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Electrons for Single Molecule Diffraction and Imaging

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Electrons have large scattering cross-sections and can be focused into small probes that are ideal for single molecule diffraction and imaging. However, radiation damage is the main limiting factor that prevents its realization. At medium high electron energies (10 to 60 keV), the elastic scattering cross section increases with decreasing electron energies but damage per elastic scattering event is constant[1], except for the knock-on damage. Knock-on damage associated with atomic bonding can be avoided by using medium electron energies below the damage threshold. However, the threshold is significantly lowered not for molecular bonding with weak Van der Waals forces. To better understand this, we used C60 molecules confined inside single-walled carbon nanotubes (C60s@SWCNT or peapod) as a model system to study [2]. A 25 nm diameter electron beam from a field emission gun source is used to record diffraction patterns from individual peapods using imaging plates. The electron beam illuminates about 25 C60 molecules. Experimentally, we found that the molecules diffract inside ~15% of the host nanotubes. With the help of simulations, we calculated the knock-on damage threshold for elastic scattering at large diffraction angles and the limits this places on electron molecular diffraction. Furthermore, we examined the electron diffraction sensitivity to the molecular configurations. We show that the combination of molecular confinement, electron diffraction and electron direct imaging provides the best approach to single molecule imaging. [1] Henderson, R., 1995, Quarterly Review of Biophysics, 28, 171-193.
[2] Ran, K., Zuo, J.M., Chen, Q., Shi, Z.J., 2011. Electron Beam Stimulated Molecular Motions. Acs Nano 5, 3367-3372.