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eV-TEM: Transmission Electron Microscopy at LEEM Energies

P.S. Neu[1], D. Geelen[1], J. Jobst[1], E.E. Krasovskii[3,4,5], R.M. Tromp[1,2], S.J. van der Molen[1]

[1]*Leiden Institute of Physics, Niels Bohrweg 2, Leiden, The Netherlands*
[2]*IBM T.J. Watson Research Center, Yorktown Heights, New York 10598, USA*
[3]*Departamento de Física de Materiales, Universidad del Pais Vasco UPV/EHU, 20080 San Sebastián/Donostia, Spain*
[4]*IKERBASQUE, Basque Foundation for Science, E-48013 Bilbao, Spain*
[5]*Donostia International Physics Center (DIPC), E-20018 San Sebastián, Spain*

Email: neu@physics.leidenuniv.nl

Transmission electron microscopy (TEM) at very low energy is a promising way to avoid damaging delicate biological samples with the incident electrons, a known problem in conventional transmission electron microscopy. For achieving imaging in the 0-30 eV range, we added a second electron source to an aberration corrected low energy electron microscopy (AC-LEEM) setup, enabling imaging in both transmission and reflection mode at nanometer (nm) resolution.
We have measured the energy-dependent transmissivity and reflectivity of 2D graphene layers up to 75 eV to determine their suitability as TEM support films and obtained the energy-dependent electron mean free path (MFP). Below approx. 30 eV we find an increase in MFP. However, the MFP is always much shorter than suggested by the so-called 'universal curve' [1]. The observed splitting of the elastic MFP maximum around 2.5 eV in multi-layer graphene [2] was explained by interference of multiply reflected electron waves, in close analogy to optical multilayer antireflection coatings.
To demonstrate the applicability of eV-TEM to biological samples, we have imaged DNA origami rectangles deposited on a graphene oxide membrane in LEEM (Fig. 1a) and eV-TEM (Fig. 1b). Individual rectangles (70 nm by 90 nm) and agglomerates are visible. The sample was illuminated with low energy electrons for one hour without observing degradation.
In combination with recent developments in 2D membranes, allowing for versatile sample preparation, eV-TEM is paving the way to damage-free imaging of biological samples at nm resolution.

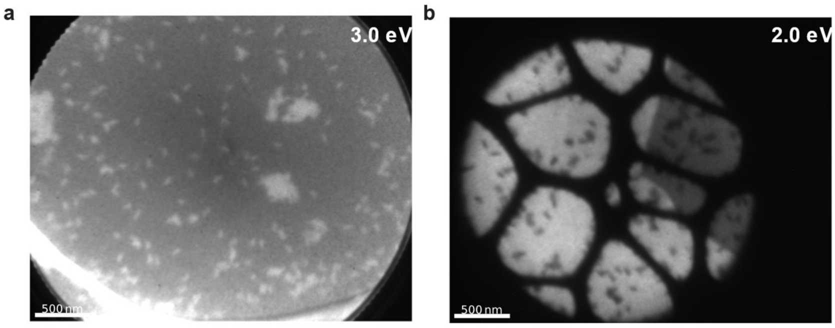

Figure 1. Rectangular DNA origami patches (70 nm by 90 nm) on top of mono- and double-layer graphene oxide suspended over lacey carbon web. LEEM (a) and eV-TEM (b) image of DNA origami on graphene oxide (different areas). The DNA origami is bright in LEEM and dark in eV-TEM.

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References

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