Preface

This book is about the freezing of colloids, and more generally the interactions of objects with a moving solidification interface, a phenomena encountered in a variety of natural and technological processes. From growth of sea ice to the making of ice cream, or the solidification of particle-reinforced alloys, all these phenomena share common features. The objects can be of various natures: solid (particles), liquid (in the case of emulsions), or gas.

These phenomena can be investigated, described, understood, and eventually controlled using three categories of parameters: the behaviour of the objects (can they move? will they be deformed? do their dimensions evolve? may the objects coalesce?), the behaviour of the crystals (what is their morphology? dimensions? what are their growth kinetics?), and, central to these phenomena, the interactions between the objects and the interface (will the objects be repelled? engulfed? deformed?).

The nature of the phenomenon strongly biases the way it is investigated. In some situations, the modifications (e.g. in terms of spatial organisation of matter) resulting from freezing are damages that must be controlled. This is typically the case of frost heave that damages the roads and infrastructures. In others, such as materials processing, advantages can be taken of the segregation of objects by the moving interface.

The (ambitious) objectives of this book are therefore to provide both a global view of the various occurrences of freezing colloids, but also a detailed, up to date description of the mechanisms involved in these phenomena, and how advantage can be taken from the knowledge gained in disparate fields that usually do not interact. Food engineers rarely have to read literature on sea ice, permafrost, or metallurgy. If they are interested in freezing, maybe they should.

Although it is comforting to silo the knowledge in well-defined domains, fields, or schools, the freezing of colloids is a striking example of how such separations are artificial, and I have tried to show it throughout this book. The history of how the interest of freezing colloids emerged simultaneously at different places through the last century, opening Chap. 4, is, I believe, a good illustration of this.

Being a materials scientist by training and years of practice, and because materials science is probably the most active domains these days regarding freezing colloids studies, an important part of the book is focused on material science. Providing an exhaustive state of the art of all the domains addressed in this book would have been unrealistic. I thus focused on materials science, while opening to other domains to reveal some relevant connexions.

The book is organised into 8 chapters, intended for various audiences.

The opening chapter is an overview of the various natural and technological occurrences of freezing colloids. It does not go into the details of each and every situation, but rather illustrate why and how it is investigated, and provides a few striking results.

Chapter 2 describes the different techniques used to investigate these phenomena. Because a complete description of the behaviour of the system require observations and measurements at length and time scales that vary over several orders of magnitudes, many techniques have been used so far. Each with its own advantages, drawbacks, and limitations. The most relevant are nevertheless techniques that provide information's at the scale of the objects and their interactions with the solidification front.

Our current understanding of the various mechanisms involved in the freezing of colloids is exposed in the third chapter, going through the behaviour of the objects, of the crystals, and central to these phenomena, the interactions between both. This chapter is still a work in progress, as our understanding of this complex phenomenon progresses every day and with every new paper.

The next four chapters are dedicated to the use of freezing colloids in materials science, a very active field of materials science, with hundreds of studies now published each year. It is thus intended as a detailed review of a process known as ice-templating or freeze-casting. To keep the book balanced, this part has been divided into four chapters.

Chapter 4 goes through the various processing routes associated to freezing and resulting architectures and microstructures of materials. Although most of the studies have focused on materials with porosity (templated by the crystals), the microstructural features that can be controlled by freezing go beyond macroporosity. This versatility may also explain the strong interest for these routes in the recent years.

Chapter 5 describes the different types of materials that have been ice-templated. As the principles that direct the formation of the structure are predominantly physical (and not chemical), almost all types of materials have been frozen, from ceramics to metals and polymers. The specificities associated to each of these classes of materials are presented.

Controlling the freezing of colloids is often desirable, either to take advantage of it, or to limit the damages induced by freezing. Chapter 6 describes how the process can be deliberately controlled. Although the chapter is focused on ice-templating, incursions are made in biology, food engineering, or geophysics. Some of the techniques developed in materials science could certainly be applied to other domains (and vice versa).

Finally, the properties and applications covered by these materials are exposed in Chap. 7. The objective is to provide an overview of what can be achieved, and which properties are worth targeting with these materials. I included thus many tables and plots, to illustrate the range of properties that has been achieved so far. As hundreds of papers about ice-templated materials are published each year, the values reported in this chapter will probably be outdated rapidly. However, it is intended to illustrate the benefits of ice-templating for a number of functional properties, rather than the absolute best values that can be achieved.

Every year, new researchers and teams are interested by freezing colloids problems, in particular in materials science. Although the basic principles are simple, it always takes a while to get started. If you are already involved in materials processing, you know that the methods section of papers often skip essential practical details, not deemed important enough. As science papers are more and more only success stories (alas), we are often not aware of what did not work, and what makes a difference. Anyone (and in particular students) who tried to enter a new domain or adopt a new technique in the lab knows how long and frustrating the first developments can be. Yet, such advices and guidelines are almost never reported. Chapter 8 is thus a practical guide to get started with ice-templating or freeze-casting in your laboratory. The advices provided here, and in particular the various defects obtained and how to fix them, are based on our own experience, after many years of freezing and developing incrementally elaborated set-ups to do so. Although mistakes are always useful to learn and improve your protocols, set-ups, and devices, I hope this will help you getting started rapidly and save you some time to do cool (ah!) new science. Drop me an email or a tweet if you have any additional questions.

Needless to say I am responsible for any mistake and misinterpretations in this book. I will be very grateful for any feedback, please do contact me. Also, if this book somehow helped you, feel free to send me chocolates. I will make good use of it.

Cavaillon, France
October 2016

Sylvain Deville

http://www.springer.com/978-3-319-50513-8

Freezing Colloids: Observations, Principles, Control, and Use

Applications in Materials Science, Life Science, Earth Science, Food Science, and Engineering

Deville, S.

2017, XXIII, 598 p. 365 illus., Hardcover
ISBN: 978-3-319-50513-8