Edited by Tharwat F. Tadros

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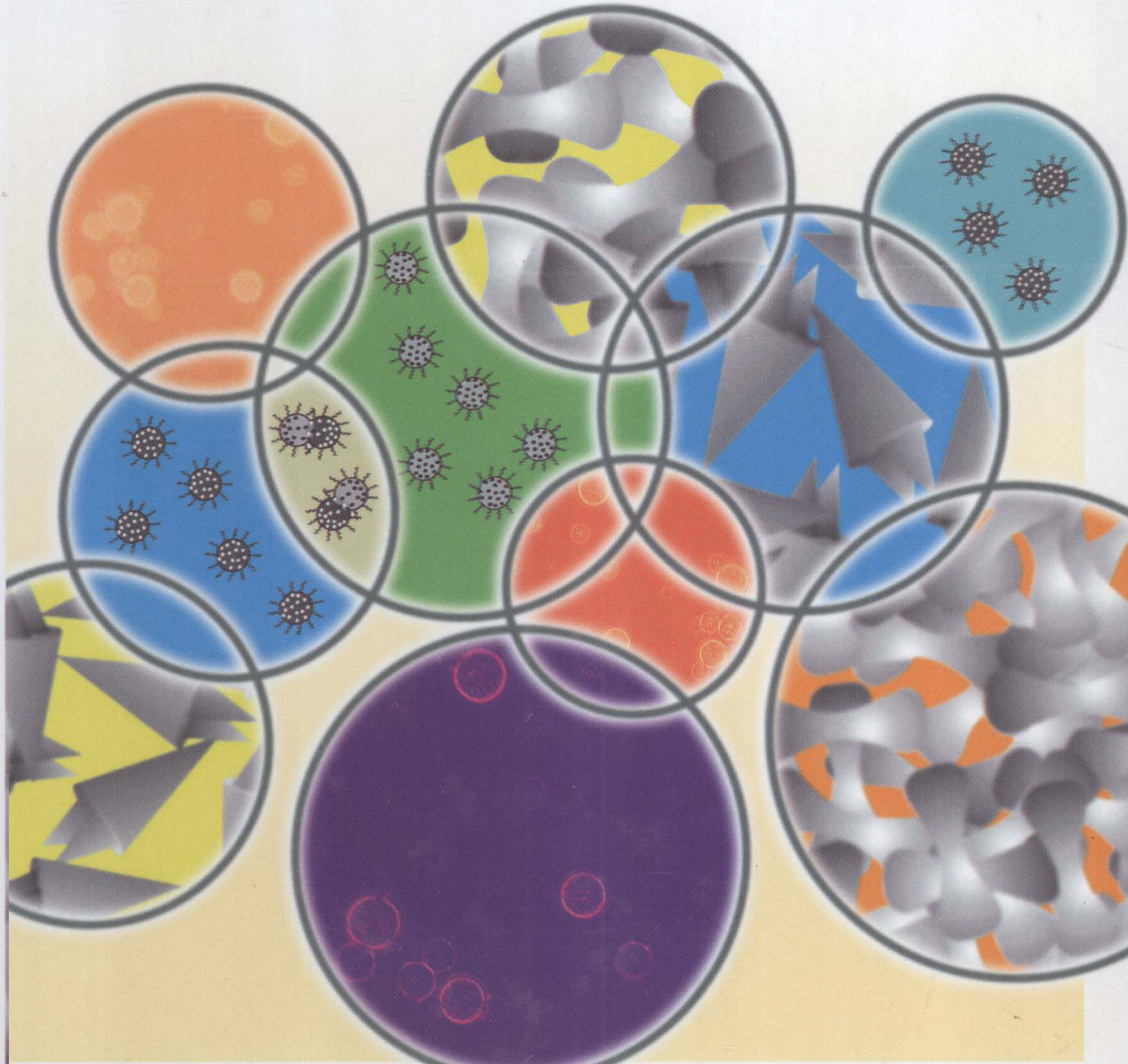
Emulsion Science and Technology



Emulsion Science and Technology

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Tharwat F. Tadros

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The Editor

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Preface

Today, emulsions are applied in a wide variety of industrial products, including food, cosmetics, pharmaceuticals, agrochemicals, and paints. With this in mind, a series of World congresses has recently been held – the first in Paris in 1993, the second in Bordeaux in 1997, the third in Lyon in 2002, and the most recent again in Lyon, in 2006. Following each meeting, a number of topics were selected, the details of which were subsequently published in the journals *Colloids and Surfaces* and *Advances in Colloid and Interface Science.*

This book contains selected topics from the Fourth World Congress, the title of which – "Emulsion Science and Technology" – reflects the importance of applying scientific principles to the preparation and stabilization of emulsion systems.

As a "introduction" to the subject, Chapter 1 provides a general description of the physical chemistry of emulsion systems, with particular attention being paid to the interaction forces that occur between emulsion droplets. The adsorption of surfactants at liquid/liquid interfaces is analyzed, and the methods and mechanism of emulsification and role of surfactants described. Those methods applicable to emulsifier selection are also detailed, as are the various emulsion breakdown processes such as creaming or sedimentation, flocculation, Ostwald ripening, coalescence and phase inversion. Methods used to prevent such breakdown processes are also detailed. Chapter 2 relates to the special application of a polymeric surfactant (a hydrophobically modified inulin) for the stabilization of emulsions, nanoemulsions, and multiple emulsions, while Chapter 3 provides the details of a fundamental study of the interaction forces in emulsion films stabilized with hydrophobically modified inulin and the correlation with emulsion stability. In Chapter 4, the application of polymeric surfactants for enhancing the stabilization and performance of personal care formulations – such as massage lotions, hydrating shower gel, soft conditioners, and sun sprays – is described, while Chapter 5 provides the details of a more fundamental study of the effect of external force fields on the self-ordering of three-phase cellular fluids in two dimensions. Here, attention is focused on the energies of cluster insertion and transformation, and the evolution of the system in a gravitational field. Chapter 6 relates to the application of the physical chemistry and sensory properties of cosmetic formulations, with the

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example of facial make-up being used to illustrate the principles involved in both drying and the evolution of viscosity. In Chapter 7, a detailed account is provided of nanoparticle preparation using miniemulsion (nanoemulsion) polymerization, and for which a variety of monomers (e.g., styrene and butylcyanoacrylate) are used to illustrate the principles. In Chapter 8, the details of some recent developments in the production of monodisperse emulsions using straight-through microchannel array devices are provided, while Chapter 9 outlines not only the preparation of isotropic and anisotropic nanoparticles (using inverse microemulsions) but also the properties of the nanoparticulate product. The preparation of nanoemulsions by spontaneous emulsification and stabilization of the resulting nanodroplets by block copolymers, namely poly(caprolactone-*b*-poly(ethylene oxide), are described in Chapter 10, while the routes for the synthesis of waterborne acrylic/clay nanocomposites (prepared by miniemulsion polymerization) are outlined in Chapter 11. The preparation of giant vesicles with a controlled size and a high entrapment efficiency, by using monodisperse water-in-oil emulsions, is detailed in Chapter 12, while the final chapter describes the preparation of polymer latexes stabilized with clay particles, and the possible preparation of nanocomposites, using the same approach.

Based on the above descriptions and details, it is clear that this book covers a wide range of topics, both fundamental and applied, and also highlights the importance of emulsion science in many modern-day industrial applications. It is hoped that the book will be of great help to emulsion research scientists in both academia and industry.

Finally, I would like to thank the organizers of the Fourth World Congress – and in particular Dr Alain Le Coroller and Dr Jean-Erik Poirier – for inviting me to edit this book.

January 2009 *Tharwat Tadros*

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Contents

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1 Emulsion Science and Technology: A General Introduction

Tharwat F. Tadros

1.1 Introduction

Emulsions are a class of disperse systems consisting of two immiscible liquids [1–3]. The liquid droplets (the disperse phase) are dispersed in a liquid medium (the continuous phase). Several classes of emulsion may be distinguished, namely oil-in-water (O/W), water-in-oil (W/O) and oil-in-oil (O/O). The latter class may be exemplified by an emulsion consisting of a polar oil (e.g. propylene glycol) dispersed in a nonpolar oil (paraffinic oil), and *vice versa*. In order to disperse two immiscible liquids a third component is required, namely the *emulsifier*; the choice of emulsifier is crucial not only for the formation of the emulsion but also for its long-term stability [1–3].

Emulsions may be classified according to the nature of the emulsifier or the structure of the system (see Table 1.1).

Several processes relating to the breakdown of emulsions may occur on storage, depending on:

- the particle size distribution and the density difference between the droplets and the medium;
- the magnitude of the attractive versus repulsive forces, which determines flocculation;
- the solubility of the disperse droplets and the particle size distribution, which in turn determines Ostwald ripening;
- the stability of the liquid film between the droplets, which determines coalescence; and
- phase inversion.

The various breakdown processes are illustrated schematically in Figure 1.1.

The physical phenomena involved in each breakdown process is not simple, and requires an analysis to be made of the various surface forces involved. In addition, the above processes may take place simultaneously rather then consecutively, which in turn complicates the analysis. Model emulsions, with monodisperse droplets, cannot be easily produced and hence any theoretical treatment must take into account the effect of

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