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A portable breath acetone analyzer for a real-time quantitative analysis of exhaled acetone using nano ZnO films and a gas separation unit

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Abstract

We have devised a portable breath acetone analyzer which is able to analyze acetone in exhaled breath quantitatively without a pre-concentrator. This analyzer employed a breath gas sampler, an ultrathin ZnO film gas sensor and a gas separation unit, which is sensitive enough to detect breath acetone with low sub ppm levels and has an upper detection limit of more than 100 ppm. Test results for the human breath acetone are favorably compared to blood ketone (beta-hydroxybutyrate) measurements, indicating that the analyzer can measure the human breath acetone selectively with a high sensitivity. This breath acetone analyzer is a promising candidate to monitor fat burning and lipolysis.

Key words: Breath analyzer, breath acetone, exhaled gas analysis, ZnO thin films, lipolysis, fat burning, ketosis

Introduction

A breath analyzer with a specific application as a point-of-care test device is appropriate for personal use, fitness centers and medical clinics. In particular, breath acetone is the biomarker related to changes to metabolism for diabetes, fat loss, and ketogenic diet. One monitoring methods for the ketosis is to measuring beta-hydroxybutyrate (BOHB) in human blood. The inconvenience and expensive of strips for blood collection can be significant drawbacks, to this technique.

According to recent research, acetate has been found with a close correlation with BOHB levels in the blood. Acetone or acetate is another ketone body resulting from the metabolism of BOHB to acetoacetate and to acetate. Therefore, breath acetone measurement is the most effective and convenient way for monitoring fat metabolism. The concentration of breath acetone has been reported from 1 ppm to more than 1250 ppm, but the range of 0.1 ppm to 100 ppm is important in practice. Here, we report a portable breath analyzer for a real-time quantitative analysis of exhaled acetone using nano ZnO films and a gas separation unit.

Experimental

A nano ZnO film was deposited on an alumina substrate (5mm x 2mm x 0.4mm) by using an ion beam sputtering system. An ion beam was used for sputtering from a ZnO target, where acceleration voltage and current density were 1.2 keV and 1.5 mA/cm^2, respectively. The deposited ZnO films were annealed in an electrical furnace at 600 °C for 10 hrs. The alumina substrate having inter-digitated electrodes on the front and a Pt heater underneath. For electrical contacts, Pt wires (70 μm diameter) were bonded to the electrode with Pt paste. The sensor was heated to 420-450 °C and the electrical resistance of the sensor was recorded by our new breath acetone analyzer. This analyzer is designed for use with a very small sample of breath eg 1 ml. This is transferred into the analyzer by an automatic sampling device of end-tidal breath, also of our design.

Results and Discussions

We measured standard acetone gases in various concentrations by using the analyzer. Fig.1 shows the analyzer is able to detect a very low level acetone ca 0.5 ppm and the peaks appear at identical retention times. The analyzer also was tested for the breath acetone of two volunteers. One has a normal diet and the other is on a ketogenic diet. These results were compared with standard acetone gas of 1 ppm and 10 ppm, respectively.

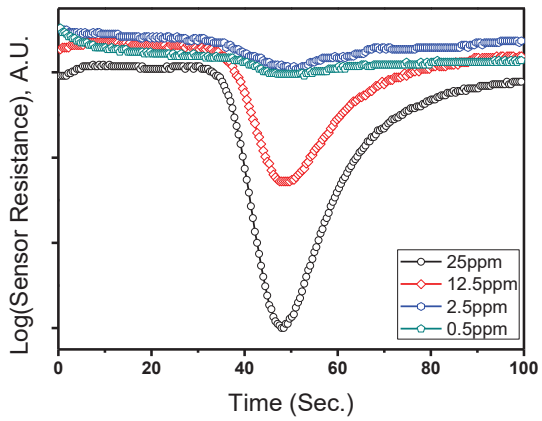

Fig. 1. Graph of retention time(seconds) Vs. Log (sensor electrical resistance) shown by the breath acetone analyzer: standard acetone gas concentrations are 0.5, 2.5, 12.5, 25 ppm, respectively.

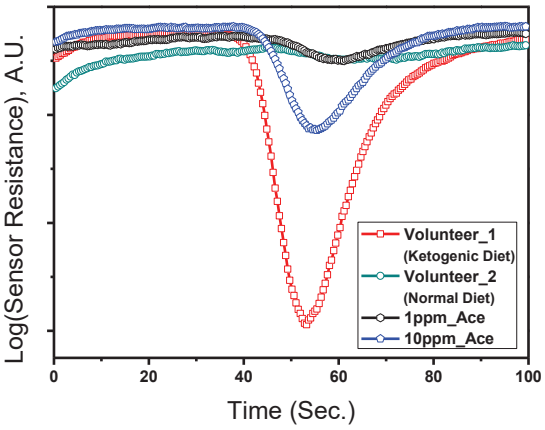

Fig.2. Comparison of retention time(seconds) Vs. Log (sensor electrical resistance) for the human breath and standard acetone gases recorded by the breath acetone analyzer: volunteer 1 (ketogenic diet) & volunteer 2 (normal diet) and 1ppm & 10 ppm standard acetone gases, respectively.

Fig. 2 illustrates good correlation between the two samples with comparable peak identification times. Though the breath has many components, the analyzer is able to detect the acetone selectively and quantitatively.

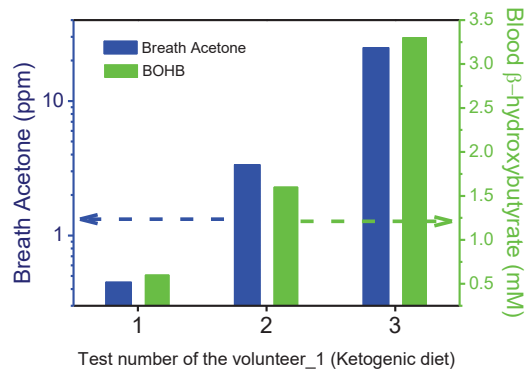

Fig.3. Comparison of Breath Acetone and Blood BOHB from the human.

According to former studies, the breath acetone is proportional to blood ketone level such as beta-hydroxybutyrate, BOHB. We measured them by using a blood ketone meter. Fig. 3 confirms the analyzed breath acetone is well matched with BOHB. An example of this test is presented in Fig. 4.

Fig.4. Blood BOHB meter(Left) and an example of the portable breath acetone analyzer(Right)

Concluding remarks

We devised a portable breath analyzer which is able to analyze acetone in exhaled breath quantitatively and selectively. This breath acetone analyzer has been demonstrated to effectively monitor fat burning and lipolysis.

Acknowledgement

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References

[1] Joseph C. Anderson, Measuring Breath Acetone for Monitoring Fat Loss: Review, Obesity 23 (2015) 2327-2334; doi:10.1002/oby.21242

[2] A. T. Güntner, N. A. Sievi, S. J. Theodore, T. Gulich, M. Kohler, and S. E. Pratsinis, Noninvasive Body Fat Burn Monitoring from Exhaled Acetone with Si-doped WO_3-sensing Nanoparticles, Anal. Chem. 89 (2017) 10578-10584; doi:10.1021/acs.analchem.7b02843

[3] Yong-Sahm Choe, New gas sensing mechanism for SnO_2 thin-film gas sensors fabricated by using dual ion beam sputtering, Sensors and Actuators B 77 (2001) 200-208

[4] Yong-Sahm Choe et al., A preliminary evaluation of a new portable gas chromatograph with an automatic sampling for VSCs measurements, Oral presentation II, The 5th annual meeting of the Japanese Academy of Malodor Syndrome, Osaka, Japan, 5-6, July, 2014