Background and Introduction

The lack of inexpensive sensor technology that would detect and monitor the concentration of a single gas with high specificity and at low trace concentrations, in the presence of numerous interfering compounds, has presented a main obstacle in advancement of the diagnostics using breath analysis.

Task: design of a sensory system for detection and discrimination of nitric oxide in exhaled breath and measurement of the trace concentration for affordable and noninvasive medical diagnostics technology.

Objective: to develop a stand-alone FENO measurement micro-system that would operate as an easy to use, robust and reliable personal device.

Challenges in the design of the system:
- a simple, low cost and small area gas sensor/sensor array specific to nitric oxide
- achieving the short-term and the long-term stability of the sensor response
- high sensitivity and low power readout circuit
- low power heating element

Sensory System Overview

Limits on sensitivity:
- electrical noise
- large baseline resistance that can be few orders of magnitude higher than the actual sensor response
- baseline variation (short-term and long-term)

Short-term sensor stability:
- drift due to chemical reactions

Long-term sensor stability:
- drift due to physical and chemical reactions

Response variations across different sensors:
- large variability of baseline resistance
- the drift in the baseline resistance over time at a different rate

Embedded Signal Processing

Goal: to obtain a calibration curve that would be independent of the baseline variations over both short and long time frame.

From the controlled measurements, with constant gas flow, we can extract the response and relaxation time of the sensor and obtain the calibration plots.

For the dynamic measurement, we are investigating how these parameters characterize the response under different flow rates.

Independent component analysis (ICA) is used for the compensation of the baseline variations.

Discrete Readout System Implementation

Handheld, portable wireless FENO breath analyzer has been designed. Signal conditioning comprises baseline compensation, variable feedback resistance for control of the dynamic range and 2^nd order low-pass filter.

Proposed signal processing techniques are implemented on a micro-controller.

Sensor resistance range: 100G ~ 10MO
Size: 7.5cm x 7.5cm
Power consumption: 168mW (360mW when Bluetooth is on)

Block diagram of the wireless prototype: Discrete implementation of signal conditioning

Integrated Readout System Implementation

VDAC provides adaptable current through a sensor for different baseline resistance.

Integration of Analog to Digital Converter

Sensor baseline resistance range: 1KΩ ~ 100MO
0.05% ~ 10% of sensor resistance change detectable
Total dynamic range: 166dB
Power Consumption: 400 μW
Chip area: 1.4mm x 0.8mm
Fabricated in 0.5μm CMOS technology

Conclusion

The proposed sensory system integrates the signal processing techniques that address important challenges in the design of the FENO monitoring device with high sensitivity and reliability.

The implemented and fabricated readout ASIC that interfaces the sensors/sensor array will be integrated in a nitric oxide breath analyzer for monitoring and managing airway diseases, such as asthma.

The proposed sensory system for monitoring FENO can be interfaced with different selective sensors and used as a coarse diagnostic tool to enable an early detection and to direct more complex diagnostic tools where to focus attention.

References


Acknowledgment

This work is supported by the National Science Foundation (NSF) grant IIS-1231761.