SELECTION OF GAS SENSOR COVER TEXTILES FOR INTELLIGENT TEXTILES

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Abstract: Textiles of various material types (polypropylene, polyamide, polyester and cotton with hybrid hydrophobic layers, blended nonwovens with standard hydrophobic layers) were measured for the best humidity transfer in the vapor state in synergy with prevention of liquid humidity transfer. Polypropylene, polyamide and polyester with hybrid hydrophobic layers appear to be the best for defined usage. Cotton is unsatisfactory

1 INTRODUCTION

The gas sensors have to be covered by a proper textile layer in intelligent textiles for protection against pollution and mechanical damage. It is also necessary to protect sensor surface against the liquid humidity together with retain of ability to transfer of the vapor humidity. Set of the measurements was done to make decision about covering textile.

2 METHOD

The tests were run on the apparatus developed for dynamical measurements of gas sensors according to modified methodology [1]. Time response of the gas sensor SHT15 made by company Sensirion [2] was experimentally measured. The sensor was covered by measured textiles and tested in the step change of the humidity. Low humidity atmosphere was realized by Erlenmeyer flask filled with saturated water solution of lithium chloride containing undissolved lithium chloride. A humidity inside the glass flask was RH = (16.0 ±1.5) % and temperature t = (24.5 ±0.5) °C in the place of stabilization. Material with sensor was stabilized for duration of 20 minutes. Tested system was transferred as fast as possible to the 3-neck glass flask with continual flow of humid air after stabilization in temperature (24.5 ±1.0) °C. Temperature and humidity recording was started in the low humidity atmosphere and finished after 930 s in the flow of humid air. Result value was converted to the water vapor concentration in $g.m^{-3}$. This conversion eliminates temperature variation during measurement and also hydration heat of the sensor layer of the sensor SHT15 [1].

The time, which is necessary to reach 63% of output signal change to steady-state after input step change of the humidity (Response Time 1/e, next only RS), was computed numerically for comparison. Free sensors SHT15 (same production) exhibits RS = (9.2 ±0.4) s respectively RS = (10.0 ±0.4) s. Inorganic-organic hybrid layers were applied on textile surface for better water repellency. Layers contain trimethoxyhexadecylsilane (sols AE2 and AE3) or triethoxy(1H,1H,2H,2H-perfluoro-1-octyl)silane (sol AE5). Textiles on polypropylene base were heat treated in 85 °C per 3 hours, other textiles in 150 °C per 3 hours. Polymerized hybrid layers raised on the fiber surface during heat treatment and they are resistant against basic solvents and markedly increase surface water repellency. Functional groups (hexadecyl respectively perfluorooctyl) are covalently bonded in hybrid layer and it is

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not possible to exclude them. It is a basic condition for usage in textiles for sensor covers because basically used procedures of hydrophobization with simple spreading of hydrophobic material without their immobilization on the surface with covalent bond go regularly to their releasing and polluting of sensor surface in intelligent textiles. Behavior of textiles compared with liquid water with the measure of contact angle on textile was tested too.

3 RESULTS

Four groups of material were used for measurement based on preliminary results [3]: polypropylene base materials with hybrid hydrophobic layers, blended nonwovens with standard hydrophobic layers, textiles from synthetic materials (polyamide, polyester) with hybrid hydrophobic layers and cotton textile with hybrid hydrophobic layers. Selected polypropylene based materials (additional fabric from polypropylene staple fiber and polypropylene nonwoven textile) were tested in original state and also with hydrophobic layers AE3 or AE5. Figure 1 exhibits time dependency of humidity value computed from sensor data SHT15 for additional fabric from polypropylene staple fiber in original state and also with hydrophobic layers. Figure 2 shows detail of the measurement start area. The delay effect of the response beginning after insertion of the wet textile is minimal and for intelligent textiles is fully suitable. The best results were reached with polypropylene textile and layer AE5. Excellent values were occurred during testing of samples behavior against liquid water immediately after drop of water for all three tested samples (wetting contact angle POP-1 140°, POP-3 145°, POP-5 148°), however polypropylene textile in original state release water in time. Both samples with hybrid layers embody impermeability of liquid water and high wetting contact angle in time. Similar behavior was realized also for polypropylene nonwoven. Its disadvantage is lower mechanical resistance during manipulation.

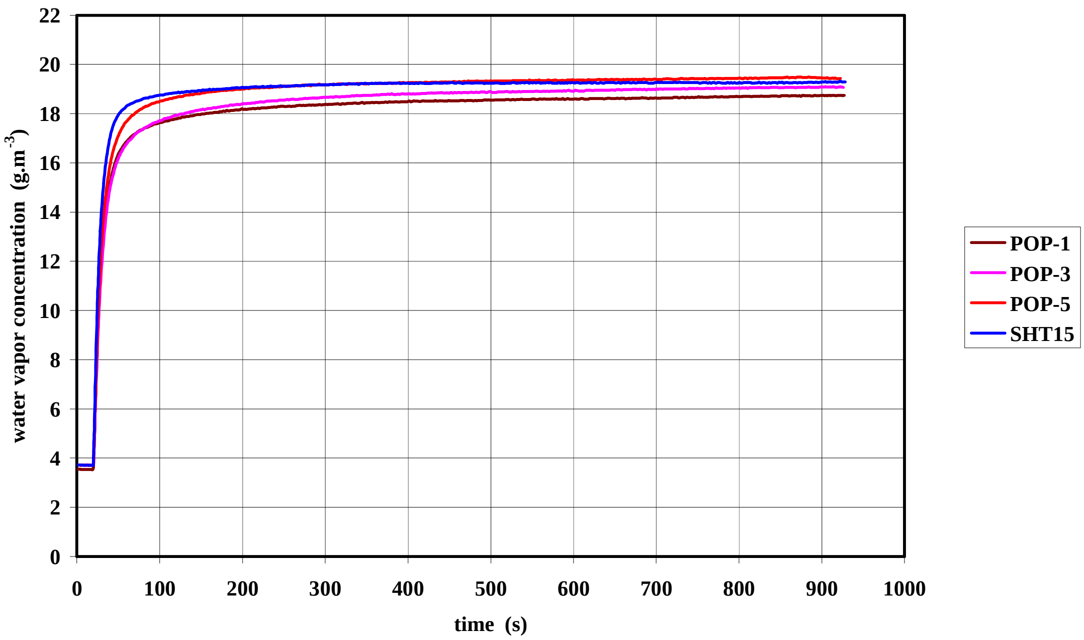

Figure 1: Dependence of the water vapor concentration computed from sensor SHT15 on time of original polypropylene staple fiber (POP-1, RS = 12.2 s), polypropylene staple fiber with layer AE3 (POP-3, RS = 13.9 s), polypropylene staple fiber with layer AE5 (POP-5, RS = 11.9 s))and free sensor SHT15 (RS = 9.2 s). Samples transferred in time 30 s from atmosphere RH = (16.0 ±1.5) % to the atmosphere RH = (86.0 ±2.0) %. .

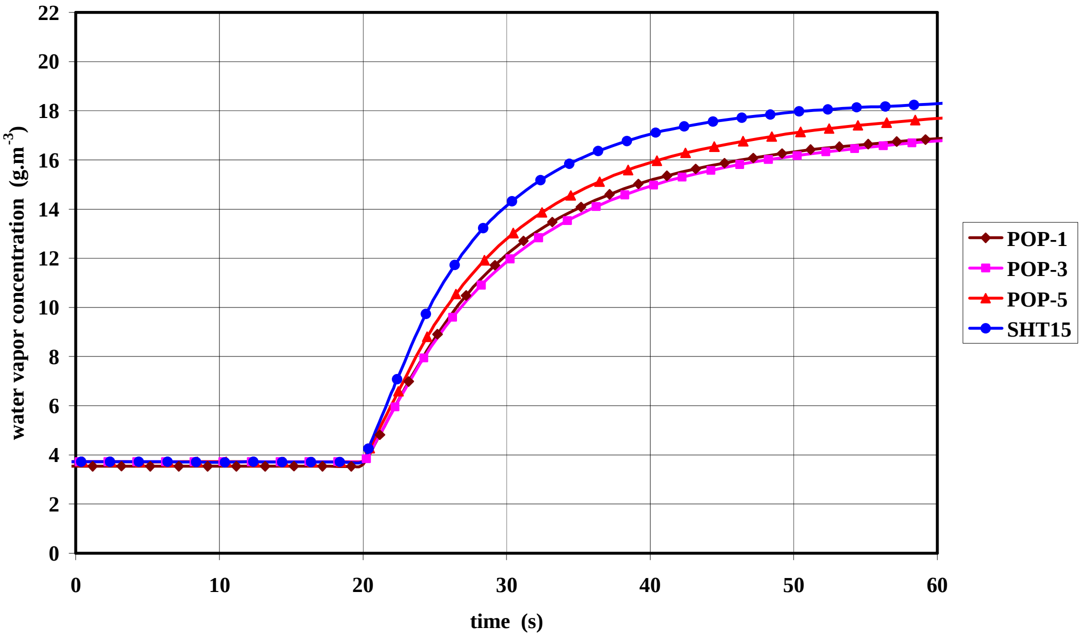

Figure 2: Detail of the measurement start area from Figure 1.

Second group of samples was nonwoven textiles from blended materials with standard hydrophobic treatment. It was measured textiles with SB FOBIC mark (spunbond hydrophobic) with blending ratio 70/30 PP/PE, 50 $g.m^{-2}$ - SB-1, 50/50 PP/PE, 50 $g.m^{-2}$, - SB-2 and SB BICO with 70/30 PP/PE, 17 $g.m^{-2}$ - SB-3. Figure 3 presents obtained dependencies. Acceptable results were obtained for gas liquid transmission and behavior to liquid water in this case too (wetting contact angle 129 - 138°), mechanical resistance during manipulation is not good. Potentially dangerous should be using in long time period and release of hydrophobic treatment from the fiber surface and their deposition on functional layers of sensor.

The third group of tested textiles were synthetic materials, namely UROJA (100% PES, fabric for technical usage by company Silk and Progress Moravská Chrastová) and UHELON (100% PAD, fine technical monofilament fabric by company Silk and Progress Moravská Chrastová). Both textiles were tested in original state and with hydrophobic layers AE2 or AE5. Figures 4 and 5 present results.

Transfer of the humidity in the vapour state was suitable for all tested textiles in this group and mechanical properties were also acceptable. Original textiles without layers had got unsatisfactory resistant against liquid water (sample UROJA absorbs water immediately, sample UHELON in short time). Results with hybrid layers were very good (wetting contact angle 115 – 124° in long term stability).

The fourth group of tested samples was cotton based materials. Summary of results is presented on Figure 6. It is clear that cotton keeps down permeability through the textile also in the case with hydrophobic layer. Raw cotton absorbs water, cotton with hydrophobic layers AE2 or AE5 do not absorb water though (wetting contact angle 125 – 133°), however value RS remains similar than raw cotton (RS = 55 – 58 s but 52.8 s raw cotton).

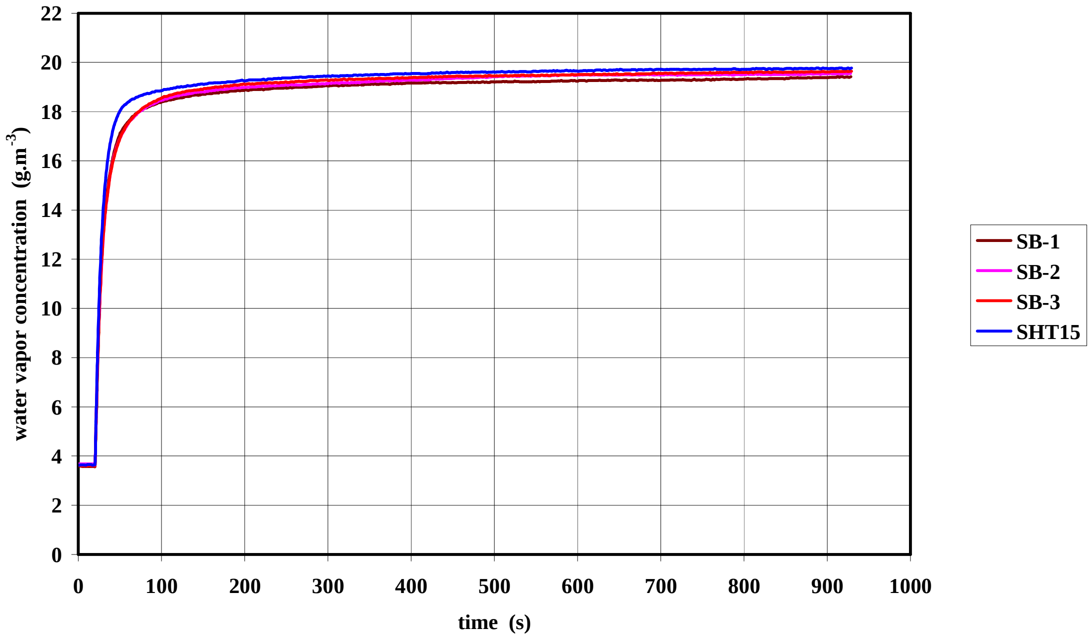

Figure 3: Dependence of the water vapor concentration computed from sensor SHT15 on time of samples of nonwovens with standard hydrophobic layer (specifications in text, RS = 11.3 – 12.0 s) and comparative free sensor SHT15 (RS = 9.2 s). Samples transferred in time 30 s from atmosphere RH = (16.0 ±1.5) % to the atmosphere RH = (86.0 ±2.0) %.

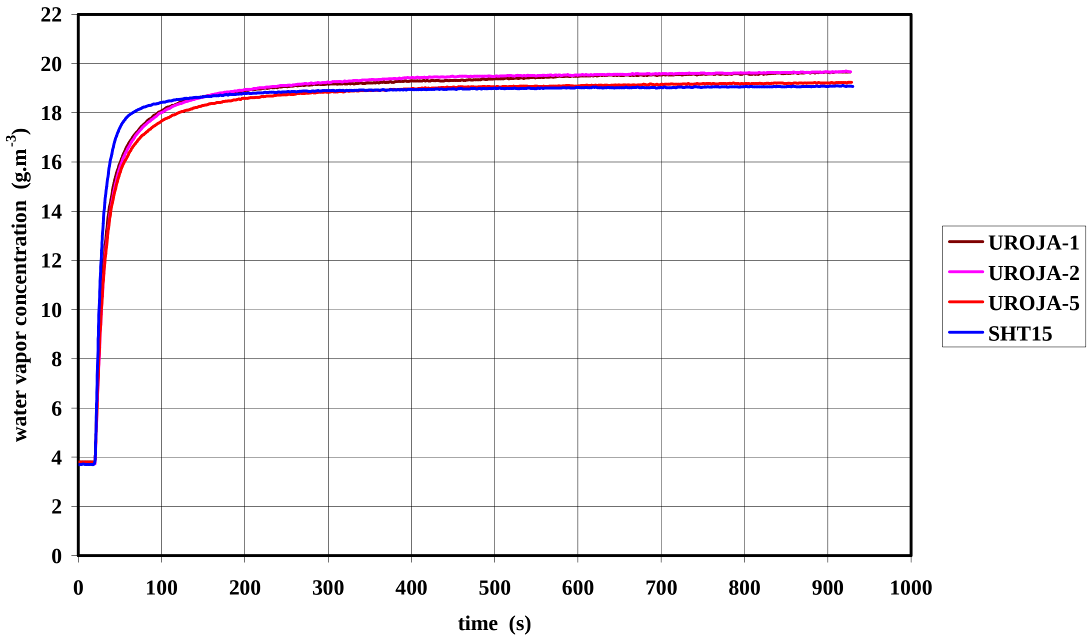

Figure 4: Dependence of the water vapor concentration computed from sensor SHT15 on time of original textile UROJA (RS = 16.0 s), textile UROJA with layer AE2 (RS = 17.6 s), textile UROJA with layer AE5 (RS = 17.0 s) and free sensor SHT15 (RS = 10.0 s). Samples transferred in time 30 s from atmosphere RH = (16.0 ±1.5) % to the atmosphere RH = (86.0 ±2.0) %.

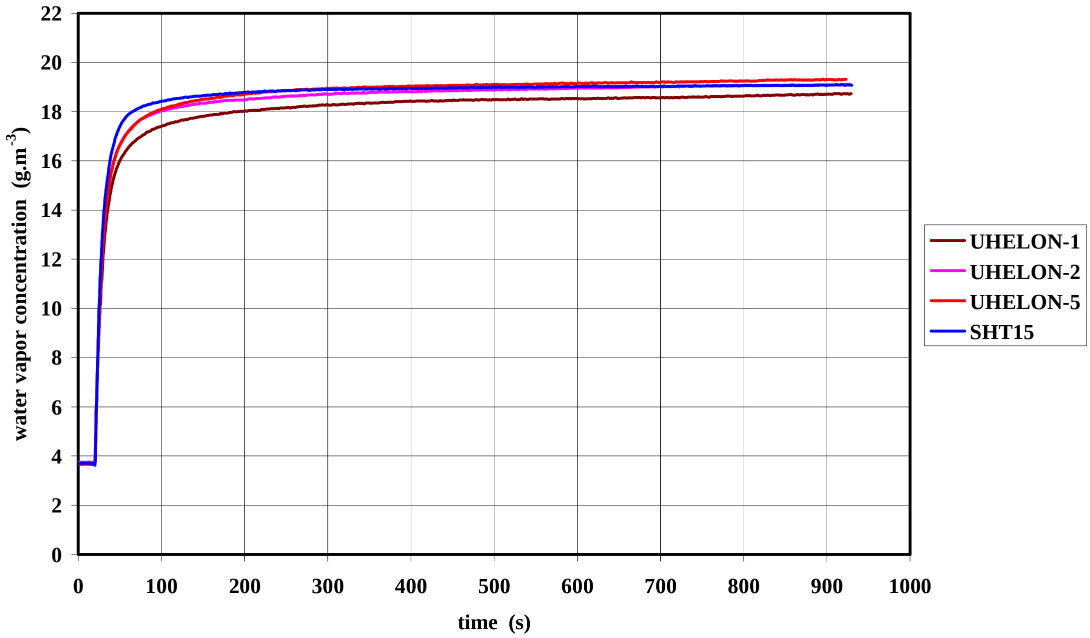

Figure 5: Dependence of the water vapor concentration computed from sensor SHT15 on time of original textile UHELON (RS = 12.5 s), textile UHELON with layer AE2 (RS = 11.3 s), textile UHELON with layer AE5 (RS = 11.9 s) and free sensor SHT15 (RS = 10.0 s). Samples transferred in time 30 s from atmosphere RH = (16.0 ±1.5) % to the atmosphere RH = (86.0 ±2.0) %.

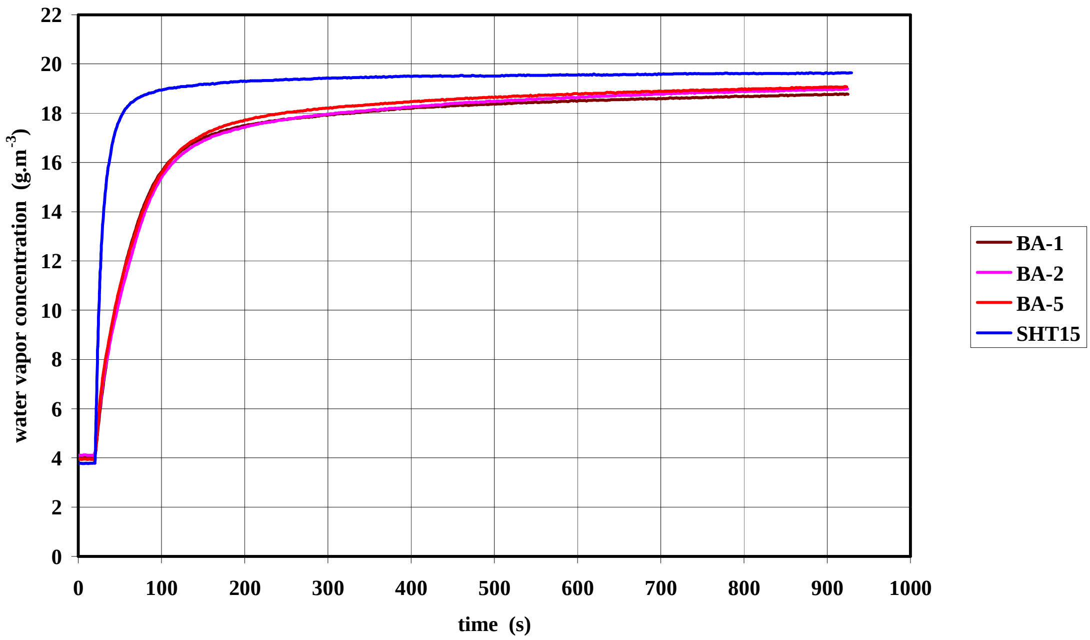

Figure 6: Dependence of the water vapor concentration computed from sensor SHT15 on time of original cotton (RS = 52.8 s), cotton with layer AE2 (RS = 58.0 s), cotton with layer AE5 (RS = 54.8 s) and free sensor SHT15 (RS = 10.0 s). Samples transferred in time 30 s from atmosphere RH = (16.0 ±1.5) % to the atmosphere RH = (86.0 ±2.0) %.

4 CONCLUSION

The best material is appeared to be on polypropylene base or synthetic materials (polyester, polyamide) from the viewpoint of transfer of the humidity in the vapour state, behavior to liquid water and mechanical resistance. However the hydrophobic treatment is necessary in addition to protect transfer of the liquid humidity. Cotton based materials are unsatisfactory in our case.

References

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