J Stat Phys (2011) 142: 220–222
DOI 10.1007/s10955-010-0105-7

# Rashmi Desai and Raymond Kapral: Dynamics of Self-Organized and Self-Assembled Structures

## Cambridge, USA: Cambridge University Press, 2009. 342 pp, USD 76

**Igor Aranson**

Received: 19 November 2010 / Accepted: 30 November 2010 / Published online: 8 December 2010


Nature exhibits the remarkable ability to self-organize into a variety of complex dynamic and static architectures when driven far from thermal equilibrium by external forces or by heat and concentration gradients. Self-assembly, an ability to create ordered structures from simpler building blocks can range from single molecules to complex protein assemblies and is one of the most common self-organization processes occurring in a majority of biological and some synthetic systems. Self-assembly is ubiquitous in everyday life—at the most basic level all living organisms are self-assembling entities. Self-assembly is also one of the few practical strategies for large-scale production of nanostructured materials and is therefore an essential part of nanotechnology. While self-assembly can take place on scales as small as the molecular, control of self-assembly is possible largely by the manipulation of macroscopic variables such as temperature, pressure, composition, and applied electric or magnetic fields.

Nature routinely exhibits self-assembly. The potential to predict, model, and ultimately tailor the properties of self-assembled materials for broad technological applications, however, has been hampered by the lack of fundamental understanding of the dynamics of self-assembly and the ability to bridge from the microscopic to the macroscopic scales.

Although the definitions of self-assembling systems are very broad, it is practical to identify two major classes: static and dynamic. Static self-assembly involves systems that are at global or local equilibrium and do not dissipate energy. For example lipid bilayers and most systems exhibiting spinodal decomposition are formed by static self-assembly. In static self-assembly the formation of ordered structures may require energy, but once they are formed they are stable. In dynamic self-assembly, such as most of the biological systems and autocatalytic chemical reactions, the interactions responsible for the formation of nontrivial structures occurs only if the system is consuming energy from an external energy source provided, for example, by an applied field from chemical reactions. Since the hierarchical

I. Aranson (✉)
Materials Science Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439 USA
e-mail: aronson@anl.gov

structures in biological systems are stabilized, adapted, renewed, and repaired through complex reaction networks; living systems are examples of dynamic self-assembly.

During the past two decades the field of non-equilibrium self-organization and pattern formation has been studied intensively, marked by the review articles in Reviews of Modern Physics by Cross and Hohenberg in 1993 on general aspects of pattern formation out of equilibrium, and the more focused paper by Aranson and Kramer in 2002 on the complex Ginzburg-Landau equation. Among the books on self-organization and pattern formation in non-equilibrium systems the most notable are by Philip Ball, *The Self-Made Tapestry: Pattern Formation in Nature* (2001), Rebecca Hoyle's *Pattern Formation: An Introduction to Methods* (2006), and the most recent by Cross and Greenside, *Pattern Formation and Dynamics in Nonequilibrium Systems*, 2009. There are also more specialized books, among them *Granular Patterns* by Aranson and Tsimring, 2009, where pattern formation and self-assembly are explored in the context of the dynamics of grains with complex interactions. While there are certain overlaps between all these books in the field, especially with the one by Cross and Greenside, in contrast, Desai and Kapral's book *Dynamics of Self-Organized and Self-Assembled Structures* has a rather unique focus and outlook, namely an attempt to present the self-organization and self-assembly from a unified viewpoint.

Both Desai and Kapral are widely recognized in the field and are well-placed to write comprehensive book on this subject. This truly interdisciplinary book covers a slew of diverse chemical, biological, and physical non-equilibrium systems exhibiting pattern formation and self-assembly. The book features a broad combination of methods and approaches starting with the phase separation kinetics in systems close to equilibrium and progressing towards more and more complex systems such as liquid crystals, oscillatory chemical reactions, nonequilibrium patterns in optics, and culminating with active materials and biological systems.

The book clearly combines two parts. The first part features a very detailed and didactic description of the phase separation kinetics occurring in systems close to equilibrium and described by some kind of free energy functional. The second part is more general, relatively brief, and covers a variety of truly non-equilibrium systems, ranging from oscillatory chemical reactions to protein-induced patterns in bio-membranes and active materials. Correspondingly, the mathematical tools in the book can be roughly divided into two groups: methods of phase separation kinetics based on the minimization of the corresponding energy functional and a variety of techniques developed for far-from-equilibrium, such as the complex Ginzburg-Landau and Kuramoto-Sivashinsky equations, equations for excitable media, etc.

While the book includes a broad range of topics it is easily readable even by non-specialists. However, the coverage of various topics is not always balanced. For example, the consideration of phase separation kinetic is very detailed in an almost textbook style. The description of other topics, such as defect dynamics, as well as excitable and oscillatory media is appropriate, but not as detailed as that given for phase separation kinetics. Finally, the topics on biomembranes and active materials are too short to grasp the status of the field. The chapter on laser-induced melting probably would be better suited among the chapters on phase separation kinetics. Understandably, since the field of self-assembly, especially in biological systems, is not mature, it is difficult to expect the same style and depth as for the more established field of separation kinetics. Hopefully, these shortcomings, mostly minor, will be addressed in the second edition.

I enthusiastically recommend this book to graduate students and young researchers entering the exciting and truly interdisciplinary field of self-organization and self-assembly in complex systems. The book is very useful, provides an excellent source of reference material, and is clearly a valuable asset and excellent introduction not only for graduate students, but also for professors looking to build a course on pattern formation and self-assembly.