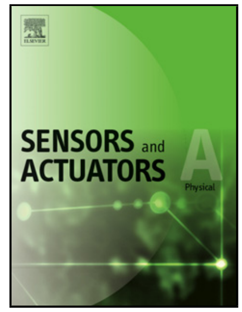
Accepted Manuscript



Title: A microoptical sidestream cuvette based on fast passive gas exchange for capnography

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PII:	S0924-4247(17)30909-3
DOI:	https://doi.org/10.1016/j.sna.2018.04.022
Reference:	SNA 10735

To appear in: *Sensors and Actuators A*

Received date:	24-5-2017
Revised date:	8-3-2018
Accepted date:	13-4-2018

Please cite this article as: Weigel C, Grewe A, Sinzinger S, Hoffmann M, A microoptical sidestream cuvette based on fast passive gas exchange for capnography, *Sensors and Actuators: A. Physical* (2010), https://doi.org/10.1016/j.sna.2018.04.022

A microoptical sidestream cuvette based on fast passive gas exchange for capnography

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Research highlight

- A new system concept for sidestream capnography sensors is shown.
- The optimized connection of the sidestream system to the breathing tube allows for a passive gas flow without valves and pumps during breathing.
- The cuvette can be freely designed for optimized optical and fluidic properties without influence of the breathing behavior.

Abstract

In the case of clinical ventilation, sensors are needed that analyze the carbon dioxide concentration during the exhalation cycle. For devices capable to individually control and adjust parameters for each patient, the analysis of the breathing conditions including carbon dioxide concentration is of critical importance. We present a miniaturized system that is optimized for a fast passive gas exchange with low dead volumes in the side stream. The presented system which is also suitable for neonates shows high dynamics and no influence on the breathing behavior due to small systems sizes. Cost reduction is achieved through a fully passive gas flow that does not require active elements such as valves and pumps. The cuvette has been designed for optimized optical and fluidic properties for surveillance in a wide range of breathing conditions.

Keywords: capnometer, infrared absorption, microoptical system, gas sensor, CO_2 sensor, clinical ventilation

1. Introduction

In clinical ventilation, sensors for analyzing the carbon dioxide concentration during the exhalation cycle are required. For high temporal resolution the quality of the output signal is of overriding importance. A stable and sufficiently high signal amplitude is needed to detect slight changes with a reasonable signal-to-noise ratio (SNR). In clinical applications, when a device is to individually change and control parameters for each patient, there exist high requirements on sensor accuracy and stability.

For CO_2 detection, the absorption of infrared light in the wavelength range from 4.2 to 4.4 µm is preferred, because anesthetic gases have no influence on this absorption bands [1]. The measurement can be done in the mainstream or in parallel tubing (sidestream). In this case the exhalation gas diffuses into the measurement cell. The system response time is slow and the technical effort to detect peak values between exhalation and inhalation increases [2]. This is why mainstream sensors are preferred. For macroscopic tubes a single optical path through the measuring volume can be sufficient as used in many available commercial systems. Miniaturized devices for sidestream measurements can help to speed up the response time while at the same time resulting in challenges for high signal to noise ratios [3]. Innovative designs can be realized applying microsystems technology. The advantages of microsystems technology are shown in [4, 5], where micro-technological approaches for capnometric sensors are already presented where the main optimization was focused on the detector system and not the cuvette system, itself. For miniaturized cuvettes, a single beam path does not result in the required optical path length for high sensitivity. To detect small carbon dioxide concentrations with a high resolution, an optimal optical path length of around 50 mm is necessary [6]. A microfluidic design needs to have small flow resistances to diminish the influence on the patients' exhalations resistance. In a sidestream design a high flow resistance decreases possible flow rates for the gas exchange in the cuvette. Furthermore, the system has to be heated to avoid water condensation from saturated exhaled air.

A complete capnometric sensor device realized in silicon technology is presented in [7]. The fabrication process includes multiple bonding procedures of silicon