EFFECT OF INSTALLING OF THE HUMIDITY SENSOR IN TEXTILES ON ITS RESPONSE TIME

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Abstract:
Sensors considered for embedding into textiles must be closely chosen and tested for this purpose. The contribution publishes experience with commercial temperature and relative humidity sensor Sensirion SHT which exhibits excellent parameters and is equipped with a digital serial interface. It was connected to PC using a microcontroller module that establish communication over this proprietary interface and a commercial serial/USB conversion module. Sensor is inserted in a chemical test apparatus that sets a flow of supporting gas with regulated concentration of an addition agent – water vapor in this case. Various textiles like POP, PAD and laminate membrane were used as a covering samples of the sensor and their response time was measured. They are to be selected as a protective layer of the sensors in firefighters' overall. Time characteristic of temperature and humidity is depicted in figures and response time is estimated. Necessity of conversion from relative to absolute humidity is explained.

1. Introduction

Selection, evaluation and application of various sensors suitable for embedding into textiles are running in scope of activity in Research Centrum TEXTIL II. Although detectors are being developed and their properties are measured, too, commercial sensors were used for opening tests.

One possible application of sensors in textiles lies in special protective overalls e.g. for firefighters where temperature, humidity, presence of dangerous gas, acceleration, position etc. could be checked.

At first, temperature and humidity sensor was chosen, measured and tested under special conditions. Results on its response time in a simulated embedding in textiles are given for various kinds of textiles usable as a protected cover of the sensors in these overalls.

2. Electronic facilities

The SENSIRION SHT15/75 relative humidity and temperature sensor was employed due to high precision, excellent resolution and a 2-wire digital serial interface. It exhibits only ±0.3 K temperature error and ±2 % relative humidity error at 25 °C with 0.01 K and 1/25 % resolution, respectively.

The single chip device is supplied in either a surface-mountable 8-pin or as a pluggable 4-pin single-in-line type package that integrates temperature and humidity detectors and appropriate electronics. The SHT15/75 requires a voltage supply between 2.4 and 5.5 V and consumes less than 1 mA. Proprietary serial interface and communication protocol are similar but incompatible to wide spread I^2C so that a remote interface had to be designed. The

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5-bit commands are sent into the device and 2 bytes of either 14-bit temperature or 12-bit humidity followed by 1 byte of the CRC polynomial are received.

A module employing the Atmel ATmega323 microcontroller realizes the interface task, data conversion and asynchronous ASCII-character serial communication to PC. The communication layer of the downlink interface is implemented in firmware; an uplink is running in hardware UART. Firmware performs conversions from binary integer N to floating point physical values – temperature (1), relative humidity (2) and its temperature corrected value (3). Value ϑ_0 having about –40 °C weakly depends on a sensor supply voltage.

$$\vartheta = \vartheta_0 + 0.01 \cdot N_\vartheta - 2 \cdot 10^{-8} \left(N_\vartheta - 7000\right)^2 \quad (1)$$

$$\varphi = -4 + 0.0405 \cdot N_\varphi - 2.8 \cdot 10^{-6} N_\varphi^2 \quad (2)$$

$$\varphi' = \left(\vartheta - 25\right) \cdot \left(0.01 + 8 \cdot 10^{-5} N_\varphi\right) + \varphi \quad (3)$$

As a portability of measuring equipment was required, a notebook as a connected computer is considered. Notebooks equipped with COM port become rare nowadays so USB adapter converting asynchronous serial data to the USB bus appeared suitable. It was realized with a commercial module that uses a device from the FTDI family of chips.

A program that runs on the notebook calls functions for handling of the FTDI USB chip in DLL library that was provided by the supplier. The program both displays and saves in file data from the sensor. Further data processing was fulfilled in MS Excel.

3. Test apparatus and measuring conditions

Experiments were carried out in special apparatus that was assembled for dynamic tests of gas sensors. A gas bottle of supporting fluid (nitrogen), a cleaning unit and a drying unit compose the first part of the apparatus. Gas stream is next split into two branches; pure supporting gas flows through the first one whilst in the second one an active fluid (water vapor in this case) is admixed. Both flow rates are set by rotameters. Behind joining of both branches, the flow of moist gas is fed into measuring 3-neck glass flask. Two necks feed and exhaust the gas. A sensor covered with the tested textile is inserted into the flask through the third neck. The feeding of gas and the measuring flask are kept at defined condition by a water bath with constant temperature.

Step change of ambient humidity was realized as a quick relocation of fixture with the sensor covered by a textile from space at 11.3 % RH (Erlenmeyer flask contained saturated solution of lithium chloride [2]) to nitrogen stream at (86 ±2) % RH in the apparatus described above. Weak overpressure of the supporting gas was maintained in the apparatus to prevent ambient air from penetrating into the apparatus. Temperature of both spaces was (20.2 ±0.3) °C, gas flow rate through the apparatus was 500 $cm^3 \cdot min^{-1}$, response was captured for 900 s.

4. Experiments

Polypropylene (POP, woven textile along Czech standard ČSN 80 0120), polyamide (PAD, woven textile along Czech standard ČSN 80 0117), laminated membrane (BI MICRO), lining (Nometex Comfort) and underwear textile were tested as sensor protective materials. Filter cap SF1 [3] which is supplied with the SHT sensors as option was tested for comparison. It carries PTFE membrane on a polyester scrim and provides protection against water, dust and other contaminants. Unfortunately, it is thick enough to be used in clothes.

Experiments lay in capturing of time response of RH and temperature measured with the sensor after it had been inserted into a stream of nitrogen with water vapor. Selected characteristics are shown in Fig. 1 and 2. One can see, that due to fairly exothermic reaction during sensor layer hydration (temperature raises over 3 K, Fig. 2) a corresponding RH value reported by the sensor was sufficiently affected. For comparison, temperature error 1 K induces the RH error about 6 %. This effect has been eliminated with conversion of relative humidity RH in percents to absolute humidity (water concentration) in grams per cubic meter (Fig. 3 and 4). Relative humidity is considered at temperature measured by a temperature detector in the sensor. This expression is temperature independent and promising for representation of conditions in protective overalls where extensive gradients and rapid changes of both temperature and humidity are expected.

Response time (RS) was estimated from obtained characteristics (Fig. 5) as usual i.e. it was determined as the time constant of first order system, at 63 % of humidity step change. It serves for quantitative comparing of suitability of various textiles as protection of the sensors.

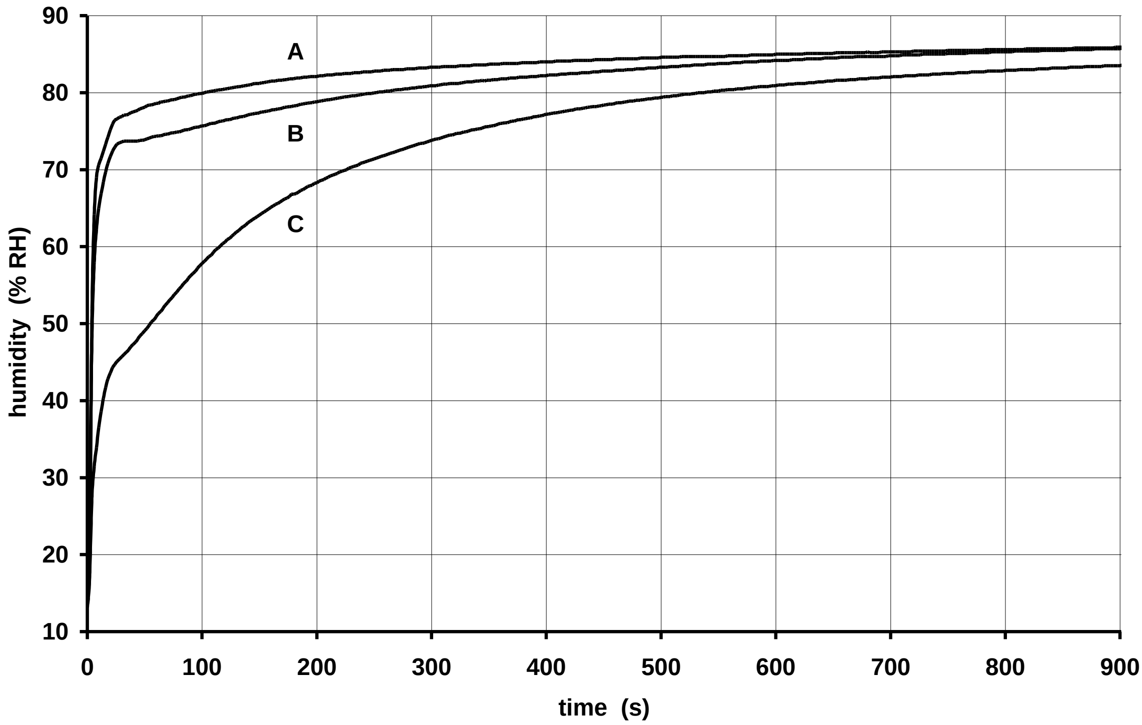

Figure 1: *Time response of sensor relative humidity value after insertion into environment (86 ±2) % RH for free sensor and selected textile samples. A .. free sensor; B .. POP; C .. lining.*

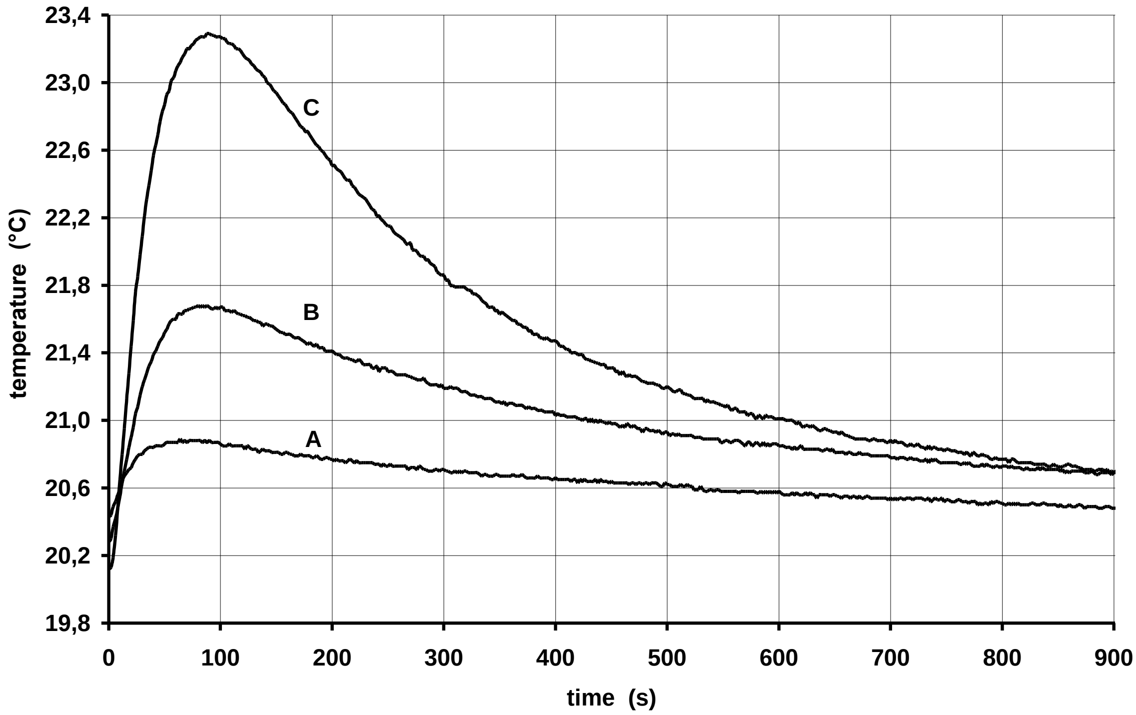

Figure 2: *Time response of sensor temperature value after insertion into environment (86 ±2) % RH for free sensor and selected textile samples. A .. free sensor; B .. POP; C .. lining.*

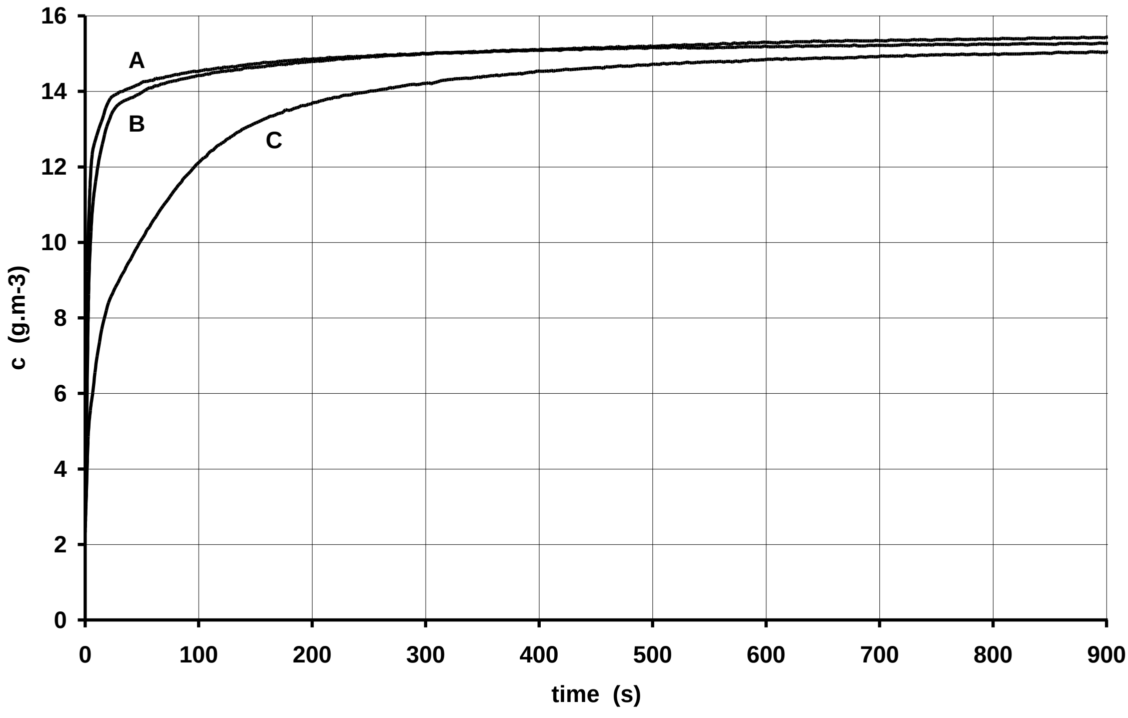

Figure 3: *Time response of water vapor concentration after insertion into environment (86 ±2) % RH for free sensor and textile samples. A .. free sensor; B .. POP; C .. lining.*

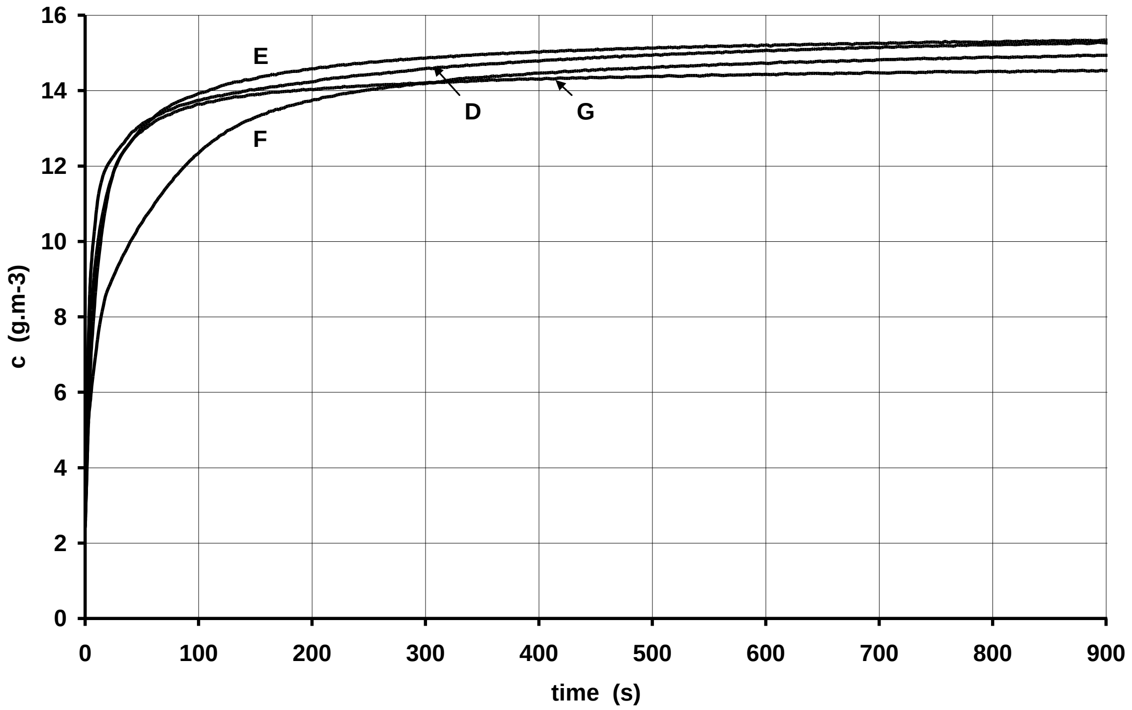

Figure 4: *Time response of water vapor concentration after insertion into environment (86 ±2) % RH for textile samples and SF1. D .. PAD; E .. BI MICRO; F .. underwear textile; G .. SF1.*

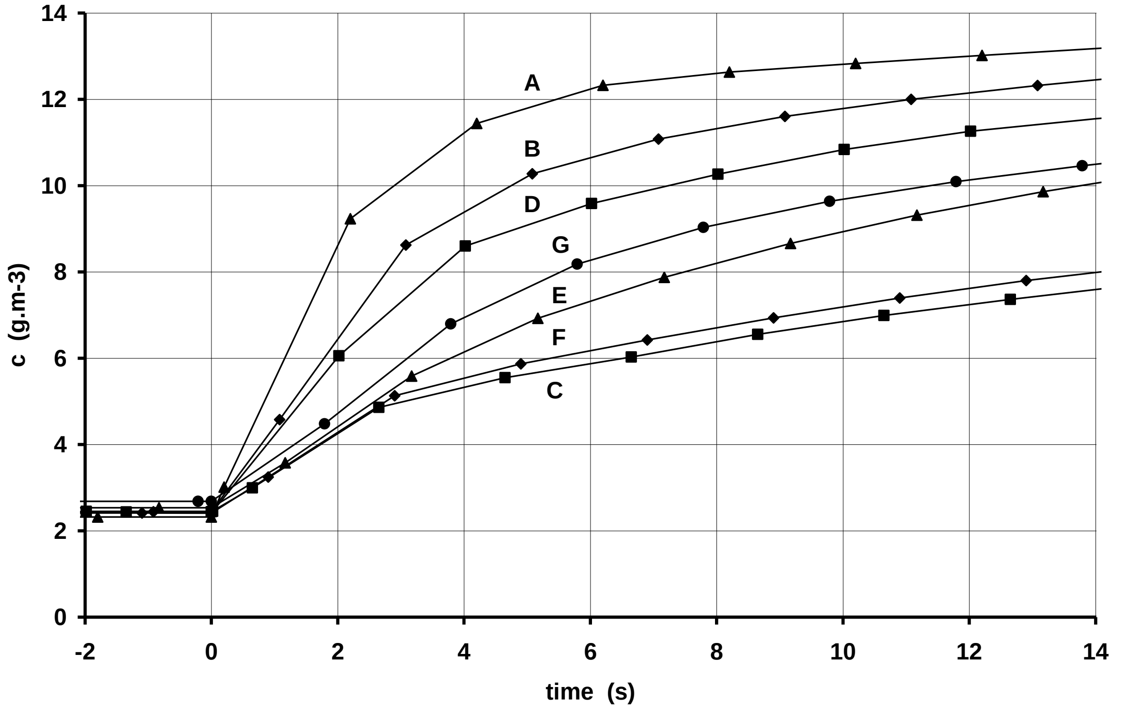

Figure 5: *Time response of water vapor concentration after insertion into environment (86 ±2) % RH for free sensor, textile samples and SF1 – detail for time origin. A .. free sensor; B .. POP; C .. lining; D .. PAD; E .. BI MICRO; F .. underwear textile; G .. SF1.*

5. Conclusions

Free SHT sensor exhibits RS = 3.6 s (RS = 4 s according to [1]). Results that were found (Fig. 3, 4) show that the most suitable material for sensor protection is polypropylene (in woven textile sample that was tested) having RS = 6 s. Polyamide reached significantly worse result (RS = 9 s). Laminate membrane (RS = 17 s) and especially lining (RS = 58 s) and underwear textile (RS = 49 s) are inapplicable to purpose in view because response time would be too long. Filter cap SF1 provided the response time on a useful limit (RS = 13 s) but steady-state value was substantially lowered (Fig. 4). This effect of PTFE membrane was also validated with a static measurement in environment with defined humidity above saturated water solutions of salts [2].

References

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Acknowledgement

This work was supported by the Research Centrum “TEXTIL II”, Code 1M4674788501.