A LARGE SCALE THERMAL MICROFLUIDIC VALVE PLATFORM
Christiane Neumann*, Achim Voigt, Bastian E. Rapp
Institute of Microstructure Technology (IMT), Karlsruhe Institute of Technology (KIT), GERMANY

ABSTRACT
Microfluidics engages with the manipulation of small amounts of liquids inside of technical systems. Often microfluidic structures need a high number of microfluidic valves to create complex systems for different applications. We suggest a phase change valve system and show its scalability to an array of $12 \times 49 = 588$ valves.

KEYWORDS: Microfluidics, Phase change valve, Freeze/thaw valve, Large scale valve platform

INTRODUCTION
In indirect microfluidic systems active (and thus expensive) components such as microvalves or micropumps are strictly separated from passive (and thus cheap) components like microfluidic channels which are in contact with the analyte. Usually such a decoupling is achieved by using an intermediary second non mixable liquid such as oils. Doing so allows the creation of cheap single use microfluidic systems [1]. These systems usually need a high number of compactly packed microvalves which only need to switch the intermediary liquid. For such systems just as for all microfluidic systems that primarily handle one class of liquid (such as oils or aqueous solutions) phase change valves (PCV) are especially suitable due to their good scalability and the fact that they require few to no mechanically movable components. In general there are two types of PCV: indirect valves (where the phase changing medium blocking the channel is separated from the channel by means of a membrane) and direct PCV (where the fluid in the channel is used to close the channel directly). The literature describes several possible ways for constructing PCV: Bevan and Mutton sprayed liquid carbon dioxide directly to the channel walls to freeze the fluid inside and used ambient heat to thaw the fluid [2] achieving low freezing but very high thawing times. Gui and Liu cooled or heated their system with a Peltier element to freeze or thaw the fluid in the channel [3]. The switching is thus controlled by electricity only. Because of the high thermal mass of such systems, they have large response times for switching between open and close state. A further approach from Gui et al. used two temperature levels for cooling and heating the system [4]: one thermoelement is used to set the operation temperature of the system to around the freezing point, a second thermoelement is used to precisely cool or heat the system to freeze or thaw the valve thus reducing response times.

THEORY AND EXPERIMENTAL
We suggest a system that uses one Peltier element to set the base temperature to below the freezing point of the liquid and a set of ohmic resistors located in the respective microfluidic channel for heating and thus thawing of the valve (see Fig. 1).

Figure 1: Schematic setup of a single valve: 1 - microfluidic chip, 2 - microfluidic channel, 3 - electronic circuit board, 4 - ohmic resistor, 5 - Peltier element, H - height (distance by which the freezing area of the valve is separated from the main level in which the fluid flows).

We created an array of $12 \times 49 = 588$ resistors, which can be separately adjusted using computer defined temperature profiles (see Fig. 2). This heating pixel array is controlled via a diode matrix (rows A-L and columns 1-49, see Fig. 3a). One pixel consists of a resistor of $330 \, \Omega$. The input signal is automatically rotated about the 12 rows in 12 ms. The temperature of the Peltier element and the power of the heating pixels are controllable by means of a custom written software. The power of the heating pixels can be graduated in steps of 10% and different groups and patterns can be created to adjust the heating at the different points on the array (for preheating or cooling the valves to optimize reaction times, see Fig. 3b).
RESULTS AND DISCUSSION

In first experiments we used a single valve set-up for analyzing the influence of the height $H$ (see Fig. 4a) and to optimize the structure and the heating temperature profile (see Fig. 4b) for achieving minimal reaction times. For all experiments we used tetradecane as the working fluid and the Peltier element was set to a working temperature of 0 °C. Figure 4a shows that response times to open the valve raise with the time the valve is closed before heating and decline with increasing height until $H = 12$ mm. The heating temperature was 24.5 °C. Simulated response times are two times smaller. Figure 4b shows that response times to close the valve are reduced with decreasing temperature of the resistor after the period to open the valve. This illustrates the need of individual temperature patterns.

Figure 4: a) This diagram shows the reaction times to open the valve in dependence from height $H$ and frozen time before thawing. b) This diagram shows the reaction times of height $H = 12$ mm to close the valve in dependence of heating temperature and heating time.
CONCLUSION AND OUTLOOK

We present the set-up of a thermal valve which is well scalable on a large valve platform. An array of $12 \times 49 = 588$ resistors has been produced and we proved them to be controllable individually. After preliminary testing we will show that such a system can be used to serve as a 588-channel microfluidic valve platform with a wide range of application in combinatorial or analytical chemistry. A first design in order to verify the system design is currently being set up in the form of a 3-bit fluidic multiplexer (see Fig. 5) which we will describe in detail.

![Experimental setup for the fluidic 3-bit multiplexer. 1 - fluidic polymer chip (produced by stereo lithography in an epoxy polymer), 2 - microfluidic multiport connector [5] for interfacing the chip, 3 - circuit board with $12 \times 49 = 588$ SMD resistors, 4 - electronic control board. The Peltier element is located below the circuit board. The total size of the area for the resistors is 6 cm x 12 cm.]

REFERENCES


CONTACT

* Christiane Neumann, phone: +49 721 608 23236; christiane.neumann@kit.edu