Automatic thickness determination in transmission electron microscopy with deep learning

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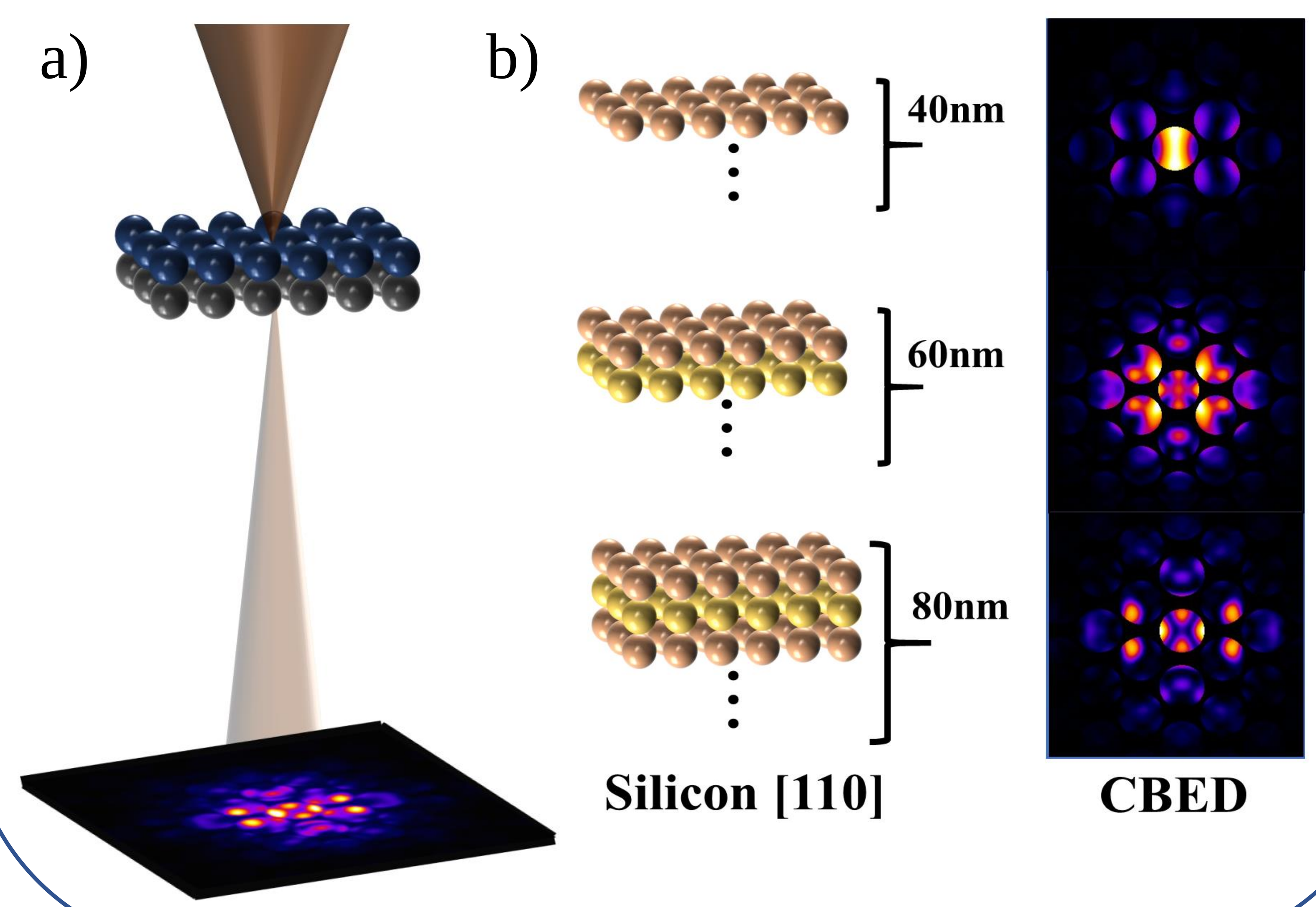
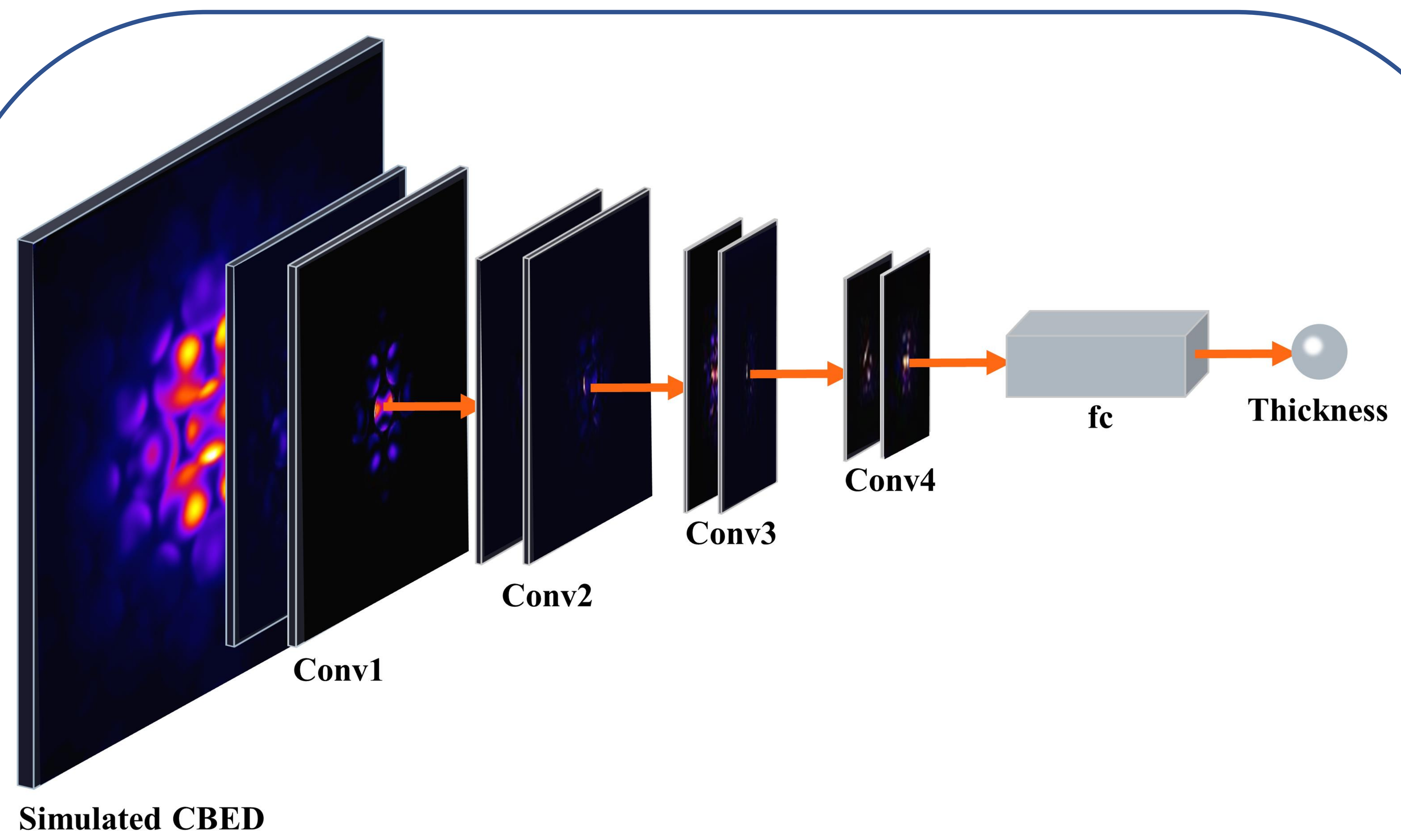
Thickness determination of TEM samples using CBED patterns

Transmission electron microscopy (TEM) is an important technique to study the microstructures of condensed matter from nano to atomic length scale. In TEM investigations, sample thickness is a critical parameter for many applications such as electron energy loss spectroscopy (EELS) or energy dispersive x-ray (EDX). Convergent beam diffraction (CBED) is a simple method to measure the sample thickness in TEM. As shown in the figure, when electrons transmit through the sample, dynamical scattering will modify the diffraction patterns in the far field plane. By comparing the experimental patterns with a set of pre-calculated patterns, the sample thickness could be uniquely determined.

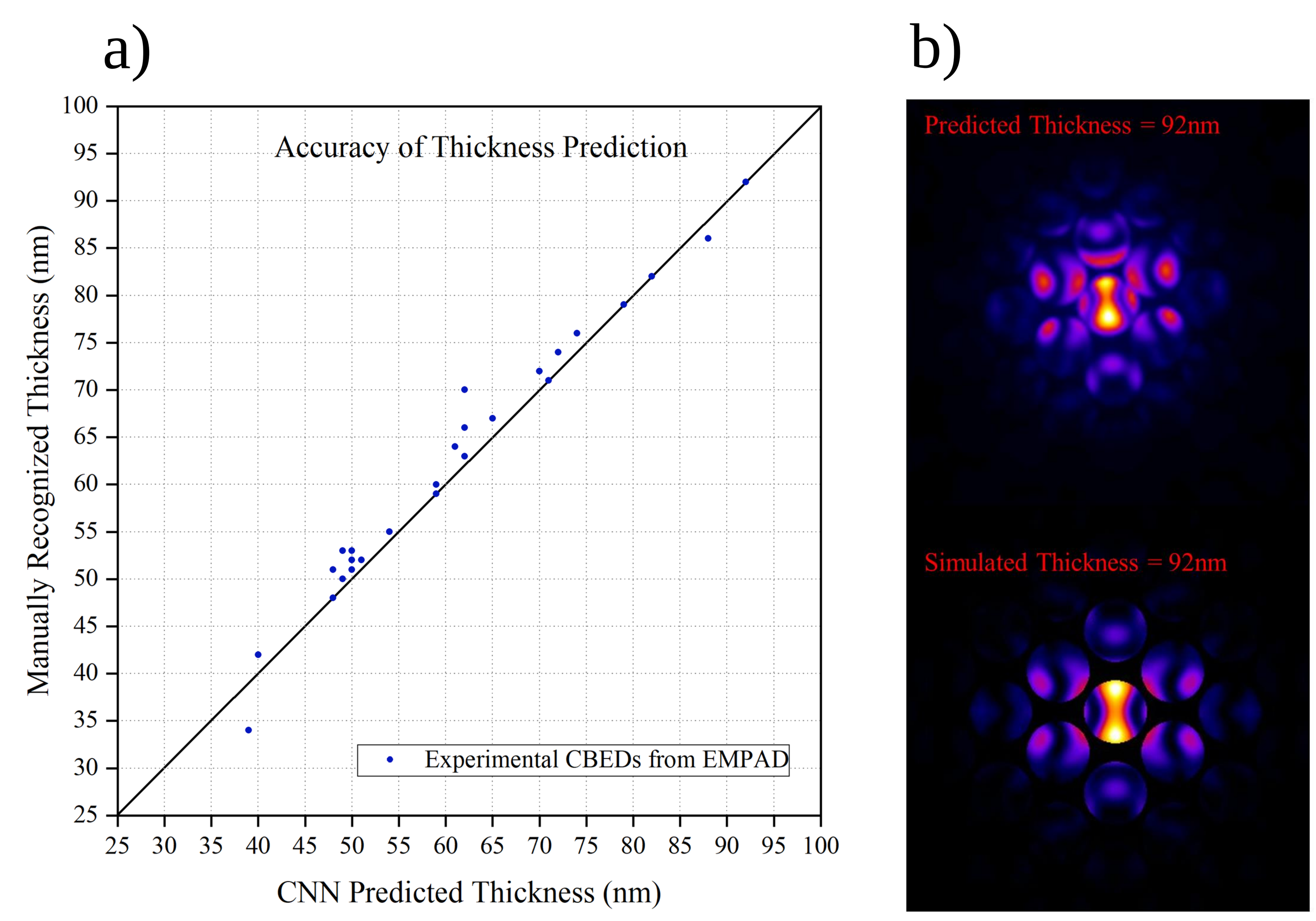


CBED pattern recognition with deep learning

Conventionally, the patterns are matched using naked eyes which is very time consuming and the precision is limited. In this work, we use deep learning to automatically search for the matched patterns to extract the thickness. The speed and precision of the image recognition process are boosted with convolutional neural network (CNN), a synthesis of feature engineering and function fitting.



Our model is modified by SE-ResNet with ensemble learning. A series of simulated CBED patterns with different thicknesses of Silicon [110] oriented CBED patterns are inputted as the training data sets. Local tilt and rotation of the crystal are considered.



The recognition results for experimental CBED pattens for thickness determination are plotted in the figure. The experimental patterns of Silicon [110] zone axis are recorded with EMPAD on Thermal Fisher Scientific Themis Z transmission electron microscope working at 300 KV. Comparing to manual recognition, the recognition by deep learning achieves 85% within ±2nm error. The results clearly indicate that deep learning is a simple and robust method for automatic thickness determination in TEM.

Reference

[1] Hu J, Shen L, Sun G. Squeeze-and-excitation networks[C], Proceedings of the IEEE conference on computer vision and pattern recognition. 2018: 7132-7141.