*Transmission Electron Microscopy for Materials Science: Seeing is Believing, to Measure is to Know*

Sara Bals

*EMAT and NanoLight Centre of Excellence, Groenenborgerlaan 171, 2020 Antwerp, Belgium*

It is well known that the properties of nanomaterials are intrinsically connected to their size, shape, composition, and crystal structure. Their characterization at the nanoscale is therefore essential to enable the optimization of a controlled synthesis, as well as to tune the structure-property connection, leading to materials with specific, predefined properties. (Scanning) transmission electron microscopy ((S)TEM) has proven to be an indispensable tool for the characterization of nanomaterials. Over the last decades, the field has significantly evolved, with most developments focusing on hardware optimisation. These efforts have e.g. enabled drastically improved spatial resolution, even down to the atomic scale and more sensitive detectors, enabling the investigation of materials that would otherwise suffer from damage causing by the electron beam.

Along with these developments, Artificial Intelligence (AI) has become increasingly important in the field of TEM, by improving data acquisition, analysis, and interpretation. Some key areas where AI is being used in TEM will be discussed in this contribution. For example, deep learning models have been shown to reconstruct high-resolution images from low-dose TEM data, reducing electron beam damage for sensitive materials. We recently demonstrated the impact of this approach when investigating strong metal support interaction in the field of catalysis [1] and when visualizing the lattice of halide perovskite materials, of importance for their use in solar cells [2]. Deep learning models may also optimize three-dimensional characterization of nanoparticles by TEM, requiring fewer two-dimensional images, which may improve the thoughput of such measurements and which may enable to establish the connection between structure and properties of the materials under investigation [3].

[1] “Restructuring of titanium oxide overlayers over nickel nanoparticles during catalysis”. Monai M, Jenkinson K, Melcherts AEM, Louwen JN, Irmak EA, Van Aert S, Altantzis T, Vogt C, van der Stam W, Duchon T, Smid B, Groeneveld E, Berben P, Bals S, Weckhuysen BM, Science 380, 644 (2023).

[2] “*Investigation of the Octahedral Network Structure in Formamidinium Lead Bromide Nanocrystals by Low-Dose Scanning Transmission Electron Microscopy*”. Schrenker NJ, Braeckevelt T, De Backer A, Livakas N, Yu C-P, Friedrich T, Roeffaers MBJ, Hofkens J, Verbeeck J, Manna L, Van Speybroeck V, Van Aert S, Bals S, Nano Letters **24**, 10936 (2024).

[3] “Electron tomography based on highly limited data using a neural network reconstruction technique”. Bladt E, Pelt DM, Bals S, Batenburg KJ, Ultramicroscopy 158, 81 (2015).