Gas sensors by flame aerosol deposition: Correlations between blood glucose and breath components from portable gas sensors and mass spectroscopy

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Breath analysis has become increasingly significant for its potential in clinical diagnoses (Manolis, 1983). It is also one of the least invasive procedures for monitoring diseases and particularly attractive for patients who have to control body parameters such as glycemia for diabetics. Among all volatile organic compounds and gases in the human breath, acetone is one of the most abundant. Its breath concentration increases in patients with uncontrolled diabetes (Cao and Duan, 2006) and during normal overnight sleep of healthy persons (King et al., 2012).

Several methods (e.g. GC-MS, PTR-MS) can be used for measurements of breath composition (Risby and Solga, 2006). They provide detailed characterization of breath composition but are usually bulky. So there is considerable interest in the development of hand-held devices for reliable monitoring of specific breath markers. For this, chemo-resistive gas sensors based on semiconductor nanoparticles are attractive for breath analysis (Righettoni et al., 2010) offering low fabrication costs, high sensitivity and high miniaturization potential (Tricoli et al., 2010). Portable gas sensors made of Si:WO_3 nanoparticles were already applied to continuous monitoring of the breath acetone from healthy subjects during rest or physical activity and these measurements were in agreement (>98%) to simultaneous PTR-MS analysis (Righettoni et al., 2012).

Here, a portable acetone sensor consisting of flame made Si-doped WO_3 nanostructured films (Righettoni et al., 2010) was used to analyze the end tidal fraction of the breath collected in Tedlar bags from eight volunteers after overnight fasting and after lunch. These samples were analyzed simultaneously by proton transfer reaction, time-of-flight, mass spectrometry (PTR-TOF-MS). Furthermore, blood glucose levels were measured for each person after breath sampling to investigate possible correlations with specific breath markers and sensor response. Figure 1 shows the PTR-TOF-MS signals of acetone (red broken line) and ethanol (blue dotted line) compared to the Si:WO_3 sensor signal (black line) of the exhaled breath of three different subjects or persons after overnight fasting. Subjects S1 and S3 showed similar acetone signals in agreement with their corresponding sensor responses. Subject 2, in contrast, showed a higher acetone signal by PTR-TOF-MS that is captured nicely by the sensor response. Additionally, the strong difference in breath ethanol content between S1 and S3 hardly affected the sensor response, confirming the high selectivity against ethanol of these sensors. These results showed a reliable sensor response to different breath acetone concentrations from different subjects independent of ethanol and other breath gas concentrations. Similar agreement was obtained for most of the subjects in the afternoon. Statistical analysis showed indeed strong correlations in the morning (after overnight fasting) between blood glucose and breath acetone (0.98), sensor response (0.96) that became, however, weaker after lunch. These results are promising for future breath-based glucose testing for further development of portable devices based on chemo-resistive gas sensors in clinical applications.

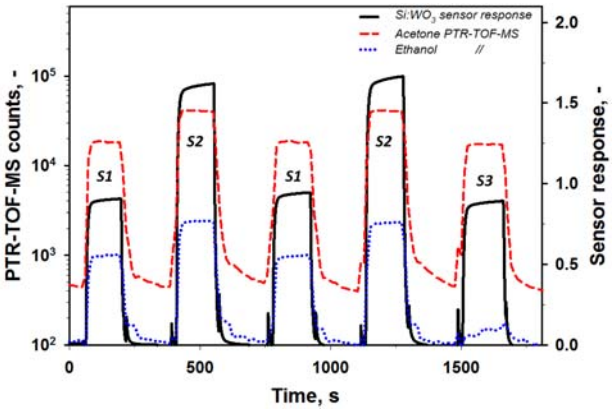

Figure 1. Exhaled breath concentrations of acetone (red broken line) and ethanol (blue dotted line) measured by PTR-TOF-MS for three different persons along with the portable sensor response (black line).

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Manolis A (1983) *Clin. Chem.* **29** 5-15.
Cao W Q and Duan Y X (2006) *Clin. Chem.* **52** 800-811.
King J, Kupferthaler A, Frauscher B, Hackner H, Unterkofler K, Teschl G, Hinterhuber H, Amann A and Hogl B (2012) *Physiol. Meas.* **33** 413-428.
Risby T H & Solga S F (2006) *Appl Phys B* **85** 421-426.
Tricoli A, Righettoni M and Teleki A (2010) *Angew. Chem. Int. Ed.* **49** 7632-7659.
Righettoni M, Tricoli A and Pratsinis S E (2010), *Anal. Chem.* **82** 3581-3587.
Righettoni M, Tricoli A, Gass S, Schmid A, Amann A, Pratsinis S E (2012) *Anal. Chim. Acta.* **738** 69-75.