Data-driven ptychographic X-ray tomography

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The biggest challenges in nano-tomography are long acquisition times and radiation damage, which occurs even in samples such as ICs. With increasing resolution demands, the image acquisition time scales up together with X-ray dose [1]. The resulting radiation damage not only makes tomographic reconstruction difficult, but can also destroy the underlying circuitry under investigation, especially at the transistor level. Radiation damage also violates the tomographic reconstruction models, which assume that the sample under investigation does not change during image capture. If deformations are severe enough the reconstructed data will suffer from artefacts and reduced resolution. With the advent of 4th generation synchrotrons, the optimal utilization of the available photon flux will necessitate smart data collection methods to minimize radiation damage.

We propose a data-driven tomography acquisition scheme to reduce the total radiation dose to at least maintain but ideally improve the 3D resolution. In tomography, the 3D resolution depends on the number of projections acquired to fill the Fourier space of the object [2]. The higher the aimed resolution, the more projections are necessary to fill in the missing frequencies. However, many samples scatter anisotropically, meaning that projections at some angles contain little to no diffraction signal at higher frequencies. This is most evident from samples such as integrated circuits composed of perpendicular connector layers, where scattering is strongest only at two angles perpendicular to the metal-connector direction. The purpose of the data-driven approach is to increase the sampling in the angular ranges that contain the most information for high-resolution projection acquisition. The remaining angular ranges can be sampled coarsely for lower-resolution projection collection, making the overall measurement faster and more dose-efficient. Combination of both high and low resolution projections yield an artefact free tomogram [3].

To validate data-driven tomography we imaged an integrated circuit using ptychographic X-ray tomography [4]. First, we acquired a low-resolution (30 nm) tomogram followed by high-resolution (3 nm pixel size) projection acquisition only at <30% of the sample rotation angles. Both tomograms were combined to reconstruct a data-driven tomogram. For comparison purposes, we also collected high-resolution projections at the remaining 70% of rotation angles. Surprisingly, comparison of the preliminary tomogram reconstructions in Fig. 1 demonstrate that the data-driven method is not only faster but also yields better tomogram quality. The lower resolution and overall quality of the fully sampled tomogram can be directly attributed to the higher radiation dose and the resulting radiation damage of the sample. In this presentation, I will introduce the computational and experimental data-driven tomography approach, followed by validation using sub-10 nm resolution tomography.

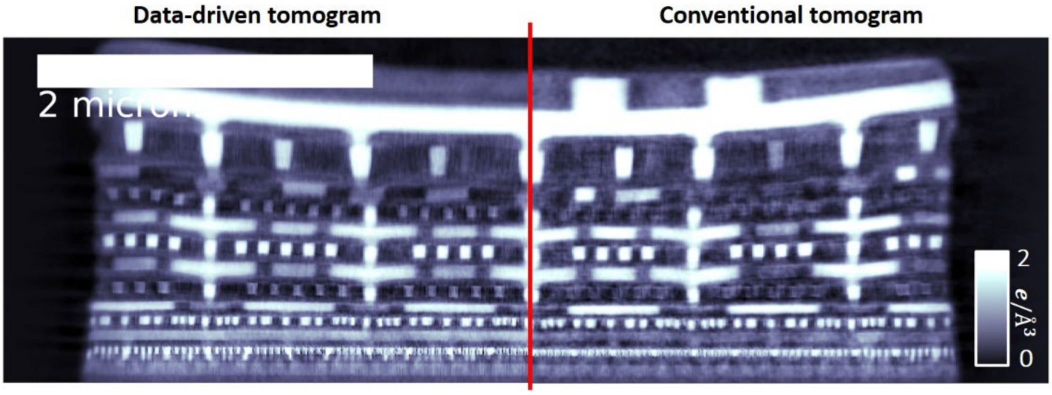

Figure 1. Slice through the reconstructed data-driven and conventional quantitative phase tomograms.

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