

Preface

Topology optimization can determine the topology, shape, and size of the structures, simultaneously. It has been regarded to be one of the most powerful approaches for the inverse design of structures in several scientific areas, including elasticity, fluid dynamics, thermodynamics, electromagnetics, etc. In fluid dynamics, one of the hot research areas is the microfluidics. And microfluidics has two typical characteristics, i.e., low Reynolds number and large surface–volume ratio. These two characteristics induces the low-efficient mass transfer and dominance of the surface tension in microfluidics. Because of these specialities, the usually used design approaches encounter the problem on synthetically considering the typical characteristics of microfluidics and manufacturability to achieve reasonable microfluidic performance. Therefore, the authors were inspired to utilize the topology optimization method and implement the inverse design of microfluidics based on the desired functional performance. Microfluidics usually has transient velocity distribution; and the actuation mechanism of microfluidics usually loads body forces or surface tensions on the microflows. However, the preliminary researches on topology optimization of flow problems mainly focused on the steady single-phase flows without body forces (including the researches of T. Borrvall & J. Petersson in 2003, A. Gersborg-Hansen, O. Sigmund & R.B. Haber in 2005, J.K. Guest & J.H. Proevost in 2006, etc). Therefore, the authors began their attempts on developing the topology optimization method for unsteady flows, flows with body forces and two-phase flows with surface tensions. In the authors' researches, the continuous adjoint method is systematically utilized to analyze the topology optimization problems; and this is can be one feature of this book. After the extension of topology optimization method, the authors have implemented several researches on the inverse design of typical microfluidic components, including micromixers, microvalves, and micropumps. There is still a plenty of room in the inverse design of microfluidics using topology optimization. The authors hope that this book can inspire more researchers in the relevant areas.

This book is a completely revised, updated, and expanded version of the authors' researches on topology optimization method for fluid dynamics. The authors knew each other since 2007, when Dr. Yongbo Deng was the Ph.D. student of Prof. Yihui

Wu and Prof. Zhenyu Liu. Before Yongbo Deng's Ph.D. defense, the authors collaborated together for pursuing the topology optimization of flow problems. During this period, they achieved the topology optimization for unsteady flows and flows with body forces; simultaneously, they have applied the developed topology optimization to implement the inverse design of the typical microfluidic components, including the passive micromixers, no-moving-part microvalves, and valveless micropumps. In the researches of passive micromixers, Prof. Zhenyu Liu's Master student Qingyong Gao played a part of the role on implementing the numerical computation; Dr. Yongshun Liu from Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP) implemented the experimental verification of the derived layouts for the passive micromixers. In the researches of no-moving-part microvalves and valveless micropumps, Yongbo Deng and Zhenyu Liu began their academic collaboration with Prof. Jan Gerrit Korvink of Freiburg University, Germany (Prof. Korvink moved to Karlsruhe Institute of Technology in 2015). After his Ph.D. study, Yongbo Deng started his professional position in the State Key Laboratory of Applied Optics (SKLAO) of CIOMP, from July of 2012. Sequentially, he achieved his researches on topology optimization of two-phase flow with two immiscible fluids and combination of the topology optimization and optimal control methods. Simultaneously, he began his attempt on applying topology optimization in electroosmotics, which is an advantageous actuation mechanism for microfluidics. During his researches on electroosmotics, Yongbo Deng knew Prof. Shizhi Qian (Old Dominion University, Norfolk, USA) and began their relevant academic collaboration. Additionally, the authors' Ph.D. candidates Song Zhou, Jianhua Fan and Yuan Ji, and the authors' colleagues Dr. Teng Zhou, Prof. Ping Zhang and Dr. Junfeng Wu participated in the relevant researches.

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