Advanced Processing for Quantitative Sub-surface Data Extraction

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INTRODUCTION

The TNO Optomechatronics Department is developing various Scanning Probe Microscopy (SPM) techniques, including Sub-surface Atomic Force Microscopy (AFM), as a way to address challenges for non destructive quality control of optically opaque samples. To support the research and technical developments and to extract quantitative data CD metrology on manufactured devices using sub surface measurements, we have developed a user friendly processing toolbox including a broad variety of scriptable image processing techniques. This toolbox enables the extraction of quantitative parameters (like pitch, orientation, width, LER, LWR, OL), from the recorded images.

PRE-PROCESSING

Typical pre-processing includes cropping and levelling. Cropping is performed to select a region of interest. Levelling consists in removing a linear or polynomial trend on the image to flatten it; this can be performed manually or automatically.

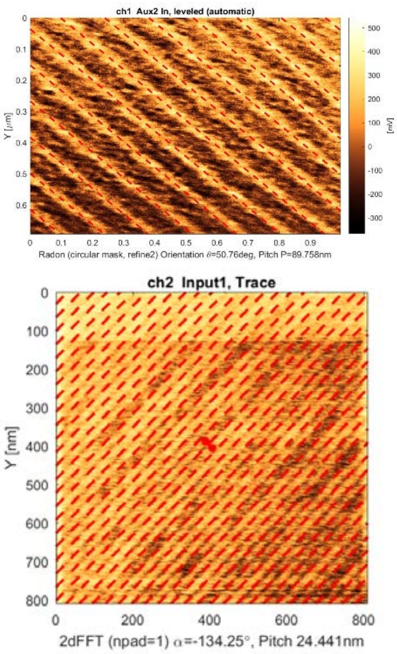

Figure 1. Line pitch and orientation estimation on sub-surface AFM images, using Radon transform (top) and 2D FFT (bottom).

CRITICAL DIMENSIONS

Various methods can be used to determine the pitch and orientation, based on the Radon transform, cross-correlation, 2D Fast Fourier Transform (FFT) and edge detection (Figures 1 and 2). The various methods typically agree within pixel accuracy. The best method to use depends on the number of features in the field of view and the image quality (presence of identifiable edges, signal to noise ratio).

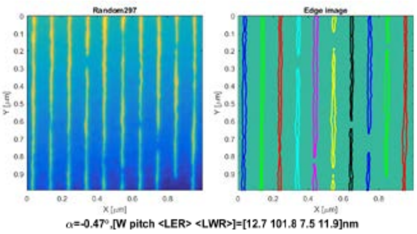

Figure 2. Width, pitch, LER and LWR estimation using edge detection.

In the semiconductor industry, pitch and orientation are typically quite precisely determined by lithographic parameters, hence other Critical Dimensions (CD) are of higher interest for quality control. These include feature width (*e.g.* fin width), Line Edge Roughness (LER) and Line Width Roughness (LWR), which are typically evaluated over surface features (Figure 2).

Another parameter of high interest is overlay (OL), which characterizes the offset/alignment between successive layers. Its measurement requires means of imaging under the surface, and evaluation and comparison of geometric parameters measured on the surface and under the surface. This is achieved by processing simultaneously recorded topographic and subsurface channels (Figure 3).

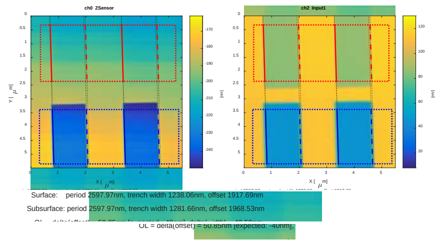

Figure 3. Example of overlay measurement, involving evaluation of positions and critical dimensions in topographic (left image, blue bounding box) and subsurface (right image, red bounding box) channels.

DEFECT INSPECTION

Another relevant aspect of quality control we have implemented in the toolbox is the detection of defects; automatic detection and quantification (Figure 4) facilitates the optimization of industrial processes.

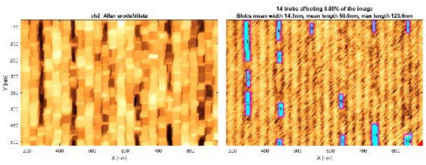

Figure 4. Automatic labelling of defects (right) and an intermediate processing step (left).

NEXT STEP

All the critical dimension measurement considered here are performed in the image plane. The next step is to perform measurements in the perpendicular direction: layer thickness, subsurface feature height and elasticity. We will address this challenge using model based processing.

CONCLUSION

- We have developed a toolbox enabling extraction of pitch, orientation, width, LER, LWR, OL.
- The processing can be automatized to include pre-processing, automatic processing parameter selection and scripting.

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ECSEL Joint Undertaking

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