Development and testing of a fast sensor for residence time distribution of gas flow through microreactors

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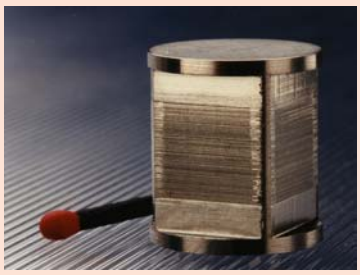
Introduction

Microreaction technology has developed different components in recent years – microreactors, mixers and heat exchangers.

These components are advantageous with respect to the mixing procedure, heat transfer and also residence time distribution. It was hitherto not, however, possible to measure the residence time distribution.



Micro heat exchanger, build by FZ Karlsruhe

This situation is very unsatisfactory because knowledge of the residence time distribution not only gives information on the real flow behavior within the microstructure but it is also necessary for the modeling and simulation of its behavior.

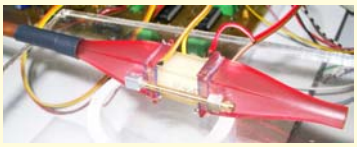
The aim of this work was to develop such a sensor system.Two conditions had to be fulfilled. The sensor had to be quick with a time constant in the lower range of milliseconds. It also had to be possible to integrate it into the microstructure.

Realization

Sensor: thermal conductivity detector (see picture in the center)

> can be built so small that integration is possible (see picture of the combined sensor and microreactor)

> time constant of approx. 12 ms (sensor wire used has a diameter of 12 µm)



Microreactor with sensors

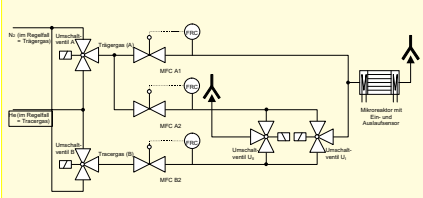
Procedure:

> create the concentration step helium in nitrogen by a combination of mass-flow-controller and magnetic valves (see flow chart) which are able to create a step within 10 ms

> measure the step response before and behind the reactor

> normalize and differentiate the step response to obtain the residence time distribution

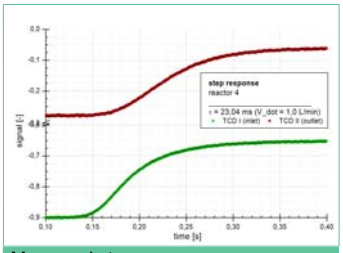
> calculate the residence time distribution of the reactor by the difference in residence time distribution before and behind the reactor



Flow chart

Results

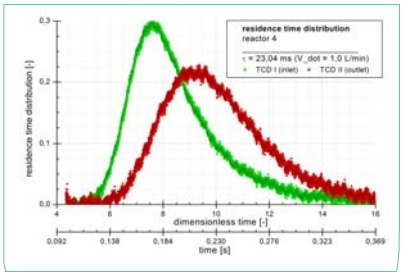
The sensor system was used to measure the residence time distribution of different microreactors, built by the partner in the project, FZK, under different conditions (see, for example, the step response and residence time distribution of a microreactor). The results shown are valid for a microreactor with 384 mm³ free reactor volume under operating conditions with a mean residence time of 23 ms.



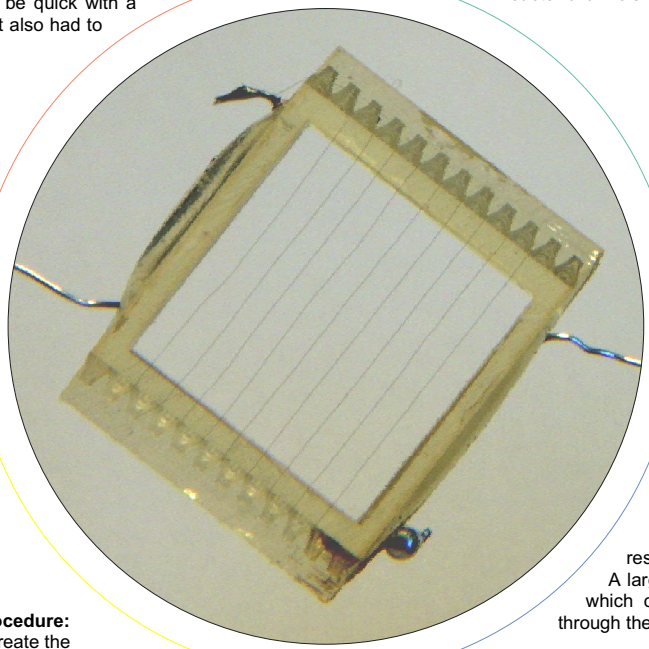
Measured step response

It could be seen that the sensor system is able to measure the residence time distribution. But it was also found that the microreactor had not the sharp residence time distribution assumed: the Bodenstein number is in the range of 3, which means that dispersion plays a significant role in microreactor behavior.

The reason for such a strong influence of the dispersion can be assumed to be the unequally distributed flow through the micro-reactor channels.



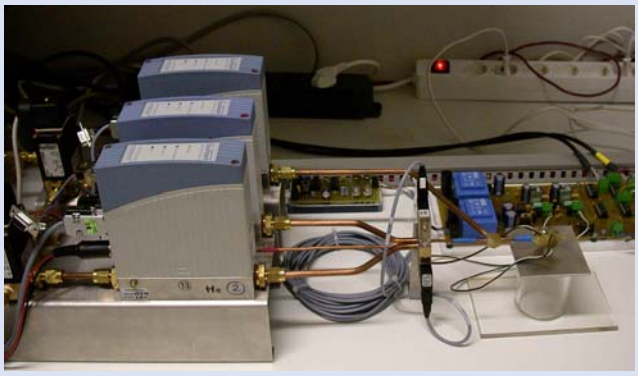
Residence time distribution



Conclusion

In this project a quick, integratable sensor system to measure the residence time distribution of microreactors was developed. The sensor is based on heat conductivity detectors.

The sensor system was used to examine the residence time distribution of different microreactors. A large dispersion within the microstructure was found, which could be the result of unequally distributed flow through the microreactor channels.



Test facility