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A New Approach in Detection of Biomarker 2-propanol with PTFE-Coated TiO_2 Nanostructured Films

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Abstract

Certain molecules act as biomarkers in exhaled breath or outgassing vapors of biological systems. Metal oxide gas sensors are of great interest to detect these molecules. However, often they are not selective enough to identify the specific molecules. In addition, they typically lose their excellent performance at high humidity levels. In this study nanoscale polytetrafluoroethylene (PTFE) thin films deposited via solvent-free initiated chemical vapor deposition (iCVD) were investigated as a possible pathway to tune the selectivity of metal oxide gas sensors as well as hydrophobic surface functionalization. The gas-sensing properties of two types of PTFE-coated gas-sensing structures are measured for this purpose at several operating temperatures. The first structure is a thermally annealed TiO_2 film while the second structure is a thermally annealed TiO_2 film with an additional CuO film. After the deposition of the iCVD PTFE thin films the structures exhibit a high response and excellent selectivity to 2-propanol vapor. The experimental data presented here, promote the use of such PTFE-coated gas sensing structures as reliable, accurate and selective sensor structures for the tracking of gases at low concentrations. This enables new possibilities in application fields like biomedical diagnosis, biosensors, and the development of non-invasive technology.

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Keywords: biomarkers, propanol, gas sensors, chemical vapor depositions, polytetrafluoroethylene thin films

References

1. Solórzano, A., et al.: Early fire detection based on gas sensor arrays: multivariate calibration and validation. Sens. Actuators B Chem. **352**, 130961 (2022). https://doi.org/10.1016/j.snb.2021.130961
2. Lupan, O., et al.: Heterostructure-based devices with enhanced humidity stability for H2 gas sensing applications in breath tests and portable batteries. Sens. Actuators A Phys. **329**, 112804 (2021). https://doi.org/10.1016/j.sna.2021.112804
3. Ghosh, C., Singh, V., Grandy, J., Pawliszyn, J.: Recent advances in breath analysis to track human health by new enrichment technologies. J Sep Sci. **43**, 226–240 (2020). https://doi.org/10.1002/jssc.201900769
4. Koureas, M., Kirgou, P., Amoutzias, G., Hadjichristodoulou, C., Gourgoulianis, K., Tsakalof, A.: Target analysis of volatile organic compounds in exhaled breath for lung cancer discrimination from other pulmonary diseases and healthy persons. Metabolites **10**, 317 (2020). https://doi.org/10.3390/metabo10080317
5. Bhandari, M.P., et al.: Volatile markers for cancer in exhaled breath—could they be the signature of the gut microbiota? Molecules **28**, 3488 (2023). https://doi.org/10.3390/molecules28083488
6. Hanouneh, I.A., et al.: The breathprints in patients with liver disease identify novel breath biomarkers in alcoholic hepatitis. Clin. Gastroenterol. Hepatol. **12**, 516–523 (2014). https://doi.org/10.1016/j.cgh.2013.08.048
7. Pirsa, S., Heidari, H., Lotfi, J.: Design selective gas sensors based on nano-sized polypyrrole/ polytetrafluoroethylene and polypropylene membranes. IEEE Sens J. **16**, 2922–2928 (2016). https://doi.org/10.1109/JSEN.2016.2527712
8. Yamashita, H., Nakao, H., Takeuchi, M., Nakatani, Y., Anpo, M.: Coating of TiO2 photocatalysts on super-hydrophobic porous teflonmembrane by an ion assisted depositionmethod and their self-cleaning performance. Nucl. Instrum. Methods Phys. Res. Sect. B Beam Interact. Mater. Atoms. **206**, 898–901 (2003). https://doi.org/10.1016/S0168-583X(03)00895-4

9. Cha, W., Meyerhoff, M.E.: Enhancing the selectivity of amperometric nitric oxide sensor over ammonia and nitrite by modifying gas-permeable membrane with Teflon AF (R). Chem. Analityczna. **51**, 949–961 (2006)

10. Schröder, S., et al.: Tuning the selectivity of metal oxide gas sensors with vapor phase deposited ultrathin polymer thin films. Polymers **15**(3), 524 (2023). https://doi.org/10.3390/polym15030524

11. Schröder, S., et al.: Sensing performance of CuO/Cu2O/ZnO: Fe heterostructure coated with thermally stable ultrathin hydrophobic PV3D3 polymer layer for battery application. Mater. Today Chem. **23**, 100642 (2022). https://doi.org/10.1016/j.mtchem.2021.100642

12. Cichosz, S., Masek, A., Zaborski, M.: Polymer-based sensors: a review. Polym Test. **67**, 342–348 (2018). https://doi.org/10.1016/j.polymertesting.2018.03.024

13. Torad, N.L., Minisy, I.M., Sharaf, H.M., Stejskal, J., Yamauchi, Y., Ayad, M.M.: Gas sensing properties of polypyrrole/poly(N-vinylpyrrolidone) nanorods/nanotubes-coated quartzcrystal microbalance sensor. Synth Met. **282**, 116935 (2021). https://doi.org/10.1016/j.synthmet.2021.116935

14. Indarit, N., Kim, Y.-H., Petchsang, N., Jaisutti, R.: Highly sensitive polyaniline-coated fiber gas sensors for real-time monitoring of ammonia gas. RSC Adv. **9**, 26773–26779 (2019). https://doi.org/10.1039/C9RA04005F

15. Lupan, O., et al.: TiO2/Cu2O/CuO multi-nanolayers as sensors for H2 and volatile organic compounds: an experimental and theoretical investigation. ACS Appl. Mater. Interfaces **13**, 32363–32380 (2021). https://doi.org/10.1021/acsami.1c04379

16. Schröder, S., Strunskus, T., Rehders, S., Gleason, K.K., Faupel, F.: Tunable polytetrafluoroethylene electret films with extraordinary charge stability synthesized by initiated chemical vapor deposition for organic electronics applications. Sci Rep. **9**, 2237 (2019). https://doi.org/10.1038/s41598-018-38390-w

17. Schröder, S., Polonskyi, O., Strunskus, T., Faupel, F.: Nanoscale gradient copolymer films via single-step deposition from the vapor phase. Mater. Today **37**, 35–42 (2020). https://doi.org/10.1016/j.mattod.2020.02.004

18. Lau, K.K.S., Gleason, K.K., Trout, B.L.: Thermochemistry of gas phase CF2 reactions: a density functional theory study. J Chem Phys. **113**, 4103–4108 (2000). https://doi.org/10.1063/1.1288378

19. Schröder, S., Hinz, A.M., Strunskus, T., Faupel, F.: Molecular insight into real-time reaction kinetics of free radical polymerization from the vapor phase by in-situ mass spectrometry. J. Phys. Chem. A. **125**, 1661–1667 (2021). https://doi.org/10.1021/acs.jpca.0c11180

20. Socrates, G.: Infrared and Raman Characteristic Group Frequencies: Tables and Charts, 3rd edn. Wiley, Chichester, UK (2004)

21. Lim, S.-H., Park, I.-J., Kwon, H.-I.: Effects of rapid thermal annealing temperature on NO2 gas sensing properties of p-type mixed phase tin oxide thin films. Ceram Int. **49**, 8478–8486 (2023). https://doi.org/10.1016/j.ceramint.2022.11.010

22. Postica,V., et al.:Multifunctionalmaterials: a case study of the effects of metal doping on ZnO Tetrapods with bismuth and tin oxides. Adv. Funct. Mater. **27**(6), 1604676 (2017). https://doi.org/10.1002/adfm.201604676

23. Lupan, O., et al.: Tailoring the selectivity of ultralow-power heterojunction gas sensors by noble metal nanoparticle functionalization. Nano Energy **88**, 106241 (2021). https://doi.org/10.1016/j.nanoen.2021.106241