Dataset: literature review of ethanol chemiresistors based on pure SnO_2 nanostructures

Andrea Ponzoni[1,2,3]
[1] National Institute of Optics (INO) Unit of Brescia, National Research Council (CNR), 25123 Brescia, Italy
[2] National Institute of Optics (INO) Unit of Lecco, National Research Council (CNR), 23900 Lecco, Italy
[3] Department of Information Engineering, University of Brescia, 25123 Brescia, Italy

Email: andrea.ponzoni@ino.cnr.it

This dataset contains a collection of experimental data retrieved from around 160 articles reporting on ethanol chemiresistors based on pure SnO_2. Pure means that they are neither intentionally doped nor intentionally loaded with any catalyst.
The retrieved data are intended to summarize the most common morphological features of the sensing layers, the characteristics of the measurement setup adopted for gas sensing tests and the figures of merit of the gas sensors, namely response intensity and response/recovery times.
The goal is to provide a dataset for benchmarking and/or statistical analysis.
An example of its use can be found in A. Ponzoni, Sensors 22 (2022) 6346 https://doi.org/10.3390/s22176346. There, this dataset was used to look for statistical correlations that may emerge between the response/recovery times of the devices and the material/setup characteristics.
Another example is reported in A. Ponzoni, Sensors 21 (2021) 29 https://doi.org/10.3390/s21010029, where a preliminary version of the dataset was used to look for correlations with the response intensities.

Most of source papers were identified through a systematic search for documents classified as 'articles' in the ISI Web of Science Core collection database and published between January 2015 and December 2020. The following searching criterium was applied: 'SnO2' and 'ethanol' and 'sens*' in the field 'topic'.

The dataset is provided as a tab delimited .txt file (SnO2-ZenodoDataset.txt). It is a matrix in which the variables are arranged by columns and the sources (articles) are by rows. In case a given data is not available in the source article, 'na' is reported in the related cell.
This readme document explains the definitions of the variables in the dataset and provides full citations of the sources from which the data were obtained.
The dataset consists of 27 columns:
-Columns from 1 to 5 are for the identification of the source papers from which data have been extrapolated;
-Columns from 6 to 27 report the scientific data.

Columns identifying the source paper from which the data were extrapolated (from 1 to 5):

- DOI-link:

Link to the DOI (Digital Objective Identifier) of the source paper from which the data have been retrieved.

- Publisher:

Publisher of the source paper.

- License:

License under which the source paper was published and is available at its own DOI link.

- Year:

Publication year of the source paper.

- Reference:

Reference number, whose full citation is reported in the References list at the end of this document.

Columns reporting scientific data (from 6 to 27).

> *Preliminary note:*
> *Variables (data) may be either numerical or categorical.*
> *Numerical variables were obtained from numerical data reported in the main text or figures of source papers. Where necessary, the Engauge Digitizer software was used to extract data from figures (Mark Mitchell, Baurzhan Muftakhidinov and Tobias Winchen et al, "Engauge Digitizer Software, Version 12.1" Webpage: http://markummitchell.github.io/engauge-digitizer, Last accessed on January 2020).*
> *Categorical variables were extrapolated from the text of the source papers or inferred from their content. Differently from numerical variables, categorical variables may not have a unique value and can depend on the intended analysis or individual preferences. In these cases, the rationale for the decision made is explained below for each specific variable.*

- MaterialN – numerical:

Numbered list of materials. This value may differ from the reference number because some papers report on more materials/sensors.

- UNIT – categorical:

Shape of the elementary units (crystallites) composing the sensing film. Shapes have been grouped into three classes:

  - Nanoparticles: crystallites with nearly spherical shape. Due to their rounded shape, these nanostructures have no surface termination corresponding to well-defined crystalline planes;

- Nanowires: crystallites featuring an elongated shape, with lateral surfaces usually identified by well-defined crystalline planes. Nanostructures such as nanorods and nanobelts are also included in this class. Crystals with cubic, octahedral or elongated octahedral morphology show similarities with both nanowires and nanoparticles: they feature a nearly equiaxed shape, typical of the nanoparticles class, as well as faceted surfaces, typical of the nanowires class. For this dataset, the author chose to label these morphologies as nanowires. A discussion about the importance of surface termination that motivated this choice can be found in A. Ponzoni, Sensors 22 (2022) 3351, https://doi.org/10.3390/s22093351;
- Nanosheets: single crystalline, thin nanostructures extending in two dimensions. Morphologies such as nanoplates, nanolamellae, nanodiscs are also included in this class.

- Diameter(nm) – numerical:

The shortest dimension of crystallites, measured in nm. For nanoparticles and nanowires it corresponds to their diameter, whereas for nanosheets it corresponds to their thickness. It is typically obtained from TEM (Transmission Electron Microscopy) or XRD (X Ray Diffraction) measurements.

- Length(nm) – numerical:

The size of the dimension other than the above Diameter(nm) variable, measured in nm. For nanowires it is the length. For nanoparticles it equals the Diameter(nm) variable due to their spherical shape; while for nanosheets it is the mean of their lateral size. In principle, for this latter shape, two sizes should be considered in addition to the nanosheet thickness. Nonetheless, most papers provide only one of these two (or an average value of the two) and this one is here reported.

- SSA(m2/g) – numerical:

Specific surface area, measured in m^2/g. It is usually obtained by means of the BET (Brunauer–Emmett–Teller) method.

- Pore radius1(nm) – numerical:

Main (modal) pore radius, measured in nm. It is usually obtained by means of the BJH (Barrett-Joyner-Halenda) method.

- Pore radius2(nm) – numerical:

Second mode pore radius, measured in nm. This applies only to materials with a clear multimodal porosity; for other materials ‘na’ is reported in this field.

- Pore radius3(nm) – numerical:

Third mode pore radius, measured in nm. This applies only to materials with a clear trimodal porosity; for other materials ‘na’ is reported in this field.

- Tsens(degC) – numerical:

Sensor working temperature, expressed in Celsius degrees.

- RH% – numerical:

Relative humidity expressed in the 0-100% scale.

- Tenv(degC) – numerical:

Temperature of the environment where gas-sensing tests are carried out. It is expressed in Celsius degrees.

- GAS – categorical:

Gas (vapor) measured in gas sensing tests. Actually, only ethanol tests are reported in this dataset, so this is a single value variable:

    - EtOH: ethanol.

- Conc(ppm) – numerical:

Gas concentration expressed in ppm (parts per million).

- Ggas/Gair – numerical:

Response intensity calculated as the ratio between G_{gas}, i.e. the sensor conductance during gas exposure, and G_{air}, i.e. the sensor conductance baseline measured in the reference air. For those papers that reports the sensor response in other ways, such as for example $(G_{gas} – G_{air})/G_{air}$, values are converted in the G_{gas}/G_{air} format.

- TestMethod – categorical:

The type of measurement setup adopted for gas-sensing tests:

    - Static: setups that do not use a carrier flow but test devices in static conditions. The target gas is injected inside the test chamber through a device, such as a syringe, which is actuated only at the time of gas injection.
    - Dynamic: setups based on mass flow controllers (MFCs) that mix fluxes from certified bottles and control the atmosphere composition inside the test chamber. Even while the atmosphere composition is kept constant, it is continuously refreshed within the chamber through the applied flow.

- ChamberVolume(cc) – numerical:

Volume of the chamber hosting the sensors during gas sensing tests. The volume is measured in centimeters cubes (cc).

- Flow(sccm) – numerical:

Total flow kept during the gas sensing measurements carried out with dynamic setups. Flow is expressed in standard centimeters cubes per minute (sccm). This variable has no meaning for static setups (see MeasurementMethod variable), for which it has been settled as ‘na’.

- Heater – categorical:

Method adopted to warm the sensor to its working temperature as reported in the Tsens(degC) variable:

    - Furnace: sensors are inserted inside a furnace that warms the whole environment around the sensor device;
    - Holder: sensors are heated through a local device that is part of the measurement setup, usually it is integrated in the sensor holder;

- Meander: sensors are based on a flat ceramic substrate and the heater, usually a metallic meander, is pre-deposited over one of its two faces;
- Coil: sensors are based on a tubular ceramic substrate, a coil-shaped heater is inserted inside the tube.

- %t_rise – numerical:

Fractional variation of the sensor response (expressed in %) used to calculate the response time (t_rise(s) variable) during the response transient.

- t_rise(s) – numerical:

time required to by the sensor response to reach the '%t_rise' fraction of it its final value.

- %t_fall – numerical:

Fractional variation of the sensor response (expressed in %) used to calculate the recovery time (t_fall(s) variable) to restore the baseline.

- t_fall(s) – numerical:

time required to by the sensor response to recover the '%t_fall' fraction of it its final (baseline) value.

References:

(1) Kida, T.; Suematsu, K.; Hara, K.; Kanie, K.; Muramatsu, A. Ultrasensitive Detection of Volatile Organic Compounds by a Pore Tuning Approach Using Anisotropically Shaped SnO2 Nanocrystals. *ACS Appl. Mater. Interfaces* **2016**, *8* (51), 35485–35495. https://doi.org/10.1021/acsami.6b13006.

(2) Kida, T.; Doi, T.; Shimanoe, K. Synthesis of Monodispersed SnO2 Nanocrystals and Their Remarkably High Sensitivity to Volatile Organic Compounds. *Chem. Mater.* **2010**, *22* (8), 2662–2667. https://doi.org/10.1021/cm100228d.

(3) Kim, B.-Y.; Cho, J. S.; Yoon, J.-W.; Na, C. W.; Lee, C.-S.; Ahn, J. H.; Kang, Y. C.; Lee, J.-H. Extremely Sensitive Ethanol Sensor Using Pt-Doped SnO2 Hollow Nanospheres Prepared by Kirkendall Diffusion. *Sensors and Actuators B: Chemical* **2016**, *234*, 353–360. https://doi.org/10.1016/j.snb.2016.05.002.

(4) Mohanapriya, P.; Segawa, H.; Watanabe, K.; Watanabe, K.; Samitsu, S.; Natarajan, T. S.; Jaya, N. V.; Ohashi, N. Enhanced Ethanol-Gas Sensing Performance of Ce-Doped SnO2 Hollow Nanofibers Prepared by Electrospinning. *Sensors and Actuators B: Chemical* **2013**, *188*, 872–878. https://doi.org/10.1016/j.snb.2013.07.016.

(5) Lee, S.-H.; Galstyan, V.; Ponzoni, A.; Gonzalo-Juan, I.; Riedel, R.; Dourges, M.-A.; Nicolas, Y.; Toupance, T. Finely Tuned SnO2 Nanoparticles for Efficient Detection of Reducing and Oxidizing Gases: The Influence of Alkali Metal Cation on Gas-Sensing Properties. *ACS Appl. Mater. Interfaces* **2018**, *10* (12), 10173–10184. https://doi.org/10.1021/acsami.7b18140.

(6) Van Hieu, N.; Kim, H.-R.; Ju, B.-K.; Lee, J.-H. Enhanced Performance of SnO2 Nanowires Ethanol Sensor by Functionalizing with La2O3. *Sensors and Actuators B: Chemical* **2008**, *133* (1), 228–234. https://doi.org/10.1016/j.snb.2008.02.018.

(7) Wang, T.; Zhang, S.; Yu, Q.; Wang, S.; Sun, P.; Lu, H.; Liu, F.; Yan, X.; Lu, G. Novel Self-Assembly Route Assisted Ultra-Fast Trace Volatile Organic Compounds Gas Sensing Based on Three-Dimensional Opal Microspheres Composites for Diabetes Diagnosis. *ACS Appl. Mater. Interfaces* **2018**, *10* (38), 32913–32921. https://doi.org/10.1021/acsami.8b13010.

(8) Xie, N.; Guo, L.; Chen, F.; Kou, X.; Wang, C.; Ma, J.; Sun, Y.; Liu, F.; Liang, X.; Gao, Y.; Yan, X.; Lu, G. Enhanced Sensing Properties of SnO2 Nanofibers with a Novel Structure by Carbonization. *Sensors and Actuators B: Chemical* **2018**, *271*, 44–53. https://doi.org/10.1016/j.snb.2018.05.039.

(9) Li, Y.-X.; Guo, Z.; Su, Y.; Jin, X.-B.; Tang, X.-H.; Huang, J.-R.; Huang, X.-J.; Li, M.-Q.; Liu, J.-H. Hierarchical Morphology-Dependent Gas-Sensing Performances of Three-Dimensional SnO2 Nanostructures. *ACS Sens.* **2017**, *2* (1), 102–110. https://doi.org/10.1021/acssensors.6b00597.

(10) Singh, G.; Kohli, N.; Singh, R. C. Sensitive and Selective Ethanol Sensor Based on Zn-Doped SnO2 Nanostructures. *Journal of Materials Science: Materials in Electronics* **2017**, *28* (17), 13013–13023. https://doi.org/10.1007/s10854-017-7133-x.

(11) Zhang, Y.; He, X.; Li, J.; Miao, Z.; Huang, F. Fabrication and Ethanol-Sensing Properties of Micro Gas Sensor Based on Electrospun SnO2 Nanofibers. *Sensors and Actuators B: Chemical* **2008**, *132* (1), 67–73. https://doi.org/10.1016/j.snb.2008.01.006.

(12) Tricoli, A.; Righettoni, M.; Pratsinis, S. E. Minimal Cross-Sensitivity to Humidity during Ethanol Detection by SnO2–TiO2solid Solutions. *Nanotechnology* **2009**, *20* (31), 315502. https://doi.org/10.1088/0957-4484/20/31/315502.

(13) Tricoli, A.; Pratsinis, S. E. Dispersed Nanoelectrode Devices. *Nature Nanotechnology* **2010**, *5* (1), 54–60. https://doi.org/10.1038/nnano.2009.349.

(14) Kassem, O.; Saadaoui, M.; Rieu, M.; Viricelle, J.-P. A Novel Approach to a Fully Inkjet Printed SnO2-Based Gas Sensor on a Flexible Foil. *J. Mater. Chem. C* **2019**, *7* (39), 12343–12353. https://doi.org/10.1039/C9TC04170B.

(15) Cui, Y.; Zhang, M.; Li, X.; Wang, B.; Wang, R. Investigation on Synthesis and Excellent Gas-Sensing Properties of Hierarchical Au-Loaded SnO2 Nanoflowers. *Journal of Materials Research* **2019**, *34* (17), 2944–2954. https://doi.org/10.1557/jmr.2019.249.

(16) Li, H.; Chu, S.; Ma, Q.; Li, H.; Che, Q.; Wang, J.; Wang, G.; Yang, P. Multilevel Effective Heterojunctions Based on SnO2/ZnO 1D Fibrous Hierarchical Structure with Unique Interface Electronic Effects. *ACS Appl. Mater. Interfaces* **2019**, *11* (34), 31551–31561. https://doi.org/10.1021/acsami.9b10410.

(17) Tofighi, G.; Degler, D.; Junker, B.; Müller, S.; Lichtenberg, H.; Wang, W.; Weimar, U.; Barsan, N.; Grunwaldt, J.-D. Microfluidically Synthesized Au, Pd and AuPd Nanoparticles Supported on SnO2 for Gas Sensing Applications. *Sensors and Actuators B: Chemical* **2019**, *292*, 48–56. https://doi.org/10.1016/j.snb.2019.02.107.

(18) Bunpang, K.; Wisitsoraat, A.; Tuantranont, A.; Singkammo, S.; Phanichphant, S.; Liewhiran, C. Highly Selective and Sensitive CH4 Gas Sensors Based on Flame-Spray-Made Cr-

Doped SnO2 Particulate Films. *Sensors and Actuators B: Chemical* **2019**, *291*, 177–191. https://doi.org/10.1016/j.snb.2019.04.049.

(19) Wei, Y.; Wang, X.; Yi, G.; Zhou, L.; Cao, J.; Sun, G.; Hari, B. Synthesis and Characterization of Monodisperse Hollow SnO2 Microspheres and Their Enhanced Sensing Properties to Ethanol. *Journal of Porous Materials* **2018**, *25* (4), 1099–1104. https://doi.org/10.1007/s10934-017-0521-z.

(20) Zhang, B.; Fu, W.; Meng, X.; Ruan, A.; Su, P.; Yang, H. Enhanced Ethanol Sensing Properties Based on Spherical-Coral-like SnO2 Nanorods Decorated with α-Fe2O3 Nanocrystallites. *Sensors and Actuators B: Chemical* **2018**, *261*, 505–514. https://doi.org/10.1016/j.snb.2018.01.133.

(21) Wang, B.; Sun, L.; Wang, Y. Template-Free Synthesis of Nanosheets-Assembled SnO2 Hollow Spheres for Enhanced Ethanol Gas Sensing. *Materials Letters* **2018**, *218*, 290–294. https://doi.org/10.1016/j.matlet.2018.02.003.

(22) Zhu, H.; Li, Q.; Ren, Y.; Gao, Q.; Chen, J.; Wang, N.; Deng, J.; Xing, X. A New Insight into Cross-Sensitivity to Humidity of SnO2 Sensor. *Small* **2018**, *14* (13), 1703974. https://doi.org/10.1002/smll.201703974.

(23) Abokifa, A. A.; Haddad, K.; Fortner, J.; Lo, C. S.; Biswas, P. Sensing Mechanism of Ethanol and Acetone at Room Temperature by SnO2 Nano-Columns Synthesized by Aerosol Routes: Theoretical Calculations Compared to Experimental Results. *J. Mater. Chem. A* **2018**, *6* (5), 2053–2066. https://doi.org/10.1039/C7TA09535J.

(24) Kotchasak, N.; Wisitsoraat, A.; Tuantranont, A.; Phanichphant, S.; Yordsri, V.; Liewhiran, C. Highly Sensitive and Selective Detection of Ethanol Vapor Using Flame-Spray-Made CeOx-Doped SnO2 Nanoparticulate Thick Films. *Sensors and Actuators B: Chemical* **2018**, *255*, 8–21. https://doi.org/10.1016/j.snb.2017.08.027.

(25) Li, X.; Peng, K.; Dou, Y.; Chen, J.; Zhang, Y.; An, G. Facile Synthesis of Wormhole-Like Mesoporous Tin Oxide via Evaporation-Induced Self-Assembly and the Enhanced Gas-Sensing Properties. *Nanoscale Research Letters* **2018**, *13* (1), 14. https://doi.org/10.1186/s11671-018-2434-4.

(26) Singh, G.; Kaur, M.; Arora, B.; Singh, R. C. Investigation of Ethanol Gas Sensing Properties of Dy-Doped SnO2 Nanostructures. *Journal of Materials Science: Materials in Electronics* **2018**, *29* (2), 867–875. https://doi.org/10.1007/s10854-017-7982-3.

(27) Punginsang, M.; Wisitsoraat, A.; Sriprachuabwong, C.; Phokharatkul, D.; Tuantranont, A.; Phanichphant, S.; Liewhiran, C. Roles of Cobalt Doping on Ethanol-Sensing Mechanisms of Flame-Spray-Made SnO2 Nanoparticles−electrolytically Exfoliated Graphene Interfaces. *Applied Surface Science* **2017**, *425*, 351–366. https://doi.org/10.1016/j.apsusc.2017.06.265.

(28) Nguyen, K.; Hung, C. M.; Ngoc, T. M.; Thanh Le, D. T.; Nguyen, D. H.; Nguyen Van, D.; Nguyen Van, H. Low-Temperature Prototype Hydrogen Sensors Using Pd-Decorated SnO2 Nanowires for Exhaled Breath Applications. *Sensors and Actuators B: Chemical* **2017**, *253*, 156–163. https://doi.org/10.1016/j.snb.2017.06.141.

(29) Zito, C. A.; Perfecto, T. M.; Volanti, D. P. Palladium-Loaded Hierarchical Flower-like Tin Dioxide Structure as Chemosensor Exhibiting High Ethanol Response in Humid Conditions. *Advanced Materials Interfaces* **2017**, *4* (22), 1700847. https://doi.org/10.1002/admi.201700847.

(30) Li, R.; Chen, S.; Lou, Z.; Li, L.; Huang, T.; Song, Y.; Chen, D.; Shen, G. Fabrication of Porous SnO2 Nanowires Gas Sensors with Enhanced Sensitivity. *Sensors and Actuators B: Chemical* **2017**, *252*, 79–85. https://doi.org/10.1016/j.snb.2017.05.161.

(31) Xue, N.; Zhang, Q.; Zhang, S.; Zong, P.; Yang, F. Highly Sensitive and Selective Hydrogen Gas Sensor Using the Mesoporous SnO2 Modified Layers. *Sensors* **2017**, *17* (10), 2351. https://doi.org/10.3390/s17102351.

(32) Asgari, M.; Saboor, F. H.; Mortazavi, Y.; Khodadadi, A. A. SnO2 Decorated SiO2 Chemical Sensors: Enhanced Sensing Performance toward Ethanol and Acetone. *Materials Science in Semiconductor Processing* **2017**, *68*, 87–96. https://doi.org/10.1016/j.mssp.2017.06.002.

(33) Zito, C. A.; Perfecto, T. M.; Volanti, D. P. Impact of Reduced Graphene Oxide on the Ethanol Sensing Performance of Hollow SnO2 Nanoparticles under Humid Atmosphere. *Sensors and Actuators B: Chemical* **2017**, *244*, 466–474. https://doi.org/10.1016/j.snb.2017.01.015.

(34) Cao, J.; Qin, C.; Wang, Y.; Zhang, B.; Gong, Y.; Zhang, H.; Sun, G.; Bala, H.; Zhang, Z. Calcination Method Synthesis of SnO2/g-C3N4 Composites for a High-Performance Ethanol Gas Sensing Application. *Nanomaterials* **2017**, *7* (5). https://doi.org/10.3390/nano7050098.

(35) Li, M.; Zhu, H.; Cheng, J.; Zhao, M.; Yan, W. Synthesis and Improved Ethanol Sensing Performance of CuO/SnO2 Based Hollow Microspheres. *Journal of Porous Materials* **2017**, *24* (2), 507–518. https://doi.org/10.1007/s10934-016-0286-9.

(36) Sankar, C.; Ponnuswamy, V.; Manickam, M.; Suresh, R.; Mariappan, R.; Vinod, P. S. Structural, Morphological, Optical and Gas Sensing Properties of Pure and Ce Doped SnO2 Thin Films Prepared by Jet Nebulizer Spray Pyrolysis (JNSP) Technique. *Journal of Materials Science: Materials in Electronics* **2017**, *28* (6), 4577–4585. https://doi.org/10.1007/s10854-016-6094-9.

(37) Shaikh, F. I.; Chikhale, L. P.; Mulla, I. S.; Suryavanshi, S. S. Synthesis and Enhanced Ethanol Sensing Performance of Nanostructured Sr Doped SnO2 Thick Film Sensor. *Journal of Materials Science: Materials in Electronics* **2017**, *28* (4), 3128–3139. https://doi.org/10.1007/s10854-016-5901-7.

(38) Choi, K. S.; Park, S.; Chang, S.-P. Enhanced Ethanol Sensing Properties Based on SnO2 Nanowires Coated with Fe2O3 Nanoparticles. *Sensors and Actuators B: Chemical* **2017**, *238*, 871–879. https://doi.org/10.1016/j.snb.2016.07.146.

(39) Li, T.; Zeng, W. New Insight into the Gas Sensing Performance of SnO2 Nanorod-Assembled Urchins Based on Their Assembly Density. *Ceramics International* **2017**, *43* (1, Part A), 728–735. https://doi.org/10.1016/j.ceramint.2016.10.001.

(40) Li, S.-H.; Meng, F.-F.; Chu, Z.; Luo, T.; Peng, F.-M.; Jin, Z. Mesoporous SnO2 Nanowires: Synthesis and Ethanol Sensing Properties. *Advances in Condensed Matter Physics* **2017**, *2017*, 9720973. https://doi.org/10.1155/2017/9720973.

(41) Liang, Y.-C.; Lee, C.-M.; Lo, Y.-J. Reducing Gas-Sensing Performance of Ce-Doped SnO2 Thin Films through a Cosputtering Method. *RSC Adv.* **2017**, *7* (8), 4724–4734. https://doi.org/10.1039/C6RA25853K.

(42) Wang, Q.; Yao, N.; An, D.; Li, Y.; Zou, Y.; Lian, X.; Tong, X. Enhanced Gas Sensing Properties of Hierarchical SnO2 Nanoflower Assembled from Nanorods via a One-Pot Template-Free

Hydrothermal Method. *Ceramics International* **2016**, *42* (14), 15889–15896. https://doi.org/10.1016/j.ceramint.2016.07.062.

(43) Singh, D.; Kundu, V. S.; Maan, A. S. Structural, Morphological and Gas Sensing Study of Zinc Doped Tin Oxide Nanoparticles Synthesized via Hydrothermal Technique. *Journal of Molecular Structure* **2016**, *1115*, 250–257. https://doi.org/10.1016/j.molstruc.2016.02.091.

(44) Yu, X.; Zeng, W. Fabrication and Gas-Sensing Performance of Nanorod-Assembled SnO2 Nanostructures. *Journal of Materials Science: Materials in Electronics* **2016**, *27* (7), 7448–7453. https://doi.org/10.1007/s10854-016-4721-0.

(45) NaderiNasrabadi, M.; Mortazavi, Y.; Khodadadi, A. A. Highly Sensitive and Selective Gd2O3-Doped SnO2 Ethanol Sensors Synthesized by a High Temperature and Pressure Solvothermal Method in a Microreactor. *Sensors and Actuators B: Chemical* **2016**, *230*, 130–139. https://doi.org/10.1016/j.snb.2016.02.045.

(46) Qu, Y.; Wang, H.; Chen, H.; Han, M.; Lin, Z. Synthesis, Characterization and Sensing Properties of Mesoporous C/SnO2 Nanocomposite. *Sensors and Actuators B: Chemical* **2016**, *228*, 595–604. https://doi.org/10.1016/j.snb.2016.01.077.

(47) Fan, X.-X.; He, X.-L.; Li, J.-P.; Gao, X.-G.; Jia, J. Ethanol Sensing Properties of Hierarchical SnO2 Fibers Fabricated with Electrospun Polyvinylpyrrolidone Template. *Vacuum* **2016**, *128*, 112–117. https://doi.org/10.1016/j.vacuum.2016.03.016.

(48) Kwon, Y. J.; Kang, S. Y.; Wu, P.; Peng, Y.; Kim, S. S.; Kim, H. W. Selective Improvement of NO2 Gas Sensing Behavior in SnO2 Nanowires by Ion-Beam Irradiation. *ACS Appl. Mater. Interfaces* **2016**, *8* (21), 13646–13658. https://doi.org/10.1021/acsami.6b01619.

(49) Li, Y.; Zhao, F.-X.; Lian, X.-X.; Zou, Y.-L.; Wang, Q.; Zhou, Q.-J. Highly Sensitive Ethanol Sensor Based on Au-Decorated SnO2 Nanoparticles Synthesized Through Precipitation and Microwave Irradiation. *Journal of Electronic Materials* **2016**, *45* (6), 3149–3156. https://doi.org/10.1007/s11664-016-4438-0.

(50) Xu, W.; Xia, L.; Ju, J.; Xi, P.; Cheng, B.; Liang, Y. Preparation and Low-Temperature Gas-Sensing Properties of SnO2 Ultra-Fine Fibers Fabricated by a Centrifugal Spinning Process. *Journal of Sol-Gel Science and Technology* **2016**, *78* (2), 353–364. https://doi.org/10.1007/s10971-016-3962-y.

(51) Palla Papavlu, A.; Mattle, T.; Temmel, S.; Lehmann, U.; Hintennach, A.; Grisel, A.; Wokaun, A.; Lippert, T. Highly Sensitive SnO2 Sensor via Reactive Laser-Induced Transfer. *Scientific Reports* **2016**, *6* (1), 25144. https://doi.org/10.1038/srep25144.

(52) Guo, W.; Wang, Z. Composite of ZnO Spheres and Functionalized SnO2 Nanofibers with an Enhanced Ethanol Gas Sensing Properties. *Materials Letters* **2016**, *169*, 246–249. https://doi.org/10.1016/j.matlet.2016.01.118.

(53) Liu, J.; Dai, M.; Wang, T.; Sun, P.; Liang, X.; Lu, G.; Shimanoe, K.; Yamazoe, N. Enhanced Gas Sensing Properties of SnO2 Hollow Spheres Decorated with CeO2 Nanoparticles Heterostructure Composite Materials. *ACS Appl. Mater. Interfaces* **2016**, *8* (10), 6669–6677. https://doi.org/10.1021/acsami.6b00169.

(54) Li, T.; Zeng, W.; Zhao, W. Gas Sensing Performance of Multiple SnO2 1D Nanostructures Based on Their Interconnect Manner. *Materials Letters* **2016**, *167*, 230–233. https://doi.org/10.1016/j.matlet.2016.01.013.

(55) Naik, A.; Parkin, I.; Binions, R. Gas Sensing Studies of an N-n Hetero-Junction Array Based on SnO2 and ZnO Composites. *Chemosensors* **2016**, *4* (1). https://doi.org/10.3390/chemosensors4010003.

(56) Yoon, J.-W.; Choi, S. H.; Kim, J.-S.; Jang, H. W.; Kang, Y. C.; Lee, J.-H. Trimodally Porous SnO2 Nanospheres with Three-Dimensional Interconnectivity and Size Tunability: A One-Pot Synthetic Route and Potential Application as an Extremely Sensitive Ethanol Detector. *NPG Asia Materials* **2016**, *8* (3), e244. https://doi.org/10.1038/am.2016.16.

(57) Zhang, B.; Fu, W.; Li, H.; Fu, X.; Wang, Y.; Bala, H.; Wang, X.; Sun, G.; Cao, J.; Zhang, Z. Synthesis and Characterization of Hierarchical Porous SnO2 for Enhancing Ethanol Sensing Properties. *Applied Surface Science* **2016**, *363*, 560–565. https://doi.org/10.1016/j.apsusc.2015.12.042.

(58) Singh, G.; Thangaraj, R.; Singh, R. C. Effect of Crystallite Size, Raman Surface Modes and Surface Basicity on the Gas Sensing Behavior of Terbium-Doped SnO2 Nanoparticles. *Ceramics International* **2016**, *42* (3), 4323–4332. https://doi.org/10.1016/j.ceramint.2015.11.111.

(59) Chen, H.; Ma, S. Y.; Jin, W. X.; Li, W. Q. The Mode of Multi-Tier Nested Tin Dioxide Polyhedral Nanoparticles with Exposed High-Energy Facets and Their Gas Sensing Properties. *Materials Letters* **2016**, *164*, 627–630. https://doi.org/10.1016/j.matlet.2015.11.088.

(60) Oros, C.; Horprathum, M.; Wisitsoraat, A.; Srichaiyaperk, T.; Samransuksamer, B.; Limwichean, S.; Eiamchai, P.; Phokharatkul, D.; Nuntawong, N.; Chananonnawathorn, C.; Patthanasettakul, V.; Klamchuen, A.; Kaewkhao, J.; Tuantranont, A.; Chindaudom, P. Ultra-Sensitive NO2 Sensor Based on Vertically Aligned SnO2 Nanorods Deposited by DC Reactive Magnetron Sputtering with Glancing Angle Deposition Technique. *Sensors and Actuators B: Chemical* **2016**, *223*, 936–945. https://doi.org/10.1016/j.snb.2015.09.104.

(61) Naghadeh, S. B.; Vahdatifar, S.; Mortazavi, Y.; Khodadadi, A. A.; Abbasi, A. Functionalized MWCNTs Effects on Dramatic Enhancement of MWCNTs/SnO2 Nanocomposite Gas Sensing Properties at Low Temperatures. *Sensors and Actuators B: Chemical* **2016**, *223*, 252–260. https://doi.org/10.1016/j.snb.2015.09.088.

(62) Yang, F.; Guo, Z. Tuning SnO2 Architectures with Unitary or Composite Microstructure for the Application of Gas Sensors. *Journal of Colloid and Interface Science* **2016**, *462*, 140–147. https://doi.org/10.1016/j.jcis.2015.09.074.

(63) Zhou, Q.; Chen, W.; Li, J.; Tang, C.; Zhang, H. Nanosheet-Assembled Flower-like SnO2 Hierarchical Structures with Enhanced Gas-Sensing Performance. *Materials Letters* **2015**, *161*, 499–502. https://doi.org/10.1016/j.matlet.2015.09.010.

(64) Hoa, L. T.; Cuong, N. D.; Hoa, T. T.; Khieu, D. Q.; Long, H. T.; Quang, D. T.; Hoa, N. D.; Hieu, N. V. Synthesis, Characterization, and Comparative Gas Sensing Properties of Tin Dioxide Nanoflowers and Porous Nanospheres. *Ceramics International* **2015**, *41* (10, Part B), 14819–14825. https://doi.org/10.1016/j.ceramint.2015.08.003.

(65) Singh, D.; Kundu, V. S.; Maan, A. S. Structural, Morphological and Gas Sensing Study of Palladium Doped Tin Oxide Nanoparticles Synthesized via Hydrothermal Technique. *Journal of Molecular Structure* **2015**, *1100*, 562–569. https://doi.org/10.1016/j.molstruc.2015.08.009.

(66) Ling-min, Y.; Sheng, L.; Bing, Y.; Miao-miao, H.; Meng-di, K.; Xinhui, F. A Highly Sensitive Ethanol Gas Sensor Based on Mesoporous SnO2 Fabricated from a Facile Double-Surfactant

Template Method. *Materials Letters* **2015**, *158*, 409–412. https://doi.org/10.1016/j.matlet.2015.06.047.

(67) Wang, T. T.; Ma, S. Y.; Cheng, L.; Luo, J.; Jiang, X. H.; Jin, W. X. Preparation of Yb-Doped SnO2 Hollow Nanofibers with an Enhanced Ethanol–Gas Sensing Performance by Electrospinning. *Sensors and Actuators B: Chemical* **2015**, *216*, 212–220. https://doi.org/10.1016/j.snb.2015.04.040.

(68) Tan, W.; Yu, Q.; Ruan, X.; Huang, X. Design of SnO2-Based Highly Sensitive Ethanol Gas Sensor Based on Quasi Molecular-Cluster Imprinting Mechanism. *Sensors and Actuators B: Chemical* **2015**, *212*, 47–54. https://doi.org/10.1016/j.snb.2015.01.035.

(69) Cao, S.; Zeng, W.; Zhu, Z.; Peng, X. Synthesis of SnO2 Nanostructures from 1D to 3D via a Facile Hydrothermal Method and Their Gas Sensing Properties. *Journal of Materials Science: Materials in Electronics* **2015**, *26* (3), 1820–1826. https://doi.org/10.1007/s10854-014-2616-5.

(70) Cho, Y. H.; Liang, X.; Kang, Y. C.; Lee, J.-H. Ultrasensitive Detection of Trimethylamine Using Rh-Doped SnO2 Hollow Spheres Prepared by Ultrasonic Spray Pyrolysis. *Sensors and Actuators B: Chemical* **2015**, *207*, 330–337. https://doi.org/10.1016/j.snb.2014.10.001.

(71) Suematsu, K.; Ma, N.; Yuasa, M.; Kida, T.; Shimanoe, K. Surface-Modification of SnO2 Nanoparticles by Incorporation of Al for the Detection of Combustible Gases in a Humid Atmosphere. *RSC Adv.* **2015**, *5* (105), 86347–86354. https://doi.org/10.1039/C5RA17556A.

(72) Zeng, W.; Zhang, H.; Li, Y.; Chen, W.; Wang, Z. Hydrothermal Synthesis of Hierarchical Flower-like SnO2 Nanostructures with Enhanced Ethanol Gas Sensing Properties. *Materials Research Bulletin* **2014**, *57*, 91–96. https://doi.org/10.1016/j.materresbull.2014.05.019.

(73) Liu, Y.; Jiao, Y.; Zhang, Z.; Qu, F.; Umar, A.; Wu, X. Hierarchical SnO2 Nanostructures Made of Intermingled Ultrathin Nanosheets for Environmental Remediation, Smart Gas Sensor, and Supercapacitor Applications. *ACS Appl. Mater. Interfaces* **2014**, *6* (3), 2174–2184. https://doi.org/10.1021/am405301v.

(74) Zeng, W.; He, Q.; Pan, K.; Wang, Y. Synthesis of Multifarious Hierarchical Flower-like SnO2 and Their Gas-Sensing Properties. *Physica E: Low-dimensional Systems and Nanostructures* **2013**, *54*, 313–318. https://doi.org/10.1016/j.physe.2013.07.014.

(75) Lou, Z.; Wang, L.; Wang, R.; Fei, T.; Zhang, T. Synthesis and Ethanol Sensing Properties of SnO2 Nanosheets via a Simple Hydrothermal Route. *Solid-State Electronics* **2012**, *76*, 91–94. https://doi.org/10.1016/j.sse.2012.05.062.

(76) Wang, X.; Han, X.; Xie, S.; Kuang, Q.; Jiang, Y.; Zhang, S.; Mu, X.; Chen, G.; Xie, Z.; Zheng, L. Controlled Synthesis and Enhanced Catalytic and Gas-Sensing Properties of Tin Dioxide Nanoparticles with Exposed High-Energy Facets. *Chemistry – A European Journal* **2012**, *18* (8), 2283–2289. https://doi.org/10.1002/chem.201103280.

(77) Xu, M.-H.; Cai, F.-S.; Yin, J.; Yuan, Z.-H.; Bie, L.-J. Facile Synthesis of Highly Ethanol-Sensitive SnO2 Nanosheets Using Homogeneous Precipitation Method. *Sensors and Actuators B: Chemical* **2010**, *145* (2), 875–878. https://doi.org/10.1016/j.snb.2010.01.002.

(78) Firooz, A. A.; Mahjoub, A. R.; Khodadadi, A. A. Highly Sensitive CO and Ethanol Nanoflower-like SnO2 Sensor among Various Morphologies Obtained by Using Single and

Mixed Ionic Surfactant Templates. *Sensors and Actuators B: Chemical* **2009**, *141* (1), 89–96. https://doi.org/10.1016/j.snb.2009.06.027.

(79) Motsoeneng, R. G.; Kortidis, I.; Rikhotso, R.; Swart, H. C.; Ray, S. S.; Motaung, D. E. Temperature-Dependent Response to C3H7OH and C2H5OH Vapors Induced by Deposition of Au Nanoparticles on SnO2/NiO Hollow Sphere-Based Conductometric Sensors. *Sensors and Actuators B: Chemical* **2020**, *316*, 128041. https://doi.org/10.1016/j.snb.2020.128041.

(80) Francioso, L.; De Pascali, C.; Creti, P.; Radogna, A. V.; Capone, S.; Taurino, A.; Epifani, M.; Baldacchini, C.; Bizzarri, A. R.; Siciliano, P. A. Nanogap Sensors Decorated with SnO2 Nanoparticles Enable Low-Temperature Detection of Volatile Organic Compounds. *ACS Appl. Nano Mater.* **2020**, *3* (4), 3337–3346. https://doi.org/10.1021/acsanm.0c00066.

(81) Khamfoo, K.; Inyawilert, K.; Wisitsoraat, A.; Tuantranont, A.; Phanichphant, S.; Liewhiran, C. Formaldehyde Sensor Based on FSP-Made AgOx-Doped SnO2 Nanoparticulate Sensing Films. *Sensors and Actuators B: Chemical* **2020**, *309*, 127705. https://doi.org/10.1016/j.snb.2020.127705.

(82) Zhang, L.; Tong, R.; Ge, W.; Guo, R.; Shirsath, S. E.; Zhu, J. Facile One-Step Hydrothermal Synthesis of SnO2 Microspheres with Oxygen Vacancies for Superior Ethanol Sensor. *Journal of Alloys and Compounds* **2020**, *814*, 152266. https://doi.org/10.1016/j.jallcom.2019.152266.

(83) Reddy, C. S.; Murali, G.; Reddy, A. S.; Park, S.; In, I. GO Incorporated SnO2 Nanotubes as Fast Response Sensors for Ethanol Vapor in Different Atmospheres. *Journal of Alloys and Compounds* **2020**, *813*, 152251. https://doi.org/10.1016/j.jallcom.2019.152251.

(84) Cai, Z.; Park, S. Enhancement Mechanisms of Ethanol-Sensing Properties Based on Cr2O3 Nanoparticle-Anchored SnO2 Nanowires. *Journal of Materials Research and Technology* **2020**, *9* (1), 271–281. https://doi.org/10.1016/j.jmrt.2019.10.055.

(85) Zhang, X.; Liu, B.; Xu, Y.; Liu, H.; Zhao, W.; Wang, P.; Ming, A.; Wei, F. Facile Fabrication of Cobalt-Doped SnO2 for Gaseous Ethanol Detection and the Catalytic Mechanism of Cobalt. *CrystEngComm* **2019**, *21* (48), 7528–7534. https://doi.org/10.1039/C9CE01530B.

(86) Kuang, X.; Liu, T.; Li, T.; Zeng, W.; Peng, X.; Zhang, H. Hydrothermal Synthesis of SnO2 Hierarchical Nanostructures and Their Gas Sensing Properties. *Mater. Technol.* **2016**, *31* (5), 260–265. https://doi.org/10.1179/1753555715Y.0000000051.

(87) Li, H.; Zhu, D.; Yang, Z.; Lu, W.; Pu, Y. The Ethanol-Sensitive Property of Hierarchical MoO3-Mixed SnO2 Aerogels via Facile Ambient Pressure Drying. *Applied Surface Science* **2019**, *489*, 384–391. https://doi.org/10.1016/j.apsusc.2019.05.368.

(88) Jayababu, N.; Poloju, M.; Shruthi, J.; Reddy, M. V. R. Semi Shield Driven P-n Heterostructures and Their Role in Enhancing the Room Temperature Ethanol Gas Sensing Performance of NiO/SnO2 Nanocomposites. *Ceramics International* **2019**, *45* (12), 15134–15142. https://doi.org/10.1016/j.ceramint.2019.04.255.

(89) Lian, X.; Li, Y.; Zhu, J.; Zou, Y.; Liu, X.; An, D.; Wang, Q. Synthesis of Coryphantha Elephantidens-like SnO2 Nanospheres and Their Gas Sensing Properties. *Current Applied Physics* **2019**, *19* (7), 849–855. https://doi.org/10.1016/j.cap.2019.04.016.

(90) Zappa, D. Low-Power Detection of Food Preservatives by a Novel Nanowire-Based Sensor Array. *Foods* **2019**, *8* (6). https://doi.org/10.3390/foods8060226.

(91) Song, L.; Yang, L.; Wang, Z.; Liu, D.; Luo, L.; Zhu, X.; Xi, Y.; Yang, Z.; Han, N.; Wang, F.; Chen, Y. One-Step Electrospun SnO2/MOx Heterostructured Nanomaterials for Highly Selective Gas Sensor Array Integration. *Sensors and Actuators B: Chemical* **2019**, *283*, 793–801. https://doi.org/10.1016/j.snb.2018.12.097.

(92) Yang, X.; Li, H.; Li, T.; Li, Z.; Wu, W.; Zhou, C.; Sun, P.; Liu, F.; Yan, X.; Gao, Y.; Liang, X.; Lu, G. Highly Efficient Ethanol Gas Sensor Based on Hierarchical SnO2/Zn2SnO4 Porous Spheres. *Sensors and Actuators B: Chemical* **2019**, *282*, 339–346. https://doi.org/10.1016/j.snb.2018.11.070.

(93) Zhao, R.; Wang, Z.; Zou, T.; Wang, Z.; Xing, X.; Yang, Y.; Wang, Y. 'Green' Prepare SnO2 Nanofibers by Shaddock Peels: Application for Detection of Volatile Organic Compound Gases. *Journal of Materials Science: Materials in Electronics* **2019**, *30* (3), 3032–3044. https://doi.org/10.1007/s10854-018-00582-5.

(94) Xu, S.; Xu, Y.; Zhao, H.; Xu, R.; Lei, Y. Sensitive Gas-Sensing by Creating Adsorption Active Sites: Coating an SnO_2 Layer on Triangle Arrays. *ACS Appl. Mater. Interfaces* **2018**, *10* (34), 29092–29099. https://doi.org/10.1021/acsami.8b08078.

(95) Zhang, R.; Jia, J.-B.; Cao, J.-L.; Wang, Y. SnO2/Graphene Nanoplatelet Nanocomposites: Solid-State Method Synthesis With High Ethanol Gas-Sensing Performance. *Frontiers in Chemistry* **2018**, *6* (https://doi.org/10.3389/fchem.2018.00337), 337. https://doi.org/10.3389/fchem.2018.00337.

(96) H. Gong; C. Zhao; F. Wang. On-Chip Growth of SnO2/ZnO Core–Shell Nanosheet Arrays for Ethanol Detection. *IEEE Electron Device Letters* **2018**, *39* (7), 1065–1068. https://doi.org/10.1109/LED.2018.2832644.

(97) Li, F.; Gao, X.; Wang, R.; Zhang, T. Design of WO3-SnO2 Core-Shell Nanofibers and Their Enhanced Gas Sensing Performance Based on Different Work Function. *Applied Surface Science* **2018**, *442*, 30–37. https://doi.org/10.1016/j.apsusc.2018.02.122.

(98) Sun, Y.; Wang, J.; Li, X.; Du, H.; Huang, Q. The Improvement of Gas-Sensing Properties of SnO2/Zeolite-Assembled Composite. *J Nanopart Res* **2018**, *20* (5), 134. https://doi.org/10.1007/s11051-018-4240-4.

(99) Yue, L.; Ge, J.; Luo, G.; Bian, K.; Yin, C.; Guan, R.; Zhang, W.; Zhou, Z.; Wang, K.; Guo, X. A Facile Large-Scale Synthesis of Porous SnO2 by Bronze for Superior Lithium Storage and Gas Sensing Properties Through a Wet Chemical Reaction Strategy. *Journal of Electronic Materials* **2018**, *47* (5), 2545–2556. https://doi.org/10.1007/s11664-018-6130-z.

(100) Huang, Q.; Wang, J.; Sun, Y.; Li, X.; Wang, X.; Zhao, Z. Gas-Sensing Properties of Composites of Y-Zeolite and SnO2. *J Mater Sci* **2018**, *53* (9), 6729–6740. https://doi.org/10.1007/s10853-018-2016-y.

(101) Chen, D.; Yi, J. One-Pot Electrospinning and Gas-Sensing Properties of LaMnO3 Perovskite/SnO2 Heterojunction Nanofibers. *J Nanopart Res* **2018**, *20* (3), 65. https://doi.org/10.1007/s11051-018-4158-x.

(102) Wang, Q.; Kou, X.; Liu, C.; Zhao, L.; Lin, T.; Liu, F.; Yang, X.; Lin, J.; Lu, G. Hydrothermal Synthesis of Hierarchical CoO/SnO2 Nanostructures for Ethanol Gas Sensor. *Journal of Colloid and Interface Science* **2018**, *513*, 760–766. https://doi.org/10.1016/j.jcis.2017.11.073.

(103) Kou, X.; Xie, N.; Chen, F.; Wang, T.; Guo, L.; Wang, C.; Wang, Q.; Ma, J.; Sun, Y.; Zhang, H.; Lu, G. Superior Acetone Gas Sensor Based on Electrospun SnO2 Nanofibers by Rh Doping. *Sensors and Actuators B: Chemical* **2018**, *256*, 861–869. https://doi.org/10.1016/j.snb.2017.10.011.

(104) Lee, D. H.; Kang, S. K.; Pak, Y.; Lim, N.; Lee, R.; Kumaresan, Y.; Lee, S.; Lee, C.; Ham, M.-H.; Jung, G. Y. Transfer of Preheat-Treated SnO2 via a Sacrificial Bridge-Type ZnO Layer for Ethanol Gas Sensor. *Sensors and Actuators B: Chemical* **2018**, *255*, 70–77. https://doi.org/10.1016/j.snb.2017.08.025.

(105) Xiao, L.; Xu, S.; Yu, G.; Liu, S. Efficient Hierarchical Mixed Pd/SnO2 Porous Architecture Deposited Microheater for Low Power Ethanol Gas Sensor. *Sensors and Actuators B: Chemical* **2018**, *255*, 2002–2010. https://doi.org/10.1016/j.snb.2017.08.216.

(106) Liu, L.; Shu, S.; Zhang, G.; Liu, S. Highly Selective Sensing of C_2H_6O, HCHO, and C_3H_6O Gases by Controlling SnO_2 Nanoparticle Vacancies. *ACS Appl. Nano Mater.* **2018**, *1* (1), 31–37. https://doi.org/10.1021/acsanm.7b00150.

(107) Peng, S.; Xie, D.; Wang, J.; Chen, M.; Xu, L. Integration of SnO2 Nanoparticles with Micro-Hotplatform for Low-Power-Consumption Gas Sensors. *Sensors and Materials* **2018**, *30* (11), 2679. https://doi.org/10.18494/SAM.2018.2006.

(108) Sun, J.; Yin, G.; Cai, T.; Yu, W.; Peng, F.; Sun, Y.; Zhang, F.; Lu, J.; Ge, M.; He, D. The Role of Oxygen Vacancies in the Sensing Properties of Ni Substituted SnO_2 Microspheres. *RSC Adv.* **2018**, *8* (58), 33080–33086. https://doi.org/10.1039/C8RA05679J.

(109) Du, L.; Li, Y.; Li, S.; Li, H.; Liu, L.; Cheng, Y.; Duan, H. The Comparison of Gas Sensing Properties between Hierarchical Porous and Nonporous SnO2 Microflowers. *J Mater Sci: Mater Electron* **2018**, *29* (1), 244–250. https://doi.org/10.1007/s10854-017-7910-6.

(110) Yan, S.; Liang, X.; Song, H.; Ma, S.; Lu, Y. Synthesis of Porous CeO2-SnO2 Nanosheets Gas Sensors with Enhanced Sensitivity. *Ceramics International* **2018**, *44* (1), 358–363. https://doi.org/10.1016/j.ceramint.2017.09.181.

(111) Yan, S.; Liang, X.; Song, H.; Ma, S.; Lu, Y. Synthesis of Porous CeO2-SnO2 Nanosheets Gas Sensors with Enhanced Sensitivity. *Ceramics International* **2018**, *44* (1), 358–363. https://doi.org/10.1016/j.ceramint.2017.09.181.

(112) Wang, Y.; Cao, J.; Qin, C.; Zhang, B.; Sun, G.; Zhang, Z. Synthesis and Enhanced Ethanol Gas Sensing Properties of the G-C3N4 Nanosheets-Decorated Tin Oxide Flower-Like Nanorods Composite. *Nanomaterials* **2017**, *7* (10), 285. https://doi.org/10.3390/nano7100285.

(113) J. Fang; Y. Zhu; D. Wu; C. Zhang; S. Xu; D. Xiong; P. Yang; L. Wang; P. K. Chu. Preparation of SnO2 Nanoparticles Doped With Palladium and Graphene and Application for Ethanol Detection. *IEEE Sensors Journal* **2017**, *17* (19), 6240–6245. https://doi.org/10.1109/JSEN.2017.2742583.

(114) Hyun, S. K.; Sun, G.-J.; Lee, J. K.; Lee, C.; In Lee, W.; Kim, H. W. Ethanol Gas Sensing Using a Networked PbO-Decorated SnO2 Nanowires. *Thin Solid Films* **2017**, *637*, 21–26. https://doi.org/10.1016/j.tsf.2017.02.054.

(115) Liu, J.; Wang, T.; Wang, B.; Sun, P.; Yang, Q.; Liang, X.; Song, H.; Lu, G. Highly Sensitive and Low Detection Limit of Ethanol Gas Sensor Based on Hollow ZnO/SnO2 Spheres

Composite Material. *Sensors and Actuators B: Chemical* **2017**, *245*, 551–559. https://doi.org/10.1016/j.snb.2017.01.148.

(116) Xu, X. L.; Chen, Y.; Zhang, G. H.; Yan, S. H.; Bian, H. Q.; Chen, Q.; Lu, Y.; Ma, S. Y. Fabrication of Pr-Doped SnO 2 Spherical Core-Shell Nanostructure with Wrinkly Shell and the Gas Sensing Properties. *Materials Letters* **2017**, *195*, 159–163. https://doi.org/10.1016/j.matlet.2017.02.104.

(117) Sun, G.-J.; Lee, J. K.; Lee, W. I.; Dwivedi, R. P.; Lee, C.; Ko, T. Ethanol Sensing Properties and Dominant Sensing Mechanism of NiO-Decorated SnO2 Nanorod Sensors. *Electronic Materials Letters* **2017**, *13* (3), 260–269. https://doi.org/10.1007/s13391-017-1719-6.

(118) Li, Z.; Yi, J. Enhanced Ethanol Sensing of Ni-Doped SnO2 Hollow Spheres Synthesized by a One-Pot Hydrothermal Method. *Sensors and Actuators B: Chemical* **2017**, *243*, 96–103. https://doi.org/10.1016/j.snb.2016.11.136.

(119) Wang, S.; Yu, W.; Cheng, C.; Zhang, T.; Ge, M.; Sun, Y.; Dai, N. Fabrication of Mesoporous SnO2 Nanocubes with Superior Ethanol Gas Sensing Property. *Materials Research Bulletin* **2017**, *89*, 267–272. https://doi.org/10.1016/j.materresbull.2017.02.010.

(120) Liu, Y.; Huang, J.; Yang, J.; Wang, S. Pt Nanoparticles Functionalized 3D SnO2 Nanoflowers for Gas Sensor Application. *Solid-State Electronics* **2017**, *130*, 20–27. https://doi.org/10.1016/j.sse.2017.01.005.

(121) Wang, Y.; Liu, C.; Wang, L.; Liu, J.; Zhang, B.; Gao, Y.; Sun, P.; Sun, Y.; Zhang, T.; Lu, G. Horseshoe-Shaped SnO2 with Annulus-like Mesoporous for Ethanol Gas Sensing Application. *Sensors and Actuators B: Chemical* **2017**, *240*, 1321–1329. https://doi.org/10.1016/j.snb.2016.07.160.

(122) Cao, J.; Qin, C.; Wang, Y.; Zhang, H.; Zhang, B.; Gong, Y.; Wang, X.; Sun, G.; Bala, H.; Zhang, Z. Synthesis of G-C $_3$ N $_4$ Nanosheet Modified SnO $_2$ Composites with Improved Performance for Ethanol Gas Sensing. *RSC Adv.* **2017**, *7* (41), 25504–25511. https://doi.org/10.1039/C7RA01901G.

(123) Qiang, Z.; Ma, S. Y.; Jiao, H. Y.; Wang, T. T.; Jiang, X. H.; Jin, W. X.; Yang, H. M.; Chen, H. Highly Sensitive and Selective Ethanol Sensors Using Porous SnO2 Hollow Spheres. *Ceramics International* **2016**, *42* (16), 18983–18990. https://doi.org/10.1016/j.ceramint.2016.09.053.

(124) Kou, X.; Wang, C.; Ding, M.; Feng, C.; Li, X.; Ma, J.; Zhang, H.; Sun, Y.; Lu, G. Synthesis of Co-Doped SnO2 Nanofibers and Their Enhanced Gas-Sensing Properties. *Sensors and Actuators B: Chemical* **2016**, *236*, 425–432. https://doi.org/10.1016/j.snb.2016.06.006.

(125) Zhu, L.; Wang, M.; Kwan Lam, T.; Zhang, C.; Du, H.; Li, B.; Yao, Y. Fast Microwave-Assisted Synthesis of Gas-Sensing SnO2 Quantum Dots with High Sensitivity. *Sensors and Actuators B: Chemical* **2016**, *236*, 646–653. https://doi.org/10.1016/j.snb.2016.04.173.

(126) Sun, G.; Chen, H.; Li, Y.; Chen, Z.; Zhang, S.; Ma, G.; Jia, T.; Cao, J.; Bala, H.; Wang, X.; Zhang, Z. Synthesis and Improved Gas Sensing Properties of NiO-Decorated SnO2 Microflowers Assembled with Porous Nanorods. *Sensors and Actuators B: Chemical* **2016**, *233*, 180–192. https://doi.org/10.1016/j.snb.2016.04.057.

(127) Suematsu, K.; Ma, N.; Kodama, K.; Yuasa, M.; Kida, T.; Shimanoe, K. Vanadium Oxide Loading on Tin Dioxide Nanoparticles for Improving Gas Detection in a Humid Atmosphere. *Materials Letters* **2016**, *179*, 214–216. https://doi.org/10.1016/j.matlet.2016.05.083.

(128) Lu, P.; Hu, X.; Huang, H.; Hu, N.; Zhang, J.; Shen, X. Controllable Low-Temperature Hydrothermal Synthesis and Gas-Sensing Investigation of Crystalline SnO2 Nanoparticles. *J. of Materi Eng and Perform* **2016**, *25* (4), 1342–1346. https://doi.org/10.1007/s11665-016-1991-x.

(129) Guo, J.; Zhang, J.; Gong, H.; Ju, D.; Cao, B. Au Nanoparticle-Functionalized 3D SnO2 Microstructures for High Performance Gas Sensor. *Sensors and Actuators B: Chemical* **2016**, *226*, 266–272. https://doi.org/10.1016/j.snb.2015.11.140.

(130) Kuang, X.; Liu, T.; Shi, D.; Wang, W.; Yang, M.; Hussain, S.; Peng, X.; Pan, F. Hydrothermal Synthesis of Hierarchical SnO2 Nanostructures Made of Superfine Nanorods for Smart Gas Sensor. *Applied Surface Science* **2016**, *364*, 371–377. https://doi.org/10.1016/j.apsusc.2015.12.172.

(131) Qin, G.; Gao, F.; Jiang, Q.; Li, Y.; Liu, Y.; Luo, L.; Zhao, K.; Zhao, H. Well-Aligned Nd-Doped SnO2 Nanorod Layered Arrays: Preparation, Characterization and Enhanced Alcohol-Gas Sensing Performance. *Phys. Chem. Chem. Phys.* **2016**, *18* (7), 5537–5549. https://doi.org/10.1039/C5CP07174G.

(132) Zhang, P.; Zeng, W.; Chen, L. Synthesis and Controlled Growth of Various SnO2 Nanostructures and Theirs Application of Gas Sensor. *J Mater Sci: Mater Electron* **2016**, *27* (2), 1201–1208. https://doi.org/10.1007/s10854-015-3876-4.

(133) Ren, F.; Gao, L.; Yuan, Y.; Zhang, Y.; Alqrni, A.; Al-Dossary, O. M.; Xu, J. Enhanced BTEX Gas-Sensing Performance of CuO/SnO 2 Composite. *Sensors and Actuators B: Chemical* **2016**, *223*, 914–920. https://doi.org/10.1016/j.snb.2015.09.140.

(134) Zhang, J.; Hu, X.; Shi, J.; Lu, P.; Shen, X.; Xu, P.; Saito, N. Synthesis of SnO2nanoparticles Using a Solution Plasma and Their Gas-Sensing Properties. *Japanese Journal of Applied Physics* **2015**, *55* (1S), 01AE17. https://doi.org/10.7567/jjap.55.01ae17.

(135) Wang, B.; Wang, Y.; Lei, Y.; Xie, S.; Wu, N.; Gou, Y.; Han, C.; Shi, Q.; Fang, D. Vertical SnO2 Nanosheet@SiC Nanofibers with Hierarchical Architecture for High-Performance Gas Sensors. *J. Mater. Chem. C* **2016**, *4* (2), 295–304. https://doi.org/10.1039/C5TC02792F.

(136) Xiao, L.; Shu, S.; Liu, S. A Facile Synthesis of Pd-Doped SnO2 Hollow Microcubes with Enhanced Sensing Performance. *Sensors and Actuators B: Chemical* **2015**, *221*, 120–126. https://doi.org/10.1016/j.snb.2015.06.099.

(137) Jiang, X. H.; Ma, S. Y.; Sun, A. M.; Zhang, Z. M.; Jin, W. X.; Wang, T. T.; Li, W. Q.; Xu, X. L.; Luo, J.; Cheng, L.; Mao, Y. Z.; Zhang, M. Hydrothermal Self-Assembly of Novel Porous Flower-like SnO2 Architecture and Its Application in Ethanol Sensor. *Applied Surface Science* **2015**, *355*, 1192–1200. https://doi.org/10.1016/j.apsusc.2015.08.014.

(138) Kaneti, Y. V.; Yue, J.; Moriceau, J.; Chen, C.; Liu, M.; Yuan, Y.; Jiang, X.; Yu, A. Experimental and Theoretical Studies on Noble Metal Decorated Tin Oxide Flower-like Nanorods with High Ethanol Sensing Performance. *Sensors and Actuators B: Chemical* **2015**, *219*, 83–93. https://doi.org/10.1016/j.snb.2015.04.136.

(139) Luo, L.; Jiang, Q.; Qin, G.; Zhao, K.; Du, G.; Wang, H.; Zhao, H. Gas Sensing Characteristics of Novel Twin-Layered SnO2 Nanoarray Fabricated by Substrate-Free Hydrothermal Route. *Sensors and Actuators B: Chemical* **2015**, *218*, 205–214. https://doi.org/10.1016/j.snb.2015.04.111.

(140) Sun, P.; Wang, C.; Liu, J.; Zhou, X.; Li, X.; Hu, X.; Lu, G. Hierarchical Assembly of α-Fe_2O_3 Nanosheets on SnO_2 Hollow Nanospheres with Enhanced Ethanol Sensing Properties. *ACS Appl. Mater. Interfaces* **2015**, *7* (34), 19119–19125. https://doi.org/10.1021/acsami.5b04751.

(141) Yang, F.; Guo, Z. Comparison of the Enhanced Gas Sensing Properties of Tin Dioxide Samples Doped with Different Catalytic Transition Elements. *Journal of Colloid and Interface Science* **2015**, *448*, 265–274. https://doi.org/10.1016/j.jcis.2015.02.045.

(142) Liu, S.; Zhang, Y.; Yu, B.; Wang, Z.; Zhao, H.; Zhou, N.; Zhang, T. Solvent-Free Infiltration Method to Prepare Mesoporous SnO2 Templated by SiO2 Nanoparticles for Ethanol Sensing. *Sensors and Actuators B: Chemical* **2015**, *210*, 700–705. https://doi.org/10.1016/j.snb.2015.01.037.

(143) Zeng, W.; Li, T.; Li, T.; Hao, J.; Li, Y. Template-Free Synthesis of Highly Ethanol-Response Hollow SnO2 Spheres Using Hydrothermal Process. *Journal of Materials Science: Materials in Electronics* **2015**, *26* (2), 1192–1197. https://doi.org/10.1007/s10854-014-2524-8.

(144) Pan, Z.; Sun, F.; Xu, S.; Long, J.; Chen, Y.; Zhuang, Z. A General Electrodeposition-Based Method for in Situ Construction of Resistive-Type Semiconductor Film Gas-Sensor with Excellent Sensing Performance. *RSC Adv.* **2015**, *5* (90), 74075–74083. https://doi.org/10.1039/C5RA14153B.

(145) Gu, C. D.; Zheng, H.; Wang, X. L.; Tu, J. P. Superior Ethanol-Sensing Behavior Based on SnO2 Mesocrystals Incorporating Orthorhombic and Tetragonal Phases. *RSC Adv.* **2015**, *5* (12), 9143–9153. https://doi.org/10.1039/C4RA13940B.

(146) Jiang, Z.; Jiang, T.; Wang, J.; Wang, Z.; Xu, X.; Wang, Z.; Zhao, R.; Li, Z.; Wang, C. Ethanol Chemiresistor with Enhanced Discriminative Ability from Acetone Based on Sr-Doped SnO2 Nanofibers. *Journal of Colloid and Interface Science* **2015**, *437*, 252–258. https://doi.org/10.1016/j.jcis.2014.09.056.

(147) Qu, Y.; Wang, H.; Chen, H.; Xiao, J.; Lin, Z.; Dai, K. Highly Sensitive and Selective Toluene Sensor Based on Ce-Doped Coral-like SnO_2. *RSC Adv.* **2015**, *5* (21), 16446–16449. https://doi.org/10.1039/C4RA12315H.

(148) Liu, Y.; Yang, P.; Li, J.; Matras-Postolek, K.; Yue, Y.; Huang, B. Morphology Adjustment of SnO2 and SnO2/CeO2 One Dimensional Nanostructures towards Applications in Gas Sensing and CO Oxidation. *RSC Adv.* **2015**, *5* (119), 98500–98507. https://doi.org/10.1039/C5RA23446H.

(149) Guan, Y.; Wang, D.; Zhou, X.; Sun, P.; Wang, H.; Ma, J.; Lu, G. Hydrothermal Preparation and Gas Sensing Properties of Zn-Doped SnO2 Hierarchical Architectures. *Sensors and Actuators B: Chemical* **2014**, *191*, 45–52. https://doi.org/10.1016/j.snb.2013.09.002.

(150) Wang, C.; Cai, D.; Liu, B.; Li, H.; Wang, D.; Liu, Y.; Wang, L.; Wang, Y.; Li, Q.; Wang, T. Ethanol-Sensing Performance of Tin Dioxide Octahedral Nanocrystals with Exposed High-Energy {111} and {332} Facets. *J. Mater. Chem. A* **2014**, *2* (27), 10623–10628. https://doi.org/10.1039/C4TA00844H.

(151) Liu, Y.; Li, X.; Wang, Y.; Li, X.; Cheng, P.; Zhao, Y.; Dang, F.; Zhang, Y. Hydrothermal Synthesis of Au@SnO2 Hierarchical Hollow Microspheres for Ethanol Detection. *Sensors and Actuators B: Chemical* **2020**, *319*, 128299. https://doi.org/10.1016/j.snb.2020.128299.

(152) Wang, B. J.; Ma, S. Y. High Response Ethanol Gas Sensor Based on Orthorhombic and Tetragonal SnO2. *Vacuum* **2020**, *177*, 109428. https://doi.org/10.1016/j.vacuum.2020.109428.

(153) Hiyoto, K. A. M.; Fisher, E. R. Utilizing Plasma Modified SnO2 Paper Gas Sensors to Better Understand Gas-Surface Interactions at Low Temperatures. *Journal of Vacuum Science & Technology A* **2020**, *38* (4), 043202. https://doi.org/10.1116/6.0000029.

(154) Zeng, Q.; Cui, Y.; Zhu, L.; Yao, Y. Increasing Oxygen Vacancies at Room Temperature in SnO2 for Enhancing Ethanol Gas Sensing. *Materials Science in Semiconductor Processing* **2020**, *111*, 104962. https://doi.org/10.1016/j.mssp.2020.104962.

(155) Qin, S.; Tang, P.; Feng, Y.; Li, D. Novel Ultrathin Mesoporous ZnO-SnO2 n-n Heterojunction Nanosheets with High Sensitivity to Ethanol. *Sensors and Actuators B: Chemical* **2020**, *309*, 127801. https://doi.org/10.1016/j.snb.2020.127801.

(156) Zhang, G.; Sang, L.; Xu, G.; Dou, Y.; Wang, X. Synthesis and Characterization of Meso-Porous Au-Modified SnO2 Fibers Using Natural Silk with Enhanced Sensitivity for n-Butanol. *J Mater Sci: Mater Electron* **2020**, *31* (11), 8220–8229. https://doi.org/10.1007/s10854-020-03357-z.

(157) Gulevich, D.; Rumyantseva, M.; Gerasimov, E.; Khmelevsky, N.; Tsvetkova, E.; Gaskov, A. Synergy Effect of Au and SiO2 Modification on SnO2 Sensor Properties in VOCs Detection in Humid Air. *Nanomaterials* **2020**, *10* (4), 813. https://doi.org/10.3390/nano10040813.

(158) Wang, X.; Xia, R.; Jiang, S.; Gao, M.; Bao, H. The Realization of an Ultrasensitive Multifunctional Sensor through the Formation of Sn O C Bonds and Favorable Electron Transfer Direction. *Applied Surface Science* **2020**, *507*, 145094. https://doi.org/10.1016/j.apsusc.2019.145094.

(159) Zhang, N.; Fan, Y.; Lu, Y.; Li, C.; Zhou, J.; Li, X.; Adimi, S.; Ruan, S. Synthesis of Au-Decorated SnO2 Crystallites with Exposed (221) Facets and Their Enhanced Acetylene Sensing Properties. *Sensors and Actuators B: Chemical* **2020**, *307*, 127629. https://doi.org/10.1016/j.snb.2019.127629.

(160) Chen, Y.; Zhou, M.; Dong, Z.; Natan, A.; Chen, S.; Yang, Y.; Huang, X.; Yang, Y. Enhanced Acetone Detection Performance Using Facile CeO2–SnO2 Nanosheets. *Appl. Phys. A* **2020**, *126* (1), 33. https://doi.org/10.1007/s00339-019-3158-8.

(161) Zhao, T.; Qiu, P.; Fan, Y.; Yang, J.; Jiang, W.; Wang, L.; Deng, Y.; Luo, W. Hierarchical Branched Mesoporous TiO2–SnO2 Nanocomposites with Well-Defined n–n Heterojunctions for Highly Efficient Ethanol Sensing. *Advanced Science* **2019**, *6* (24), 1902008. https://doi.org/10.1002/advs.201902008.