YY1.02

STEM Imaging of Unstained DNA Nanostructures Using Suspended Graphene at High and Low Voltages

Nabil D. Bassim[1], Susan Buckout-White[1,2], Jeremy Robinson[1], Igor Medintz[1], Ellen Goldman[1], Mario Ancona[1]
1. Naval Research Laboratory, Washington, DC, USA, 2. George Mason University, Manassas, VA, USA

Structural DNA as a templating technology for energy, sensing and other applications has much promise because of its ability to self-assemble complex architectures with nanoscale precision. These architectures can vary in form from linear DNA, to dendrimers, to custom DNA origami or tiles, and they can by tagged site-specifically with fluorophores or nanoparticles to achieve specific functions such as fluoresence resonance energy transfer (FRET). In order to assess yield and to examine stuctural characteristics, high-resolution characterization methods are essential. Heretofore such characterization has been performed primarily with atomic-force microscopy, a method that is often limited in its lateral resolution and that can disturb the structure under examination through its contact. Given its extraordinary resolution, TEM would seem to have great potential. Since, however, most such work with biological structures has involved high-energy beams and negative staining, templates, or other techniques that can compromise resolution. Moreover, that the DNA materials of interest are mostly composed of low-Z atoms means that contrast is paramount and ultrathin substrates a neccesity. In this study, we report on a method for TEM imaging of low-contrast biomolecules using suspended graphene supports. A sacrificial silicon membrane beneath the graphene provides crucial mechanical support during the aqueous sample deposition but is then eliminated in a final step using a XeF2 dry etch. Taking advantage of these supports, we perform direct unstained imaging of DNA origami and other DNA nanostructures in TEM (JEOL 2200 FS, 200 kV) mode for non-aberration phase contrast imaging and in low-voltage STEM mode (aberration-corrected, FEI Titan 80keV, Nion UltraSTEM, 60keV) for lowered damage to both the DNA structure and the graphene support. STEM characterization targets both tagged and untagged DNA origami and dendrimer structures. We find that the high substrate quality of the fluorinated graphene opens a new way to probe DNA structures and measure the efficacy of the self-assembly. In general, we were able to directly characterize DNA structures and found variations in deliberate shape design of up to 15% in the origami, which may be due to flexibility within the molecule, as well as issues of adhesion to the graphene.