Direct Imaging of Loaded Metal−Organic Framework Materials (Metal@MOF-5)

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We illustrate the potential of advanced transmission electron microscopy for the characterization of a new class of soft porous materials: metal@$Zn_4O(bdc)_3$ (metal@MOF-5; bdc = 1,4-benzenedicarboxylate). By combining several electron microscopy techniques (transmission electron microscopy (TEM), high-resolution transmission electron microscopy (HRTEM), electron diffraction (ED), high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM), and electron tomography) and by carefully reducing the electron dose to avoid beam damage, it is possible to simultaneously characterize the MOF-5 framework material and the loaded metal nanoparticles. We also demonstrate that electron tomography can be used to accurately determine the position and distribution of the particles within the MOF-5 framework. To demonstrate the implementation of these microscopy techniques and what kind of results can be expected, measurements on gas-phase-loaded metal−organic framework materials Ru@MOF-5 and Pd@MOF-5 are presented.