DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING & MATERIALS AND NANOTECHNOLOGY PROGRAM

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STUDY OF NEW FUNCTIONALIZED NANOMATERIALS FOR NON-INVASIVE POINT-OF-CARE BIOSENSOR DEVICES

By

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Abstract:

Early disease detection and in-time health monitoring via novel sensing systems are in high demand for modern medicine and health management. Recent development in nanotechnology and nanomaterials such as functionalized nanostructured metal-oxide semiconductors and newly discovered two-dimensional Ti_3C_2 MXenes have offered exciting areas of research as nanomaterial-based biomedical sensing devices. In this thesis, two major nanomaterials, 1-dimensional nanostructured new ferroelectric material, KWO for application in

diabetes and 2-dimensional nanosheets, Ti_3C_2 MXene for cancer management and further improvement of the KWO related diabetes sensors are intensively studied. KWO shows great potential as a breath acetone sensor, which can be utilized to monitor and diagnose diabetes. It also shows the unique ferroelectric property and porous morphology, which allow for a room-temperature gas sensing operation. Synthesis methods and characterization are done to further the understanding of KWO as an acetone sensor and improve its capability towards becoming the cornerstone of a handheld sensor for non-invasive, portable, and easy-to-use medical tools for diabetes patients. In addition, Ti_3C_2 MXenes are studied and characterized under various synthesis conditions to create both accordion-like structures with varying gap widths, and single-to-few layered nanosheets created by the intercalation of Li^+ ions. Integration as a novel lung cancer therapy sensor tool is explored using the newly synthesized MXenes. Lastly, the innovation of new 2D nanomaterial combined with 1D KWO to form KWO/Ti_3C_2 nanocomposite has proved to significantly improve the KWO based sensor on acetone detection by minimizing the humidity interference while enhancing the sensitivity and selectivity. Moreover, a new sensor based on 2D nanosheets, Ti_3C_2 MXene, has been designed and used for the sensing response to 8-HOA and PGE-2 in lung cancer cells. The preliminary results indicate an important conclusion: this new Ti_3C_2-based sensor can provide a convenient and simple method for anti-cancer treatment guidance. Herein, a focus on these materials' synthesis parameters is explored for optimal characteristics for applied medical sensor devices.

Publications: [1-11]

[1] M. M. Raju, F. Altayran, **M. Johnson**, D. Wang, and Q. Zhang, "Crystal Structure and Preparation of Li7La3Zr2O12 (LLZO) Solid-State Electrolyte and Doping Impacts on the Conductivity: An Overview," *Electrochem,* vol. 2, pp. 390-414, 2021.

[2] **M. Johnson**, S. Koirala, A. Rudie, Q. Zhang, and D. Wang, "Nanomaterial-Based Sensing Technology for the Application in Breath Analyzer as for Early Disease Detection and Prevention. Recent Trends in Biotechnology," ed: MedDocs Publishers, 2021.

[3] S. Saha, **M. Johnson**, F. Altayaran, Y. Wang, D. Wang, and Q. Zhang, "Electrodeposition Fabrication of Chalcogenide Thin Films for Photovoltaic Applications," *Electrochem,* vol. 1, pp. 286-321, 2020.

[4] M. Sadiq, L. Pang, **M. Johnson**, V. Sathish, and D. Wang, "2D Nanomaterial, Ti3C2 MXene-Based Sensor to Guide Lung Cancer Therapy and Management," in *Multidisciplinary Digital Publishing Institute Proceedings*, 2020, p. 29.

[5] **M. Johnson**, Q. Zhang, and D. Wang, "Kxwo is a novel ferroelectric nanomaterial for application as a room temperature acetone sensor," *Nanomaterials,* vol. 10, p. 225, 2020.

[6] O. Ama, M. Sadiq, **M. Johnson**, Q. Zhang, and D. Wang, "Novel 1D/2D KWO/Ti3C2Tx Nanocomposite-Based Acetone Sensor for Diabetes Prevention and Monitoring," *Chemosensors,* vol. 8, p. 102, 2020.

[7] **M. Johnson**, Q. Zhang, and D. Wang, "Room-temperature ferroelectric K2W7O22 (KWO) nanorods as a sensor material for the detection of acetone," *Medical Devices & Sensors,* vol. 2, p. e10044, 2019.

[8] **M. Johnson**, Q. Zhang, and D. Wang, "Titanium carbide MXene: Synthesis, electrical and optical properties and their applications in sensors and energy storage devices," *Nanomaterials and Nanotechnology,* vol. 9, p. 1847980418824470, 2019.

[9] M. R. Hossain, O. Ama, Q. Zhang, **M. Johnson**, and D. Wang, "Investigation of Different Materials as Acetone Sensors for Application in Type-1 Diabetes Diagnosis," *Biomedical Journal of Scientific & Technical Research,* vol. 14, pp. 10940-10945, 2019.
[10] D. Wang, Q. Zhang, M. R. Hossain, and **M. Johnson**, "High sensitive breath sensor based on nanostructured K2W7O22 for detection of type 1 diabetes," *IEEE Sensors Journal,* vol. 18, pp. 4399-4404, 2018.
[11] M. R. Hossain, Q. Zhang, **M. Johnson**, and D. Wang, "Highly sensitive room-temperature sensor based on nanostructured K2W7O22 for application in the non-invasive diagnosis of diabetes," *Sensors,* vol. 18, p. 3703, 2018.