Structural Dynamics Measured Using In Situ Electron Microscopy

Hansen, Thomas W.; Lomholdt, William Bang; Leth Larsen, Matthew Helmi; Valencia, Cuauhtémoc Núñez; Liu, Pei; Schiøtz, Jakob

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

Structural Dynamics Measured Using In Situ Electron Microscopy

Thomas W. Hansen[1*], William Bang Lomholdt[1], Matthew Helmi Leth Larsen[2], Cuauhtémoc Núñez Valencia[2], Pei Liu[1] and Jakob Schiøtz[2]

[1.] DTU Nanolab, Technical University of Denmark, DK-2800, Kgs. Lyngby, Denmark
[2.] Department of Physics, Technical University of Denmark, DK-2800, Kgs. Lyngby, Denmark
* Corresponding author: thwh@dtu.dk

Understanding the atomic-scale structure of materials and devices, as well as the potential structural changes that may occur during use in real-world operating conditions, is essential to developing next-generation functional materials. Materials which can provide new solutions within a diverse range of fields including chemistry, electronics, and medicine. A core challenge when characterizing such materials is how to obtain atomic-resolution information under operating conditions, without affecting them by the imaging process? State-of-the-art transmission electron microscopy techniques can routinely provide sub-angstrom spatial resolution and high spectroscopic and temporal resolution datasets of devices, even in the presence of gases and liquids. However, making these observations application-relevant requires minimization of electron beam effects and unbiased analysis.

Minimizing electron dose rate during data acquisition reduces the impact of imaging but at the cost of a reduced signal to noise ratio of the acquired data. The result is often that the data becomes so noisy that it is not analyzable using a manual approach. An automated approach which has gathered significant traction over the last decade is machine learning. Well-trained networks, where noisy data is included in the training sets have shown promising performance, even on *in situ* data. Figure 1 shows a gold nanoparticle imaged at in 4.5 Pa carbon monoxide at 300°C [1, 2]. The positions of atomic columns have successfully been located using a convolutional neural network. Analyzing sequences of such frames reveals the dynamic nature and structural variations due to changes in the environmental conditions. Data analysis by means of convolutional neural networks is also efficient for analyzing images of low-Z materials with poor contrast.

Here we will discuss the challenges of imaging materials in a way that is as noninvasive as possible.

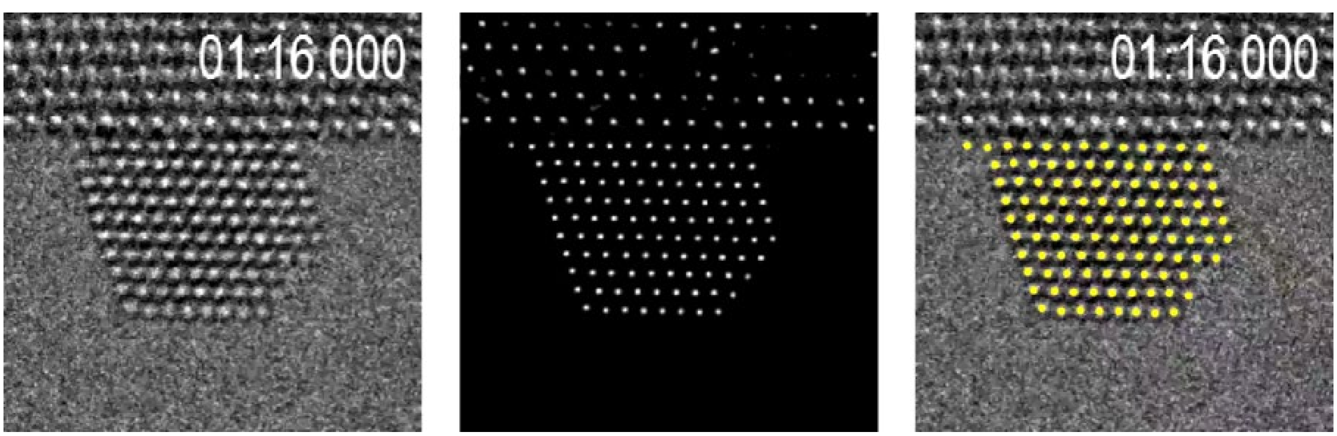

Figure 1. Times New Roman, 10pt justified. Provide a short description including labels / scale bars as appropriate.

References: (Times New Roman, 10-pt, left justified)
[1] P. Liu, J. Madsen, J. Schiøtz et al., J. Phys.: Mater. 3 (2020), 024009.
[2] P. Liu, T. T. Wu, J. Madsen et al., Nanoscale 11 (2019), 11885-11891.