Graphene and 2D Layered Materials for Energy Applications

Pagona Papakonstantinou

Engineering Research Institute (ERI), School of Engineering, Ulster University, Newtownabbey, BT37 0QB, UK, *p.papakonstantinou@ulster.ac.uk*

Layered two-dimensional materials such as graphene and transition metal chalcogenides possess a rare combination of properties, which are distinctly different from their bulk counterparts. One of the emerging applications of 2D materials is in electrocatalysis; the field of catalysis that is concerned with electrochemical reactions that involve charge transfer at the catalyst electrode-electrolyte interface. This area is key to the development of energy conversion and storage devices such as fuel cells, air batteries, electrolysers, solar cells and solar fuels. A major bottleneck to the commercialization of these devices is the discovery of efficient and cost-effective catalysts for accelerating important reactions such as the oxygen evolution reaction (OER), oxygen reduction reaction (ORR) and Hydrogen evolution reaction (HER), which take place at the electrodes of these devices. All three reactions are sluggish in nature and traditionally require the use of precious metal catalysts. Thus, the focus of our work is to develop inexpensive, stable and catalytically active materials for the ORR, OER and HER reactions, that can compete the performance of precious based catalysts.

In this talk, I will highlight some of our key contributions [1-7] employing various forms of graphene including nanosized graphene, nitrogenated reduced graphene oxide (RGO), vertical graphene nanoflakes as well as MoS_2 nanodots as electrodes. Specifically, I will highlight the role of edge plane defects and thickness for catalysing reactions and present strategies for increasing the active edges of graphene and chalcogenide nanosheets. In addition, I will discuss the strategic implementation of highly coupled graphene based hybrid systems, which can lead to highly desirable properties for ORR, OER, and HER reactions.

References

[1] Benson J., Li M., Wang, S., Wang P, Papakonstantinou, P. "Electrocatalytic Hydrogen Evolution reaction on edges of a few layer Molybdenum disulfide nanodots", ACS Applied Materials and Interfaces, 7 (2015) 14113–14122.

[2] Benson J., Xu Q., Wang P., Shen Y., Sun L., Wang T., Li M., Papakonstantinou P. "Tuning the catalytic activity of graphene nanosheets for oxygen reduction reaction via size and thickness reduction", ACS Applied Materials & Interfaces, 6 (2014) 19726–19736.

[3] Bikkarolla S.K., Papakonstantinou P. "*$CuCo_2O4$ nanoparticles on nitrogenated graphene as highly efficient oxygen evolution catalyst*", Journal of Power Sources 281 (2015) 243-251.

[4] Bikkarolla SK., Cumpson P., Joseph P., Papakonstantinou P. "Oxygen Reduction Reaction in Electrochemically Reduced Graphene Oxide." Faraday Discussions, 173 (2014) 415-428.

[5] Bikkarolla, SK., Yu, F., Zhou, W., Joseph P., Cumpson P., Papakonstantinou P. "A three-dimensional Mn_3O_4 network supported on a nitrogenated graphene electrocatalyst for efficient oxygen reduction reaction in alkaline media." Journal of Materials Chemistry A, 2 (2014) 14493-14501.

[6] Wang T., Gao D., Zhuo J., Zhu Z., Papakonstantinou P., Li Y., Li M. "*Size-Dependent Enhancement of Electrocatalytic Oxygen-Reduction and Hydrogen-Evolution Performance of MoS_2 Particles*", Chemistry-A European Journal 19 (2013) 11939-11948.

[7] Wang T., Liu L., Zhu Z., Papakonstantinou P., Hu J., Liu H., Li M. "*Enhanced Electrocatalytic Activity for Hydrogen Evolution Reaction from Self-Assembled Monodispersed Molybdenum Sulfides nanoparticles on an Au electrode*", Energy Environ. Sci., 6 (2013) 625-633.