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# Investigation of SiNW Structures Response to Ammonia at Different Humidity Conditions

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**Summary:**

We demonstrated the silicon nanowires structure sensing response by measuring the change in electrical conductance upon $NH_3$ gas exposure. Measurements were taken for SiNW and $TiO_2$ decorated SiNW samples at very low concentrations of ammonia gas starting from 1 ppm up to 11.8 ppm in dry and humidity atmosphere. Results showed an increase in sensitivity and lower response time to ammonia gas in presence of 50 % humidity.

**Keywords:** SiNW, gas sensing, ammonia, humidity

### Background, Motivation an Objective

Silicon nanowire strucutresarepromising platforms for gas sensing, thanks to their exceptionally high surfacetovolume ratio, and favorable chargetransport properties.The reduced dimensionality and large density of surfaceactive sites in these nanostructures enhance adsorption and chargetransfer, enabling the realization of gas sensors with high sensitivity and chemical selectivity [1].

This this work demonstrates the analysis of the sensor mechanisms in SiNWs structure during exposure to ammonia gas. SiNW samples were produced by chemical etching using silver nanoparticles (MACE) on standard Si (001) p-type substrates, with a thickness of 525 µm and resistivity ρ of 0.1–0.5 Ω·cm. The MACE method is a relatively simple and inexpensive technique for producing highly sensitive sensor nanostructures [2]. The results showed that the structures respond very well to ammonia. In addition, the sensor response was significantly improved in the presence of humid air. Ammonia ($NH_3$) is a toxic gas with reducing properties. Long-term exposure can cause serious health problems [3]. This gas can also be used as a biomarker for selected diseases by monitor-ing its concentration in exhaled air. However, it is difficult to produce $NH_3$ sensors that can operate at high humidity levels, such as in human breath [4].

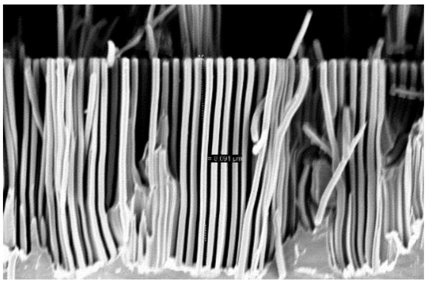
### Description of the New Method or System

Our results showed that proposed sensor structure revealed superior sensitivity and functionality in humid conditions. The effect can be utilized in clinical application to detect various disease and dysfunctions, as well as for air-pollution.

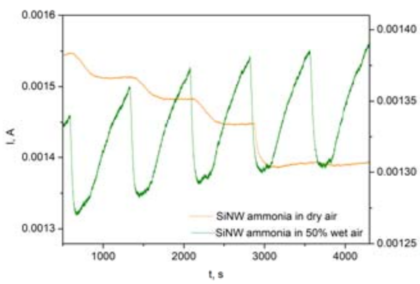
### Results

An example of a cross-sectional image of a SiNW sample obtained from a scanning electron microscope and measurements of the current response versus time for a p-type SiNW structure are shown in the figure below (Fig. 1). As can be seen in Fig. 1 b), c) the sensor response was measured for different NH3 concentrations: 1 ppm, 2 ppm, 3.7 ppm, 6.7 ppm, 11.8 ppm, in dry air and at 50% humidity for bare SiNW as well as $TiO_2$ nanoparticles decorated SiNW. All measured structures exhibited sensitivity to NH3 concentrations from 1 ppm. However, for bare SiNW the response for the concentrations up to 6.7 ppm was very low and independent form the concentration level. A more stable and pronounced sensor response to ammonia was observed when measuring under humid conditions (i.e. 50% humidity). This is a promising result from the point of view of the application as sensor of NH3 low concentrations from the human breath. The disadvantage of this type of sensor is a long recovery time. As one can see from the Fig. 1 b), the current value does not return to the baseline after recovery time two-fold higher than exposure time. In contrary, the $TiO_2$ nanoparticles decorated SiNW revealed more pronounced response compared to bare SiNW in the dry air, and better recovery time in the humid conditions. Similarly to bare structure, $TiO_2$ decorated one shows higher sensitivity to NH3 under 50% humidity than in the dry air. It can potentially be applied to measure higher concentration for the air pollution control within broad humidity range as well as for the very low concentrations from the human breath.

a)



b)




## Conclusions

Silicon nanowires exhibit pronounced sensitivity to ammonia, enabling reliable detection of $NH_3$over a wide concentration range and often with superior selectivity compared to many competing analytes. The high surface-to-volume ratio and tunable surface chemistry of SiNWs promote efficient adsorption and chargetransfer interactions with ammonia molecules, which results reversible modulation of the electrical response.

c)

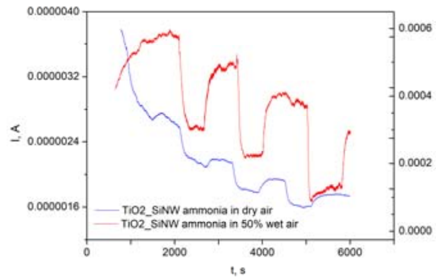



*Fig. 1. SEM image of the cross-section of SiNW (a), Current signal measured as a function of time for the SiNW structure (b), and the SiNW structure decorated with $TiO_2$ (c). Measurements were performed in ammonia exposure in dry air and 50% humidity.*

The presence of humid air significantly influences the sensing behaviour.Water molecules modify the baseline conductance and can either enhance the $NH_3$ response by facilitating adsorption at high humidity level, introduce competitive adsorption that complicates quantitative calibration. Overall, SiNWbased sensors remain operational and responsive under humid conditions relevant to environmental monitoring and breath analysis, but accurate deployment requires careful optimization of surface functionalization and humidity compensation strategies.

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