Preface

I became engaged in meso-scale research in 1984 when beginning a Ph.D. degree supervised by Prof. Mooson Kwauk, who believed that the phenomenon of particle clustering was critical to understanding flowing gas-solid systems. Not long after, we formulated the energy-minimization multiscale (EMMS) model by integrating the conservation equations and stability conditions. Later, the model was verified, extended, generalized, and applied to other systems, resulting in the formulation of the multi-objective variational problem and the EMMS paradigm for supercomputing. Gradually, we recognized that all meso-scale phenomena might follow common principles with respect to their stability criteria; that is, the possibility of meso-science, and that the EMMS model might be extended to a promising computation paradigm with respect to the structural consistency between modeling, software, and hardware to raise the efficiency and capability of supercomputing. This book summarizes the progression of this research, which was conducted at the Institute of Process Engineering of the Chinese Academy of Sciences (CAS).

What stimulated us to write a book summarizing this work at such a premature stage is the important possibility of developing it into a general methodology to describe various meso-scale phenomena in complex systems. Such methodology would include the compromise in competition between dominant mechanisms in defining stability conditions using computational modeling, and structural consistency between problem, model, software, and hardware. To generalize our work into a common methodology is, however, far beyond our current capability, and requires further interdisciplinary contributions, particularly from mathematics and physics. Therefore, we hope this book will stimulate interest from different fields to promote further exploration of this important topic. It should be noted that current progress is as yet insufficient for this book to present mature knowledge. Instead, we introduce a nascent idea, a potential framework, and prospects for the emerging discipline of meso-science for all meso-scales between elemental particles and the universe. The possibility of developing a general knowledge base of meso-scales at different levels encouraged us to write this book before the relevant knowledge matures. This may provide a more concrete understanding of meso-scales than the related domain of complexity science.

Experience in this field over three decades has led us to believe that the direction of multiscale research should shift to “meso-scales” because of the recognition of difficulties in understanding these intermediate scales at different levels. This book will show that all meso-scale structures form through compromise in competition between dominant mechanisms, thus defining the correlation between scales and stability criteria of complex systems.

What encouraged us to explore a general methodology or paradigm to describe meso-scales was the predictability of the EMMS model when used in our previous studies to characterize particle clustering phenomena in gas-solid systems, and the capability of the EMMS paradigm to speed up computation and to solve current practical problems. The EMMS paradigm even shows potential to realize virtual process engineering. More importantly, the prevalence of meso-scale phenomena and clues to the existence of common principles between them are the main driving forces promoting our study of meso-scales. We even discuss the governance of compromise at the quantum level, and hypothesize that wave-particle duality arises from the compromise between two or more mechanisms.

We hope this book will stimulate more study of meso-scales worldwide, and expect and welcome critiques and suggestions from the whole community. We have confidence in the future of the EMMS paradigm, but believe that the concepts described in this book need to be improved. We hope that our current limited grasp of meso-scales will not distort the description of the framework of the EMMS strategy or mislead our readers.

What should be made clear is the definition of meso-scales. A meso-scale is not an absolute dimension of size, but a relative concept meaning the intermediate scale between the smaller scale of the constituent elements and the larger scale of the composited system. Therefore, meso-science is the science of all meso-scales of many different dimensions.

This is a collective contribution by the EMMS Group. We are lucky to have the honor of writing a book based on work by many others as well as ourselves. Although most of the content in the book has been published as journal papers, this is the first time to integrate our thoughts on multiscale modeling and meso-science systematically in the form of a monograph to present a whole picture of strategies, principles and perspectives. Readers interested in details are suggested to read original publications cited in each chapter. We express our sincere thanks to all our colleagues who are working or ever worked as part of the EMMS Group for their important contributions, as detailed in the acknowledgment section that follows. It is my luck working with Prof. Kwauk for nearly 30 years. He guided me to this exciting direction of research, educated and influenced me in every respect. Without his supervision, encouragement and support, this book would be impossible. Even at his age of 92, just before his passing away, he revised part of manuscript of the book as usual and wrote the foreword. His sudden leaving is a great loss and sadness for the EMMS group. He lives in our heart forever! I appreciate Prof. Lothar Reh at the Swiss Federal Institute of Technology for allowing me to continue EMMS research without disruption in his group, where the radial EMMS model was proposed and the phenomenon of choking was explored. He encouraged this research for a long term, gave suggestions on the manuscript of the book, and heartily helped young generations of the EMMS group. He also made possible the transfer of a circulating fluidized bed unit from the Swiss Federal Institute of Technology to Beijing to validate simulations. Thanks should be extended to Prof. Peter P. Edwards of University of Oxford for a fruitful discussion on meso-science and its terminology during his stay at IPE. We thank CAS and the National Science Foundation of China (NSFC) for their long-term financial support of this work and Ministry of Finance of China for supporting the construction of supercomputers. We also express our gratitude to those who encouraged or questioned us, both of which promoted our study. Special acknowledgment should be extended again to NSFC for initiating the meso-science program recently called "Mechanisms and manipulation of meso-scales in multi-phase reaction systems".

We eagerly anticipate the emergence of a branch of science, meso-science, which encompasses all meso-scales in different fields and at different levels ranging from elementary particles to the universe and even beyond. Such a field may make it possible to correlate the whole spectrum of scales and levels, and to program simulations and design computers in accordance with the physical relationship between scales. This direction of research is promising and deserves significant attention and effort.

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