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IT-14-P-2422 Instrument induced artifacts in scanning probe microscopy.

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In the last three decades, scanning probe microscopy (SPM) techniques have been established as the major way to directly probe the 3 dimensional structure of a sample surface. The images are acquired by accurate movements of a sharp tip (probe) above the sample surface, controlled by a scanning electronic. For topography images van der Waals interaction between tip and sample is generally used as feedback mechanism. The two major classes of topography images artifacts are: the tip-sample convolution resulting in a broadening of the observed structures as well as digitalization artifacts arising from the analog-digital conversion carried out during image acquiring.

In this work, we carry out a detailed analysis of the tip-sample convolution artifacts to topographic image formation in regard of the finite resolution implied by the analog-digital conversation. We discuss possible ways to identify these artifacts and wrote a software module to identify them in obtained images. As shown in Fig. 1, the resolution in the X-Y is limited by the tip-sample surface convolution depending on the geometry of the probe-scan-plane and sample-surface-plane. Commonly, the real tip-sample contact occurs on the tip side and not at the tip apex. Furthermore, the tip scans over the surface and the microscopy converts the obtained analog signal to a digital image with a certain number of points. Hence, the lateral resolution depends on the number of points for a given scan size as illustrated in Fig. 2. As illustrated in Fig. 3, for a small enough pixel size, the tip-sample convolution dominates the maximal obtainable resolution as the real contact point is not the tip apex. Furthermore, the tip-sample convolution in conjunction with the finite pixel size results in an interpolation of the surface, which is shallower than the real surface feature and is determined by the tip geometry.

We implemented a software module in the free SPM software Gwyddion that analysis the sample surface inclination in regard of such sample-tip convolution gradients. By assuming a certain tip radius and tip slope, we mark areas in the obtained topographic image, which are most likely exhibiting the wrong topographic information. The artifact analysis allows a better understanding of the instrument or acquisition parameters, i.e. tip radius needed to obtain artifact free images (e.g. use of super sharp tips), inclination of scan/surface planes, number of points needed for a image, or dynamic scanner range.

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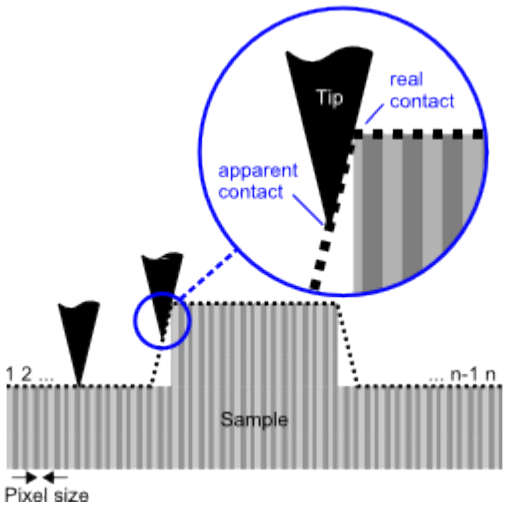

Fig. 1: Illustration of tip apex /sample surface geometry convolution. The black line shows the surface profile obtained due to the convolution.

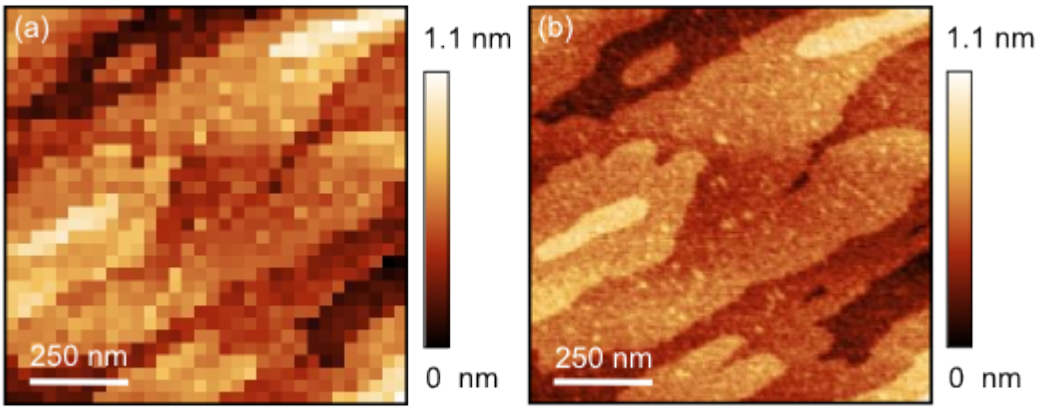

Fig. 2: AFM topography images of InGaAs surface in the same area scanned with (a) 32 X 32 pixels and (b) 256 X 256 pixels.

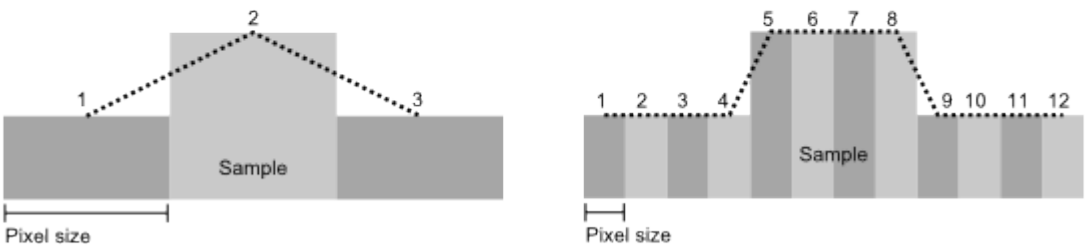

Fig. 3: Illustration of a profile interpolation resulting from the pixel size.