘slow dynamics in supercooled, glassy liquids and dense colloidal systems’ which has been an intense area of current research for some time. Although it can be well described by the mode-coupling theory of dense liquids, controversial viewpoints persist. Thus, the authors have written about the exciting modern aspects of the physics of liquids by selecting only the most interesting contemporary development in this rich field of research in the last decades.

This book presents and summarises a wide variety of recent research on the physics of complex liquids and suggests that the use of established techniques, essentially neutron, X-ray and light scattering together with theoretical and computer molecular dynamic simulation approaches, can be fruitfully applied to solve many new phenomena. These techniques are also central to investigating new interesting findings in liquid water such as liquid–liquid transition and its associated low-temperature critical point.

Although many materials found in nature can be classed as complex fluids, the authors have chosen to focus on water and colloids in this book for the following reasons:

- Water is the most important liquid for life on Earth. It covers 71% of the Earth’s surface and is probably the most ubiquitous, as well as the most essential, molecule on Earth. It is a vital element controlling not only all aspects of life itself but also the environmental factors that make life enjoyable. Water is a simple molecule yet possesses unique and anomalous properties at low temperatures that have fascinated scientists for many years. Thus in selecting the categories of complex liquids to include in this book, water is the obvious top choice.
- Colloids are another class of complex liquids characterised by the slowing down of the dynamics. They are becoming increasingly studied for their potential applications and the availability of degrees of freedom that are relatively simple

to vary experimentally through physical and chemical control parameters, giving rise to a much larger variety of phenomena compared to simple liquids. Initially a few relevant and classical examples of clustering and percolation in supramolecular colloidal aggregates are treated. Then various aspects of the physics of complex liquids are considered, focusing in particular on glass transition in colloidal systems, emphasising the role of the mode-coupling theory of the kinetic glass transition. The theory predicted and allowed us to study in detail many interesting new phenomena in colloids, such as re-entrant transitions and higher-order singularities in systems where short-range attraction is added to the usual short-distance repulsion between particles.

In order to provide an in-depth analysis examining the topics of complex liquids from a modern perspective, addressing the experimental, computational and theoretical aspect of the field, the book consists of ten chapters divided into three parts:

- Part I with three chapters deals with ‘scattering and liquids’.
- Part II with three chapters deals with ‘structural arrest’ phenomena.
- Part III with four chapters deals mainly with ‘water’.

Setting a good foundation for the rest of the book, the first two chapters cover elements of scattering techniques and theories commonly used in studying the structure and dynamics of liquid state matter. They are the outgrowth of parts of SHC’s lecture notes used in two of his graduate courses at MIT for many years – ‘Photon and neutron scattering spectroscopy and its applications in condensed matter’ and ‘Statistical thermodynamics of complex liquids’. In some of the chapters, certain sections are prefaced ‘Module’ to show that the topics they cover are significant, although they may not be in strict sequential order within the chapter.

Both authors, SHC and PT, have spent a large portion of their lives studying complex liquids, specifically water and colloidal systems, and collectively they have published several hundred research papers on these topics. Furthermore, they have been collaborating on these subjects for over 40 years, which has resulted in more than 50 joint scientific papers. Thus, it is natural for them to want to complement their mutual research interests and summarise their respective research on these topics throughout these long and productive years. A selection of arguments is made in the book, collecting what they consider relevant to the modern physics of liquids, in order to share their knowledge and insights with their readers. The research coverage is very up-to-date to June 2014.

This unique book should be of interest to all scientists who are interested in the dynamical properties of glassy liquids. It will also be an invaluable resource for

science and engineering graduate students and researchers looking to explore and understand the advancing field of complex fluids.

The authors want to thank their colleagues, former Ph.D. students and post-doctoral associates with whom they have shared many research topics reported in this book. They acknowledge in particular the long and fruitful collaboration with, amongst others, Professors Chung-Yuan Mou, Francesco Mallamace, Piero Baglioni and Paola Gallo (for SHC), and Francesco Sciortino (for both PT and SHC). For over a decade, all Chen's research projects have been funded by the Office of Basic Energy Sciences of the US Department of Energy. Their support is gratefully acknowledged. SHC also wants to thank Dr. P. Thiyagarajan for his encouragement and discussions.

During the course of preparing and writing this book, for SHC, due to his physical limitation in efficient typing, particularly the equations, he wishes to gratefully acknowledge the persistent help from his Ph.D student, Zhe Wang, for preparing some initial background information and typing revised paragraphs and equations of a few initial chapters during 2011–2013. He appreciates his postdoc Kao-Hsiang Liu for similar help in a few months around late 2012. He also wishes to thank his Ph.D. student, Peisi Le, who has redrawn numerous required graphics from April to August 2014. To his co-author, PT, he has enjoyed greatly the extensive discussions and interactions with PT, and appreciates greatly the additional typesetting work his co-author, PT, had to take on his behalf. Finally, SHC is particularly thankful to his wife, Ching-chih, for her indispensable and time-consuming work in reformatting all his chapters and references, converting and processing many colour graphics to publishable form, as well as performing the final editing, proofreading and indexing of his part of the book, without whose efforts this work could never have been completed.

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