Retrieving SEM sample positions under limited relocation accuracy using digital image processing

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1 Introduction

For many applications in Scanning Electron Microscopy (SEM), it is of high practical relevance to retrieve selected regions-of-interest (ROI) that were identified in previously acquired images. Examples include investigations of specimen with analysis techniques that require different microscopes or working distances. Tasks like a repeated measurement of a ROI to study changes resulting from intermittently applied sample processing steps motivate high accuracy localization techniques. However, the stage relocation accuracy of SEMs is limited by the stage motorization and position control hardware and relocation errors generally exceed a few microns [1].

2 Objectives

To overcome stage hardware limitations, we have developed a numerical, software-based approach that aligns SEM images with higher than stage relocation accuracy. Our approach is beneficial especially for repeated automated specimen mapping. Its usefulness is demonstrated for imaging the progress of a dry-etching process and for studying the motility of nanofibres.

3 Materials & methods

The software presented here controls stage movement and image acquisition. It combines mechanical and numerical alignment procedures to optimize ROI retrieval. For this, it starts from previously stored ROI location and image data. It then moves the stage to the specified location and acquires a second image. The matching algorithm then searches for coinciding characteristic image features in both images and calculates an affine transformation to connect both image versions [2]. For feature recognition, a Förstner- and a histogram-based approach were studied and implemented [3]. If, due to inaccurate stage relocation, only an insufficient number of features is recognized, image alignment may fail or not reach the desired accuracy. In this case, a 2-4 lower resolution survey image is acquired to obtain surrounding specimen features for matching to the (down-sampled) initial image. For successful alignment, image stitching or iterative stage re-adjustment to maximize region overlap becomes possible. For retrieved ROIs, additional analyses can be performed for multi-channel specimen information, e.g., EDS analysis at large working distance combined with very high resolution SEM at short working distance. Our retrieval procedure was studied for progress monitoring of dry-etching processes and nanofibre motility by acquiring image stacks and differences.

4 Results

The accuracy of numerical image alignment strongly depended on the presence of a sufficiently large number of well-localizable specimen features. The pores of track-etched membranes were well-suited high contrast

features. The resulting alignment quality is shown in Fig.1. It reveals tiniest movements of the nanofibres during successive analyses and excellent alignment of the filter pores. For pore-edge derived image features used by our histogram-based alignment approach for these filter specimen were found to achieve accuracies well below two pixels. Fig. 2 compares a mixture of nanofibers and soot prior and after a dry-etching step and reveals a selective removal of soot.

5 Conclusions

Our approach enables retrieving relevant specimen regions in consecutive SEM analyses and allows acquiring additional analysis data, high-resolution image stitching and identification of specimen modifications caused by intermittent processes. The stage control, image acquisition and alignment software can overcome hardware-related relocation limitations to well below two pixels.

References

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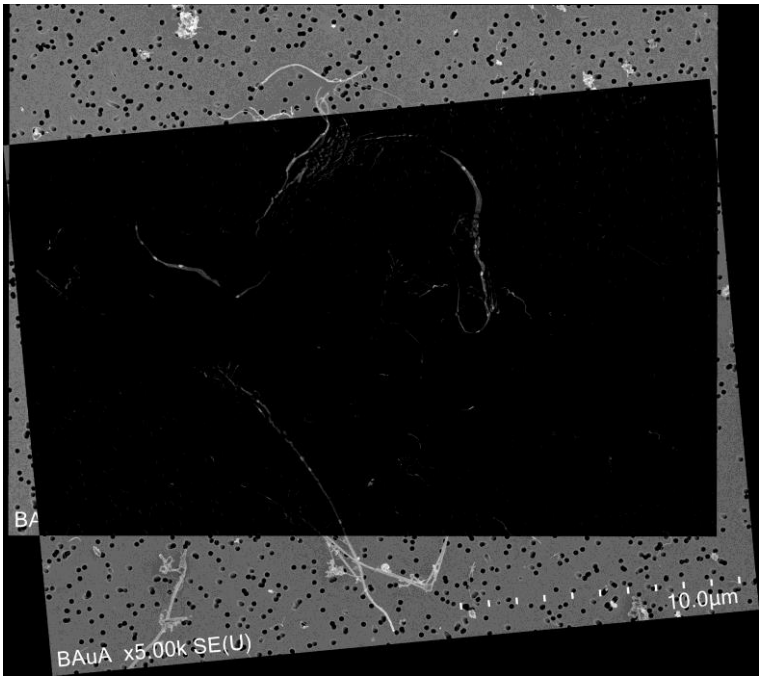

Figure 1: Difference image of two track-etch membrane filter images with nanofibres that were aligned numerically.

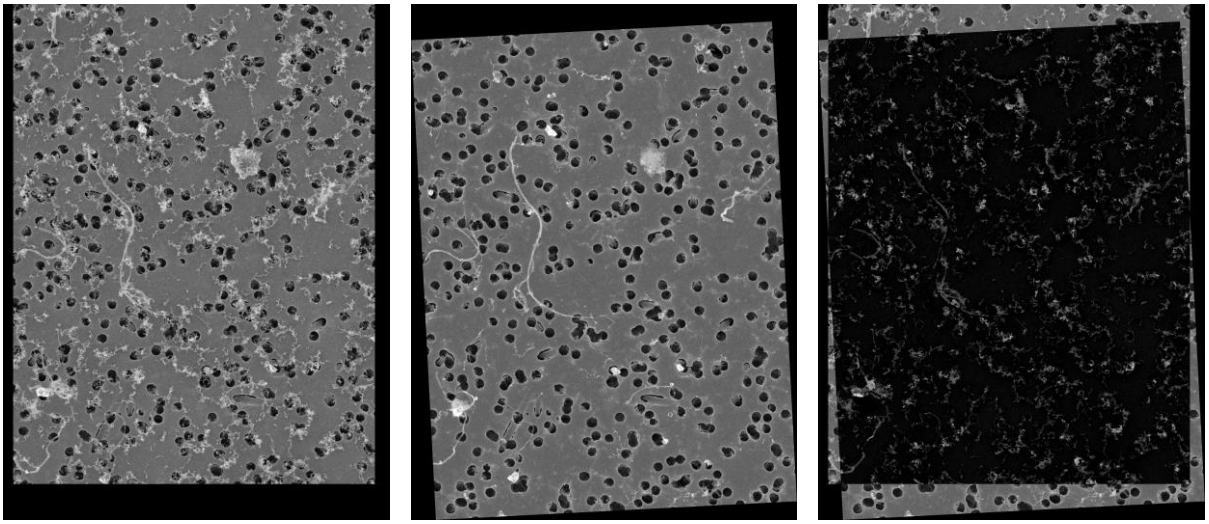

Figure 2: Initial (left) and retrieved (middle) SEM image of a mixture of nanofibres and soot before (left) and after (middle) dry-etching in oxygen plasma. Also shown (right) is a difference image of the two aligned images. The pore diameter of the membrane is about 250 nm.