Understanding electron-beam-stimulated dynamics in low-dimensional heterostructures

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To obtain structural and electronic properties of low-dimensional materials at the atomic scale, a new type of transmission electron microscope operating at electron energies between 80 and 20keV has been developed which allows to undercut the knock-on damage thresholds even of low-Z-number materials, to increase the contrast and to compensate for the reduced resolution at lower electron energies by a new spherical and chromatic aberration corrector. Sub-Angstroem resolution is achieved down to 40keV in a wide field of view of 4000x4000 pixels [1,2], making the tool predestined for in-situ studies of dynamic effects in low-dimensional materials. As especially non-conducting materials suffer from ionization effects during imaging, which increase at lower voltages [3], sophisticated sample preparation methods are needed to reduce these effects: Here the production of clean surfaces [4] and sandwiching the radiation-sensitive material between two single layers of graphene [5] provide good results.
Briefly key instrumental and methodological developments will be outlined and main emphasis will be made on the application for finding very different low-dimensional material's atomic and electronic structure. We report on the structure of two-dimensional glass [6], charge-density-wave-associated periodic lattice distortions in single-layer 1T-$TaSe_2$ [7] and the structure of 1T-TaS_2 intercalated with Pyridine (C_5H_5N) and Triethylenediamine ($C_6H_{12}N_2$) [8]. It will be reported, moreover, on electron-beam-stimulated transformations from point to extended defects in 2H-$MoTe_2$ associated with phase change to distorted 1T'-$MoTe_2$ [9]. Another example shows in-situ the transformation of a 2-dimensional BN structure to an atomic chain [9]. In addition we show by high-resolution TEM and EELS experiments accompanied by DFT calculations that the lithiation between bilayer graphene results in a new highly dense crystalline Li- Phase [10].

References

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