Preface

Microfluidics is a recent research area; it has only recently reached a phase of maturity and today it is an extremely active scientific field. It relates to everything that concerns flows in structures or systems involving characteristic dimensions in the order of 1 µm. Until 1990, literature in this domain was still confidential, but in 2010, researchers have access to a very important database, including books presenting the main research results and applications in microfluidics. This book gives more emphasis to the peculiarities of microflows than the applications themselves, which are nevertheless widely cited. The idea is to provide the researcher or engineer with tools for the modeling of microflows, as a preliminary stage for the design of fluidic microsystems.

From a scale analysis, Chapter 1 presents the main consequences of miniaturization on flows in a synthetic manner. Simple scaling effects, which give more weight to quantities often neglected in equations relative to macroscopic flows, are distinguished from real microeffects that require us to take new terms into account and involve original properties, linked for example to rarefaction, electrokinetic or micropolar properties of the flow. It is pointed out that scientific issues are very different for liquid and gas microflows.

Gas microflows are discussed in Chapter 2. This chapter details the modeling of various flow regimes encountered that require a continuum or a molecular approach. Analytical as well as numerical tools are presented. Original pumping techniques, the principles of which are based on thermal properties of rarefied gases, are also explained.

Chapter 3 covers the analysis of the behavior of liquid microflows forms. The role of intermolecular forces is highlighted and electrokinetic phenomena are more specifically detailed: the importance of electric double layers at the wall is shown. The main numerical tools are also presented. Several techniques for the nonmechanical control of liquid microflows, in microchannels or as microdroplets, illustrate the variety of possibilities in the field of liquid microfluidics. Microflows of physiological fluids, including blood, are analyzed in detail in Chapter 4. These particular microflows are characterized by non-Newtonian behavior and by transport in microchannel networks with soft walls.

Miniaturization gives a predominant role to surface effects, to the detriment of volume effects. This dramatically enhances heat transfer efficiency. It allows us, for example, to evacuate high heat fluxes in order to cool high-power electronic components. These aspects are detailed in Chapter 5 for gases as well as liquids.

Chapter 6 deals with two-phase microflows, emphasizing the role of basic phenomena (surface tension, contact angles, etc.). Two-phase flow configurations in microchannels are analyzed and the main applications of two-phase microfluidics conclude this chapter.

Every model should be supported by careful experimental analysis. Unfortunately the very small sizes of microsystems pose experimental problems. Chapter 7 reviews global and local measurement techniques (flowrate, pressure, temperature, velocity) as well as visualization techniques.

Chapters 8 and 9 give a more precise idea of what current fluidic microsystems look like: micropumps, microvalves, micromixers and more complex microsystems are shown. Chapter 9 focuses on microsensors and microactuators that are used for the active control of aerodynamic flows. These microsystems have local multiple and coordinated actions and are able to modify the boundary layer of the flow around the wings of an airplane to reduce drag or increase lift.

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