Probing the nanoscale origin of strain and doping in graphene-hBN heterostructures

We use confocal Raman microscopy and a recently proposed vector analysis scheme to investigate the nanoscale origin of strain and carrier concentration in exfoliated graphene-hexagonal boron nitride (hBN) heterostructures on silicon dioxide (SiO₂). Two types of heterostructures are studied: graphene on SiO₂ partially covered by hBN, and graphene fully encapsulated between two hBN flakes. We extend the vector analysis method to produce separated spatial maps of the strain and doping variation across the heterostructures. This allows us to visualise and directly quantify the much-speculated effect of the environment on carrier concentration in graphene. Moreover, we demonstrate that variations in strain and carrier concentration in graphene arise from nanoscale features of the heterostructures such as fractures, folds and bubbles trapped between layers. For bubbles in hBN-encapsulated graphene, hydrostatic strain is shown to be greatest at bubble centres, whereas the maximum carrier concentration is localised at bubble edges. Raman spectroscopy is shown to be a non-invasive tool for probing strain and doping in graphene, which could prove useful for engineering of two-dimensional devices.