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RESEARCH PAPER

Computer-aided microfluidics (CAMF): from digital 3D-CAD models to physical structures within a day

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Abstract In this paper, we introduce computer-aided microfluidics (CAMF), a process that allows the creation of complex microfluidic structures from their concept to the actual chip within a day. During design and testing of new microfluidic systems, rapid and frequent design modifications have to be carried out. For this purpose, a device using maskless projection lithography based on a digital mirror device (DMD) has been developed. Digital mask layouts may be created using any graphics program (Microsoft Paint, Adobe Photoshop) and can be used as such by the custom-written control software of the system. However, we suggest using another approach: direct importing of three-dimensional digital computer-aided design (CAD) models from which mask information can be directly parsed. This process is advantageous as commercial 3D-CAD systems allow the rapid generation of static or parameterized models which can be used for computerized analyses like, e.g., flow simulation. After model validation, the mask information is extracted from these models and directly used by the lithography device. A chip or replication master is then created by means of lithography using curable monomers or resists as, e.g., Accura 60 or SU-8. With CAMF, the whole process from digital 3D model creation to actually running the experiment can be done within a day.

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1 Introduction

Creation of microfluidic chips is the key to microfluidic research itself. In research, experimental throughput is often significantly lower than desired because the overall time span between the first conceptual microfluidic layout and the first testable physical structure is, depending on the manufacturing strategy chosen, in the range of several days or weeks. If chip prototyping was more flexible and rapid, experimental throughput could be significantly increased. The aim of this work is to introduce a prototyping strategy that allows the generation of a physical microfluidic structure from 3D digital models within a day.

Microfluidics is among the most important disciplines in chemical or biochemical analysis, biomedical applications, and biosensing. High reaction rates due to small diffusion distances, strictly laminar flow, low sample consumption, and large surface-to-volume ratios are only a few of the numerous advantages that microfluidics offers. If microfluidic systems are created in polymers, established industrial processes for mass replication can be used which allows for dramatic cost reduction compared to classical materials such as glass or silicon (de Mello 2002). However, in academia, microfluidic chips are predominantly fabricated by casting using photolithographically structured resist layers as replication masters (Duffy et al. 1998). Mask-based photolithography using static photomasks is by far the most common method for creating a replication master. Photomasks used in this process are either created using classical microstructure technology processes such as electron beam, X-ray, or laser lithography, or, if lower