The demands of modern energy consumption present new challenges regarding the storage of electrical and chemical energy. Traditional materials for creating batteries and capacitors can be examined in new ways with a view to increasing their efficiency and lifetime, whilst minimising device size. Research has discovered that the use of 2-dimensional versions of traditional energy storage materials can deliver significant advances in energy-storage technology [1]. However the use of and interactions of these materials with one another is still not well understood. One challenge to date has been how to image liquid-dispersed materials and their chemical interactions in situ. With the advent of a new generation of liquid-cell TEM holders, it is possible to conduct electron microscopy studies on 2D materials dispersed in liquid, thus presenting a new range of experimental conditions for better understanding material interactions and processes.

We conducted electron microscopy including CTEM (conventional transmission electron microscopy) and STEM (scanning transmission electron microscopy) in an FEI Titan 300kV S/TEM using a Liquid Cell TEM holder from Hummingbird Scientific Inc. Imaging can be carried out in both static and dynamic liquid environments and electrical bias can be applied to the materials for electrochemical interaction studies. Examples of the materials we examined include WS2, graphene, MoS2 and MnO2. This data can then be compared with previous, ex situ studies of materials conducted previously in our group [2].

For the first time these 2D layered-nanomaterials have been directly imaged and characterised in a TEM whilst suspended in liquid dispersion. We have demonstrated the ability to measure lattice resolution of these types of materials including graphene. We are also able to investigate and characterise the interactions of these materials in a dynamic environment whilst under electrical bias. It is hoped that using these techniques will provide us with vital information regarding the fundamental science behind the material interactions. This information can then be applied to a range of 2D layered-nanomaterials with the possibility of optimising existing battery and super-capacitor materials and discovering new and inexpensive materials for use in energy-storage technology.


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Fig. 1: Schematic of a Liquid Cell Holder design and use in a Transmission Electron Microscope

Fig. 2: CTEM image and diffraction pattern of a graphene flake in a water/surfactant dispersion. Note the resolution of the lattice spacing of the graphene flake.