Evaluation of a four-layer lamination micro mixer used for time resolved FTIR spectroscopy on the low ms time scale



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Abstract

Time resolved measurements are a hot topic in IR spectroscopy today. Two well established techniques, step scan and rapid scan measurements, suffer from the same major drawback. For both techniques the (bio)chemical reaction under investigation needs to be triggered and additionally, the classical step scan experiment can only be applied for cyclic reactions.

A very promising approach to overcome the triggering problem is to use micro mixers for time resolved measurements. The basic principle of this technique is to mix two liquids through diffusion in a mixing channel that also serves as measurement area. The actual measurements take place at well defined spots along this channel, corresponding to specific reaction times: moving the measurement spot towards the entry yields shorter reaction times, moving it towards the channel's end gives longer reaction times.

For time resolved FTIR measurements, utilising micro mixers, fast mixing times are crucial to ensure a well defined starting point of the (bio)chemical reaction. This is challenging to achieve in small dimensions, limited by the experimental parameters, due to the laminar flow regime present.





The CFD simulation above shows the concentration distribution at the channel inlets over the depth of the mixing channel. Shortly after the last inlet channel the four layers of liquid can be seen.



To evaluate the mixing performance of our new four layer lamination micromixer the chemical reaction of Na₂SO₃ with formalin was investigated. The 0.2 M solutions were pumped through the mixer by a kDs 100 syringe pump equipped with two 500 µl syringes. The size of the measurement spot was 100x180 µm and 86 spectra have been recorded with a Bruker Hyperion 3000 microscope along the mixing channel.

The occuring reaction can be seen in the figure above. The Na₂SO₃ band at 942 cm⁻¹ decreases whereas the product band of CH₂(OH)SO₂⁻ at 1180 cm⁻¹ increases. The formalin band at 1025 cm⁻¹ splits into two bands during the reaction.

In the figures below the influence of different pumping speeds to the mixing process was evaluated. The speed was varied from 4 to 7 µl/min and as can be seen below had hardly any effect on the mixing. Compared to our previous two-layer mixer design [3] the mixing time improved by a factor of ~25.

2.25



This CFD simulation shows the concentration distribution over the width of the mixing channel at a) 50 μ m, b) 100 μ m and c) 150 μ m along the channel length. In a) the first two liquid layers can be seen. Fig. b) already shows the four layers and in c) the two liquids are almost mixed. Only at the very edges of the mixing channel a non uniform concentration profile can be observed.

The *fabrication process* of the mixer starts with spincoating the lower side of the silicon wafer with a photoresist. After photolithography the inlet holes are etched with KOH. After that the upper side is structured with photolithography and the 200 µm deep inlet channels are formed by deep reactive ion etching (DRIE). The channel is realised using a photopatternable silicone polymer which is spincoated onto the CaF, wafer and photostructured afterwards. The last processing steps include the bonding of the Si and CaF, wafers and cutting out the mixers.



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