MEASURING THE THICKNESS OF MATERIAL LAYERS REMOVED FROM A SAMPLE IN AN ELECTRON MICROSCOPE

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MOTIVATION & PROBLEM DEFINITION

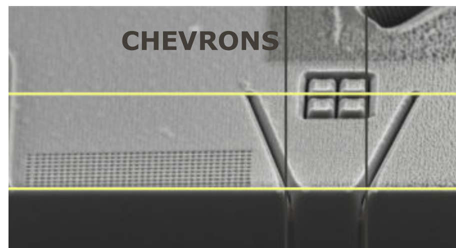
The motivation for this thesis arises from the aim of the Thermo Fisher Scientific company to develop a method capable of measuring the thickness of material layers ("slices") removed from a sample in an electron microscope, which would be more practical from a user point of view compared to the existing methods. Unfortunately, there is no way of how to compare such methods and evaluate their precision, because there is no ground truth. To be able to do so, a ground truth for the measurement must be obtained as well.

Iterative removing of material layers and imaging the sample surface from which the material was removed is a method for destructive 3D sample analysis in the electron microscopy. The methods measure the thickness of such layers by detecting simple features and calculating their distances in the images acquired during the process of material removal. These methods should be both accurate and easy to use. Additionally, it is crucial that the values produced by the ground truth obtaining method, needed for evaluating the other methods' performance, correspond to the real ones.

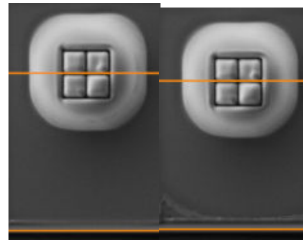
RELATED WORK

So far, there is only one state-of-the-art method for measuring the thickness of removed material layers, lying in carving a chevron pattern into the sample surface and quantifying the slice thickness by measuring the changes in pattern position between consecutive images. Unfortunately, the requirement of carving the marks before the start of the material layers removal adds an extra overhead to the entire process.

Y-SHIFT SEM



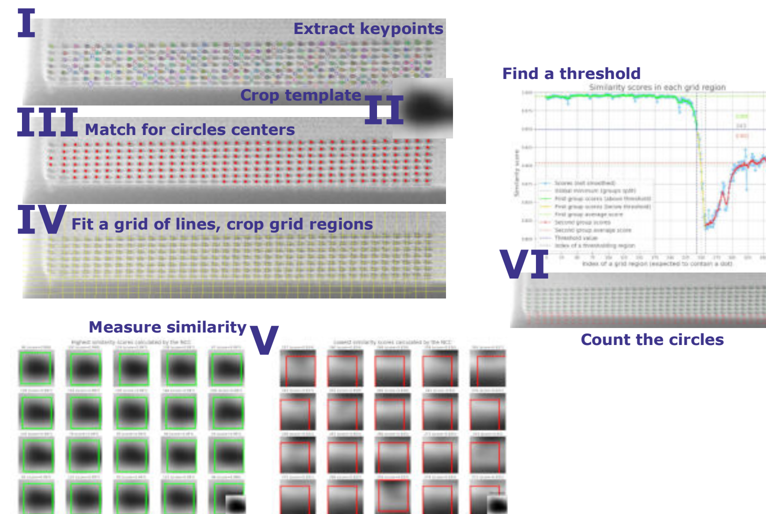
TOP-DOWN FIB



PROPOSED METHODS

This project proposes two new methods, which both measure the slice thickness by detecting features already present on the sample surface, meaning that they do not require any preparation steps. One of these features is the sample edge, at which material layers are being removed, causing a gradual change of its position, and the other one may be any sample feature whose position does not change over time. The resulting thickness is then determined by comparing distances of both features in two consecutive images. The methods differ from each other in the modality of the acquired images.

GROUND TRUTH OBTAINING

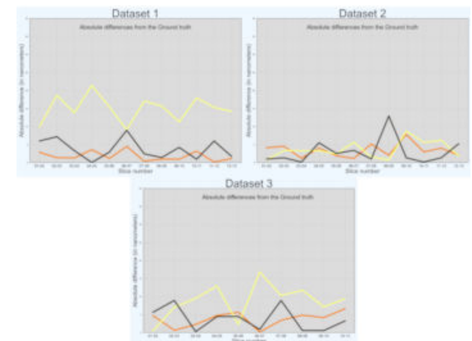


To obtain the ground truth, a pattern of hundreds of tiny circles of a predefined shape is carved into the sample surface near the sample edge, before the iterative process of material removal and sample imaging occurs. In each iteration, a number of circles is removed from the sample surface. By detecting their numbers in each image, the slice thickness can be determined, because the actual distances between the circles in the pattern are known.

EXPERIMENTAL RESULTS

Mean + Standard deviation

Dataset	Ground Truth (A.)	Ground Truth (M.)	Top-Down FIB M.	Y-Shift SEM M.	Chevrons M.
1	40.278 nm ± 4.103 nm	38.131 nm ± 7.794 nm	40.684 nm ± 4.690 nm	39.305 nm ± 15.892 nm	37.517 nm ± 4.063 nm
2	39.410 nm ± 4.393 nm	38.100 nm ± 11.276 nm	41.242 nm ± 4.565 nm	39.600 nm ± 4.519 nm	39.095 nm ± 4.071 nm
3	39.583 nm ± 3.106 nm	39.583 nm ± 5.603 nm	39.410 nm ± 2.390 nm	39.951 nm ± 10.667 nm	36.598 nm ± 3.980 nm



The experimental results show that the Top-Down FIB, one of the proposed methods, measures consistent values, which are close to the expected slice thickness. Also, when compared to the ground truth, it showed a slightly better performance compared to the existing Chevrons method. Furthermore, the algorithm for counting the tiny circular features in image appears to be usable for obtaining the ground truth for the measurement, as it produced more stable results than the alternative method, manually annotating the data.