Micro-fluidic / Lab-on-a-chip Systems

The rapidly developing fields of μ-TAS (Micro-Total Analysis Systems), Lab-on-a-Chip-systems and micro-reactors used for bio-analytics and chemical processing relies on the extensive use of computational fluid dynamics (CFD) and mathematical modeling in general. The design of micro-technology applications requires a thorough understanding of

- Laminar flows
- Mass transfer
- Heat transfer
- Rarefied gas dynamics and non-equilibrium phenomena
- Free-surface flows, droplets, surface tension effects
- Reactive flows
- Particulate Flows
- Electrokinetic and electroosmotic flows
- Surface effects (hydrophobic/hydrophilic boundaries or adsorption)

In practice, many of these phenomena are present in a single device and their often complex interplay requires a detailed knowledge of fluid dynamics at a mesoscopic scale.
Micro-fluidic implies, that on the one hand, typical values of dimensionless groups characterizing the flow are shifted to unusual regimes due to characteristic dimensions in the micron range (e.g. gaseous transport can be strongly affected by rarefaction effects). On the other hand, new physics is found on very small length scales opening up new pathways of transport and actuation mechanisms.

To name a few outstanding features of micro-fluidic systems:

- Contrary to macro systems, where turbulent mixing is dominant, the mixing in μ-systems is due to diffusive mass transport. Thus alternative principles such as multi-lamination or split-and-recombine have to be utilized.
- Micro-channels allow for increased heat-transfer leading to improved heat-exchangers, which enable a superior thermal control of chemical reactions conducted in microfluidic systems as compared to macroscopic systems. .
- The inherent safety of micro-reactors allows the continuous process control of hazardous chemical reactions.
- In particular in the case of mass-transfer limited reactions (e.g. in heterogeneous catalysis) micro-systems facilitate an increased product yield and selectivity due to considerably reduced diffusion times.
- The dominant role of surface tensions effects enables alternative actuation mechanisms, valve principles and fluid pumping.
- Electrokinetic flow phenomena such as electrophoresis and electroosmosis can be utilized as a microfluidic actuation principle.
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The importance of mathematical modeling in the development of innovative micro-technological systems is also reflected in the enormous and still increasing number of related scientific articles.
The goal of the workshop is to bring together experts presenting their latest research results, allowing a cross-disciplinary exchange of knowledge to further advance numerical methods for micro-fluidics as well computer-aided system design. Contributions ranging from atomistic models to Lattice-Botzmann-, continuum approaches and network models, as well as contributions on further modeling approaches and application-oriented simulations are welcome.

The 'Mathematical Modeling & Simulation' group at IMM has a profound knowledge in modeling and analysis of micro systems in industrial and scientific contexts. Furthermore, we have expertise in the organization and accomplishment of symposia and sessions related to conferences with a focus on simulation techniques:

- Organizer of FSRM Course: 'Modelling and Simulation of Micro Fluidic Systems' held annually from 2004-2006 (http://www.fsrm.ch/doc/c202.asp?lan=e)
- Workshop organization 'Modeling and Simulation of BioMEMS, Microsystems and Microfluidic Components' part of the CADFEM User's Meeting, Dresden, 09 – 12 Nov 2004.
- Minisymposium organization 'Simulation of µ-fluidic and Lab-on-a-chip systems' at the European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS), Jyväskylä, Finland, 24 -28 July 2004.
- Workshops dedicated to simulating micro-systems have been jointly organized by IMM and CFDRC, Huntsville, AL, in the years 2001 and 2003
- Co-organizer of 'Workshop on Modeling and Simulation of Integrated Microfluidic Systems' which was held in connection with SmallTalk2003 (July, 13-16, San Jose, CA)

The Centre for Microfluidics and Microsystems Modelling at Daresbury Laboratory have been involved in analytical and numerical studies of a broad range of microfluidic problems ranging from droplet control to nonequilibrium problems in gas-phase micro-devices. We have organized many relevant meetings and contributed to a number of courses

- Course on microfluidics to be held in Valparaiso, Chile, in January 2007.
- Organizer for Institute of Mechanical Engineers' conference "Micro and Nanoscale Flows: Advancing the Engineering Science and Design", 7-8 December 2006, University of Strathclyde, Glasgow, UK.
- Course presentation at the PATENT-DfMM summer school "overview of microfluidic modelling for MEMS", 13-15 September 2005, ISLI, Livingston, Scotland.
- Invited Parallel CFD course presentation "microfluidics: small devices meet big iron" Las Palmas, Gran Canaria, Spain May 2004.
- Course presentation "an introduction to microfluidics" to students at University of Lancaster, 24th October 2003.
- Organized a Special Technological Session on Industrial Design Using Parallel CFD for ECCOMAS 1998, Athens, Greece, 7-11 September 1998.

We would like to propose holding two special sessions to cover the different areas and applications of microfluidics. We believe that the strength of interest in this rapidly developing field will ensure a positive response from researchers active in this topic. Moreover, this multidisciplinary topic is crucial to European industries and particularly SMEs and will have a major impact on technological developments in the medical, biological, chemical and pharmaceutical fields.

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