Development of Sensor Systems for Continuous Exhaled Breath Diagnostics

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Traumatic shock usually leads to associated acute metabolic stress, which reflects in an enhanced energy expenditure usually determined via the analysis of oxygen uptake (VO_2) or CO_2-production (VCO_2) with the breath matrix. When infusing isotopically (i.e., ^{13}C) labeled glucose, quantification of the exhaled $^{13}CO_2/^{12}CO_2$ ratio is facilitated for directly determining glucose oxidation rates, and – if the isotope enrichment is simultaneously determined in blood – for analyzing endogenous glucose release. Conventionally, $^{13}CO_2/^{12}CO_2$ ratios are determined via non-dispersive infrared spectroscopy (NDIR), or using gas chromatography coupled with mass spectrometric detection (GC-MS). However, for more precisely tracing the energy budget and the associated metabolic parameters, such measurements should ideally provide direct and continuous information on intubated mouse models under artificial breathing conditions. Hence, it is necessary developing analytical tools and methods, which may continuously operate in minute breath volumes provided by the mouse (i.e., few hundreds of microliters), and which enable molecular differentiation of relevant metabolites with the required temporal resolution and analytical accuracy.

The aims of this dissertation project are therefore (i) the development of next-generation miniaturized and integrated infrared spectroscopic sensing technologies for continuously determining exhaled $^{13}CO_2/^{12}CO_2$ and inhaled O_2 during artificial breathing conditions utilizing innovative waveguide technologies pioneered at IABC (substrate-integrated hollow waveguides - iHWGs), (ii) the application of advanced quantum cascade and interband cascade laser technologies (QCLs, ICLs) along with optimized multivariate data evaluation schemes for improved detection capabilities, and (iii) the combination of IR sensing technologies with fluorescence sensors and ion mobility spectrometry for comprehensive multi-component diagnostics in exhaled breath.

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