1 Introductory Remarks

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If God will send me readers, then, may be,
it will be interesting for them . . .
Alexander S. Pushkin
cited after: B.S. Cantor: Talks on Minerals
(Astrel, Moscow, 1997) (in Russian)

Clustering processes in first-order phase transformations play an important role in a huge variety of processes in nature, and in scientific and technological applications. An adequate theoretical description of such processes is therefore of considerable interest. One of the tools allowing the theoretical description of such processes is the nucleation theory. The theoretical approach predominantly employed so far in the interpretation of experimental results of nucleation-growth processes is based on the classical nucleation theory, its extensions and modifications. It is supplemented by density functional computations, statistical mechanical model analyses, and computer modeling of model systems allowing us to gain additional insights into the respective processes and to specify the possible limitations of the classical approaches.

Although the basic concepts of the classical approach to the description of nucleation processes were developed about 80 years ago, a number of problems remain, however, unsettled till now which are partly of fundamental character. Several of these problems are analyzed in the present book. One of these analyzes is directed to the method of determination of the coefficients of emission in nucleation theory avoiding the concept of constraint equilibrium distributions (Chap. 3). A second such topic is the proper determination of the work of critical cluster formation for the different processes under investigation. It is discussed in detail in Chaps. 4 (in application to crystallization) and 5 (in application to boiling of binary liquid–gas solutions). A third topic, a relatively recent development of the nucleation theory with a wide spectrum of possible applications, consists in the theoretical description of nucleation and growth processes in solid solutions with sharp concentration gradients (Chap. 10).

The majority of theoretical approaches to the description of nucleation and growth processes rely, as far as thermodynamic aspects are involved, on Gibbs' classical thermodynamic theory of interfacial phenomena. In recent years it has been shown that, by generalizing Gibbs' thermodynamic approach, a number of problems of the classical theory can be resolved. In particular, as is shown in Chap. 11, the generalized Gibbs' approach leads to predictions for the properties of the critical clusters and the work of critical cluster formation, which are equivalent to the results of van der Waals' square gradient and more sophisticated density functional approaches. Some additional new insights, which have been obtained recently employing the generalized Gibbs' approach, are sketched in Chap. 12.

The nucleation theory has the unique advantage that its basic principles are equally well applicable to quite a variety of different systems. As a reflection of this general applicability, the spectrum of analyses, presented in the monograph, includes condensation and boiling, crystallization and melting, self-organization of ferroelectric domains and nanofilms, for-

Nucleation Theory and Applications. edited by J. W. P. Schmelzer

ISBN: 3-527-40469-4

mation of micellar solutions, formation and growth of diamonds from vitreous carbon. The analysis of different types of phase equilibria and different applications of the nucleation theory starts with a comparison of similarities and differences of solid–liquid and liquid–vapor phase transitions (Chap. 2). It is followed by an extended review of the state of knowledge in the field of nucleation and crystallization kinetics in silicate glasses (Chap. 4) as a particular example of the phase transition liquid–solid. An overview of the kinetics of boiling of binary liquid–gas solutions is given in Chap. 5. In Chap. 6, it is shown that nucleation concepts can be applied successfully to the description of the polarization reversal phenomenon in ferroelectric materials allowing the treatment of different modes of domain evolution from a single universal point of view. Of similar current direct technological significance are the analyses of formation and growth processes of nanofilms on surfaces reviewed in Chap. 7. Chapter 8 deals with an overview on traditional and novel methods of diamond synthesis, while Chap. 9 employs nucleation theory methods to the description of micellization processes. Some summary of the results and outlook on possible future developments is given in Chap. 12.

All of the chapters included in the present book are written by internationally outstanding scientists in their respective fields. It is of particular pleasure to have among the authors the Corresponding Member of the Ukrainian Academy of Sciences, Vitali V. Slezov (Slyozov), one of the authors of the well-known L(ifshitz)S(lezov)W(agner)-theory of coarsening, the description of the late stages of first-order phase transitions being till now one of the corner stones of the theory of first-order phase transformation processes, the Member of the Russian Academy of Sciences, Vladimir P. Skripov, well known for his enormous work devoted, in particular, to the kinetics of boiling processes and reflected in part in his book *Metastable Liquids*, published also by Wiley in 1974 [3], the member of the Russian Academy of Sciences, Anatoli I. Rusanov, well known for his monographs devoted to the thermodynamics of heterogeneous systems which has served as a comprehensive introduction to theses topics for decades, and the Member of the Bulgarian Academy of Sciences, Ivan S. Gutzow, who continued with his colleagues and coworkers the traditions of the Bulgarian school of nucleation theory originated by Ivan Stranski and Rostislav A. Kaischew.

As already mentioned in the preface, the contributions, included in the present book, have been presented and discussed in detail at the Research Workshops *Nucleation Theory and Applications* in Dubna, Russia, in the course of the years 1997–2003. Of course, neither all the contributions presented nor all of the results obtained in the common research can be reflected in one book. Some other highly interesting topics are contained in the specialized workshop proceedings [1] and in the publications [2–15] of the participants of the meetings and the authors of the present book we refer to for a more detailed outline of some of the topics discussed here and related aspects.

References

[1] J.W.P. Schmelzer, G. Röpke, and V.B. Prieezhev (Eds.), *Nucleation Theory and Applications*, Proceedings of the Research Workshops Nucleation Theory and Applications held at the Joint Institute for Nuclear Research in Dubna/Russia, JINR Publishing Department, Dubna, 1999 (covering the period 1997–1999) and 2002 (for the period 2000–

2002). Copies of the proceedings can be ordered via the editor of the present book by electronic mail (Email: juern-w.schmelzer@physik.uni-rostock.de).

[2] J.W.P. Schmelzer, G. Röpke, and R. Mahnke (Eds.), *Aggregation Phenomena in Complex Systems* (Wiley-VCH, Weinheim, 1999).

[3] V.P. Skripov, *Metastable Liquids* (Nauka, Moscow, 1972 (in Russian); Wiley, New York, 1974 (in English)).

[4] A.I. Rusanov, *Phasengleichgewichte und Grenzflächenerscheinungen* (Akademie-Verlag, Berlin, 1978).

[5] V.P. Skripov and V.P. Koverda, *Spontaneous Crystallization of Superheated Liquids* (Nauka, Moscow, 1984) (in Russian).

[6] V.G. Baidakov, *Thermophysical Properties of Superheated Liquids*, Soviet Technology Reviews, Section B, Thermal Physics Reviews (Harwood Academic, New York, 1994) vol. 5, part 4.

[7] V.G. Baidakov, *The Interface of Simple Classical and Quantum Liquids* (Nauka, Ekaterinburg, Russia, 1994) (in Russian).

[8] V.G. Baidakov, *Superheating of Cryogenic Liquids* (Ural Branch of the Russian Academy of Sciences Publishers, Ekaterinburg, Russia, 1995) (in Russian).

[9] I. Gutzow and J. Schmelzer, *The Vitreous State: Thermodynamics, Structure, Rheology, and Crystallization* (Springer, Berlin, 1995).

[10] V.V. Slezov, *Theory of Diffusive Decomposition of Solid Solutions*. In: Soviet Scientific Reviews/Section A, Physics Reviews, Ed. I. M. Khalatnikov (Harwood Academic, London, 1995).

[11] S.A. Kukushkin and V.V. Slezov, *Disperse Systems on Solid Surfaces* (Nauka, St. Petersburg, 1996) (in Russian).

[12] B.M. Smirnov, *Clusters and Small Particles in Gases and Plasmas*, Graduate Texts in Contemporary Physics (Springer, New York, Berlin, Heidelberg, 2000).

[13] F.M. Kuni, A.K. Shchekin, and A.P. Grinin, Phys.-Usp. **171**, 331 (2001).

[14] B.M. Smirnov, *Physics of Atoms and Ions*, Graduate Texts in Contemporary Physics (Springer, New York, Berlin, Heidelberg, 2003).

[15] V.P. Skripov and M.Z. Faizullin, *Crystal–Liquid–Gas Phase Transitions and Thermodynamic Similarity* (Fizmatlit Publishers, Moscow, 2003) (in Russian).