Russell Berrie Nanotechnology Institute
Technion - Israel Institute of Technology

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"Understanding 'beyond-graphene' heterostructures & Nanoparticle catalysts using advanced analytical scanning transmission electron microscopy"

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12:00 refreshments
12:30 lecture

Wang Auditorium
The Dalia Maydan Building
Faculty of Materials Science and Engineering

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UNDERSTANDING 'BEYOND-GRAPHENE' HETEROSTRUCTURES AND NANOPARTICLE CATALYSTS USING ADVANCED ANALYTICAL SCANNING TRANSMISSION ELECTRON MICROSCOPY

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The current generation of aberration corrected scanning transmission electron microscope (STEM) instruments optimized for high spatial resolution energy dispersive x-ray (EDX) spectroscopy provide exciting opportunities for structural and elemental analysis of nanoscale objects. Here I will discuss recent example applications from our studies of 2D device heterostructures and nanoparticle catalysts, where these analytical capabilities have provided new insights to interpret the optical, electronic and catalytic properties of such systems.

The emerging area of 2D materials has attracted a great deal of attention in recent years. Like graphene, these materials can be exfoliated to single atom thickness and can then be layered together to create new van der Waals crystals with bespoke properties. We have been developing methods for investigating the structure of these novel materials at the atomic scale. I will present work demonstrating that cross sectional STEM-EDX spectrum imaging can be used to better understand device performance by revealing the internal atomic structure of van der Waals heterostructure devices[1,2]. For example, we have studied light emitting diode (LED) devices (Fig 1), produced by mechanical exfoliation and subsequent stacking of up to 13 different 2D crystals, including four MoS_2 monolayer quantum wells[3]. Using cross sectional STEM spectrum imaging we reveal that the crystal interfaces of such devices are atomically flat and provide detailed structural information to help to explain the photoluminescence and electroluminescence results obtained. Other 2D crystal heterostructures will also be discussed including those incorporating air sensitive 2D crystals, such as $NbSe_2$, which are fabricated under an argon atmosphere to preserve the structure of the material.[4,5] Recent results where heterostructures containing atomically engineered nanoscale channels have been used to study water transport will also be discussed.[6]

Most (S)TEM imaging and analysis gives only a 2D projection of the structure but elementally sensitive STEM EDX electron tomography can provide a route to understanding the full 3D morphology and chemistry with nanometre resolution. I will demonstrate results measuring elemental segregation in 3D and measuring the effect on catalytic performance of bimetallic nanoparticles[7,8,9] (Fig 2). I will also present recent work where customised modification of an *in situ* STEM holder system[10] has allowed us to perform high spatial resolution STEM-EDX spectrum imaging during in-situ liquid and gas phase experiments and at elevated temperature, correlated to X-ray absorption spectroscopy data[11,12].

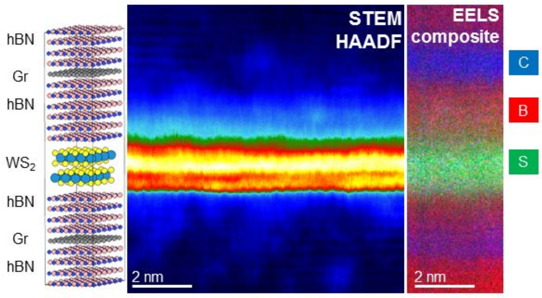

Figure 1. Cross Sectional STEM images and EELS mapping of a WS_2 quantum well LED structure.[3]

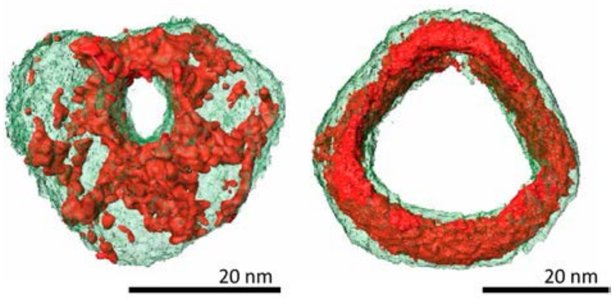

Figure 2. Elemental tomographic 3D imaging of nanoparticles achieved using STEM EDX. [6]

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