Electroactive low dimensional materials for advanced electrocatalysis and sensors applications

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Abstract

This presentation focuses on multifunctional 2D and 3D materials and structure/property relationships to control graphene-like and transition metal dichalcogenides nanostructure to be used as three-dimensional hybrid electrodes for hydrogen evolution reaction, sensors and supercapacitors fabrication. We developed a platinum-free electrocatalyst (3D $MoSe_2$ rose-like structure) for the hydrogen evolution reaction (HER) as a first step for large-scale production and application of water splitting devices. Recently, we demonstrated a facile strategy to synthesize decorated molybdenum oxide (MoO_2) nanoparticles on graphene oxide (GO) layers. The hybrid membrane exhibits excellent performance for HER. In the same endeavor, we showed a novel strategy to synthesize vertically aligned porous $MoSe_2$. This designed architecture based on an oriented vertical structure possesses fully exposed active edges and open structures for fast ion/electron transfer, leads to remarkable HER activity with a low onset potential and a 3D binder-free without the need for a transferring step or a conductive additive to build the electrodes. This work opened a new class of nanomaterials in my lab, in which we start the fabrication of photoanodes via in-situ reduction–graphitization approach toward efficient solar hydrogen evolution. For sensing applications, we investigated the direct effect of GO sheets sizes on biosensor performance. For that, we developed a procedure yielding graphene flakes with various amounts of oxygenated defects by using a double liquid phase extraction technique (DLPE) assisted by cholesterol-based polymers and a green method to avoid the use of chemicals and heat to promote the coprecipitation and the reduction of GO and GO based foam (membranes) immobilized aptamer as a highly selective hormone removal. Recent emphasis is on controllable synthesis and development of one-dimensional oriented CdS-based nanoarray photoanodes for efficient solar water splitting / solar hydrogen.

Figure: *Many uses of 2D and 3D materials, with applications in sensing, biomedical diagnostics, catalysis, functional materials, electronic devices and processes, and energy-related technologies.*

Recent Publications

1. Poorahong, S. et al. Nanoporous Graphite-like Membranes Decorated with MoSe Nanosheets for Hydrogen Evolution. ACS Applied Nano Materials 5, 2769–2778 (2022).
2. Peng, Z., Zhang, J., Liu, P., Claverie, J. & Siaj, M. One-Dimensional CdS/Carbon/Au Plasmonic Nanoarray Photoanodes via in Situ Reduction-Graphitization Approach toward Efficient Solar Hydrogen Evolution. ACS Applied Materials and Interfaces 13, 34658–34670 (2021).
3. a) Brisebois, P. P. & Siaj, M. Harvesting graphene oxide-years 1859 to 2019: A review of its structure, synthesis, properties and exfoliation. Journal of Materials Chemistry C 8, 1517–1547 (2020). b) Eissa, S. et al. Probing the influence of graphene oxide sheets size on the performance of label-free electrochemical biosensors. Scientific Reports 10, (2020).
4. a) Huang, S. et al. Highly Stable Ag–Au Core–Shell Nanowire Network for ITO-Free Flexible Organic Electrochromic Device. Advanced Functional Materials 31, (2021). b) Yu, T. et al. 3D Nanoscale Morphology Characterization of Ternary Organic Solar Cells. Small Methods 6, (2022).
5. Abrego-Martinez, J. C. et al. Aptamer-based electrochemical biosensor for rapid detection of SARS-CoV-2: Nanoscale electrode-aptamer-SARS-CoV-2 imaging by photo-induced force microscopy. Biosensors and Bioelectronics 195, (2022).

Biography

Mohamed Siaj received his Ph.D. in Chemistry at Laval University, Quebec, Canada. Following postdoctoral training at the Colin Nuckolls group at Columbia University, New York, a leading institution in 2D materials research, Siaj joined the Department of Chemistry at université de Quebec à Montréal as an assistant professor in 2008, and he is holding the rank of full professor since 2016. He is the Director of the Research Center on Nanomaterials and Energy (NanoQAM), (http://nanoqam.ca/wp/en/), the adjunct Director of Quebec Centre for Advanced Materials center (QCAM) (http://cqmf-qcam.ca) and Director of Analysis of Materials and Microsystems Regrouping (RAMM), Faculty of Science, UQAM. Prof. Siaj has extensive experience in different areas of surface science and nanomaterials-based graphene. Siaj's group activities focus on the growth, synthesis, processing and characterization of advanced nanostructured electroactive materials and their integration into chemical and biosensors and 2D-Materials for Energy Harvesting and Storage Applications.

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