On the influence of sputtering in determining the resolution of a Scanning Ion Microscope

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The determination of the quality of an imaging system is not an easy task, for in general at least three parameters, strictly interdependent, concur in defining it: resolution, contrast and Signal-to-Noise Ratio (SNR). The definition of resolution itself is elusive, and the case of Scanning Ion Microscopy (SIM) is complicated by the damage of the sample under the ion beam. Several studies exist in which this phenomenon is studied and/or simulated, but the effect on the resolution is still to be satisfactorily stated [1, 2]. It appears that for small features ($\sim nm$) it is determined by the competition between sputtering and Secondary Electrons (SE) production. This is indeed the case of most FIB systems, which exploit beams of Ga^+. The only way to overcome this limit is thus exploiting sources of low mass ions, such as H^+ and He^+ [3].

We have already proposed a method to quantify the accuracy with which a feature in a micrograph can be measured, which considers the effect of the sputtering [4]. The idea is that two different uncertainties must be taken into account. The Information Uncertainty (IU), which depends on the amount of collected SE ($IU \propto 1/\sqrt{N}$, where N is the number of counts), decreasing for increasing scan times. The Sputtering Uncertainty (SU), arising from the geaometrical changes, which increases for increasing scan times. The main difficulty is that standard statistics can not be performed on traditional SIM images, since the same sample can not, in principle, be observed more than once. It is possible, however, to calculate a theoretical measurement error based on the noise level in the image and on the knowledge available for the feature in the object.

In this paper we apply the method to different target materials and different ion energies, in order to make a further step towards the optimisation of the use of FIBs for different fields of interest (general purpose imaging, feature measurement, feature recognition). It appears that the evolution of a feature under ion bombardment can be of two different types (or a mix of them): fading and shrinking. While the fading only affects the ability of observing small features, since it limits the collectable SNR, the effect of shrinking is more subtle, for it must be taken into account when determining the accuracy of measurements. Factors that determine the "evolution type" are shape and size: planar geometries will mainly fade (fig. 2), while non planar features, like spheres, can fade or shrink, depending on the size (fig. 1). Eventually, the problem of modeling and predicting the imaging performances of ion machines, based on the interaction of ions and target materials at the nanoscale, will be addressed.

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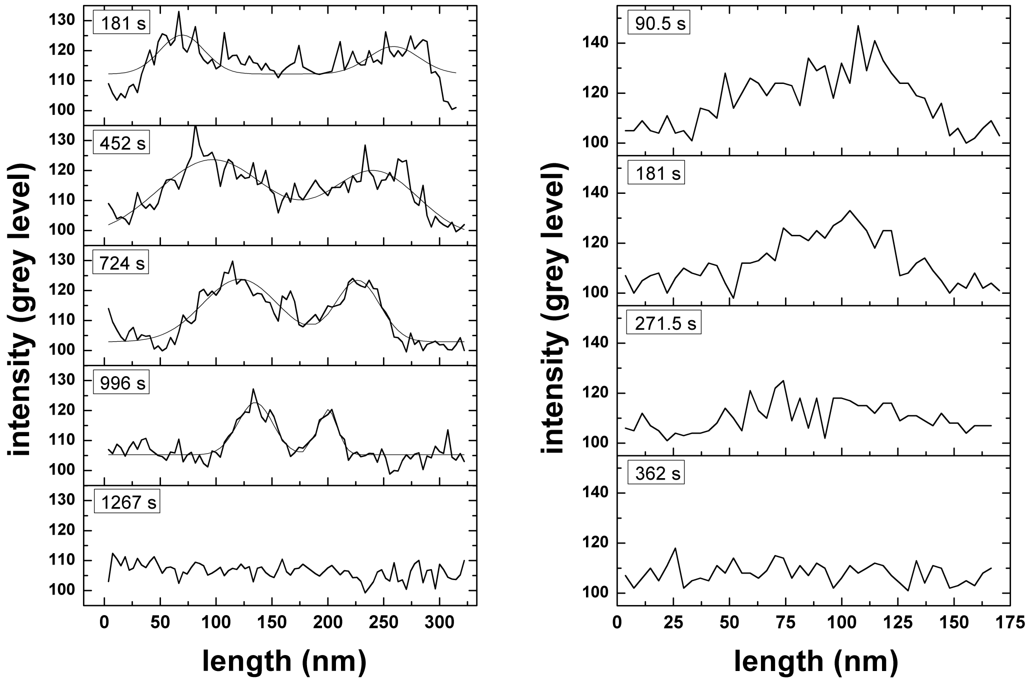
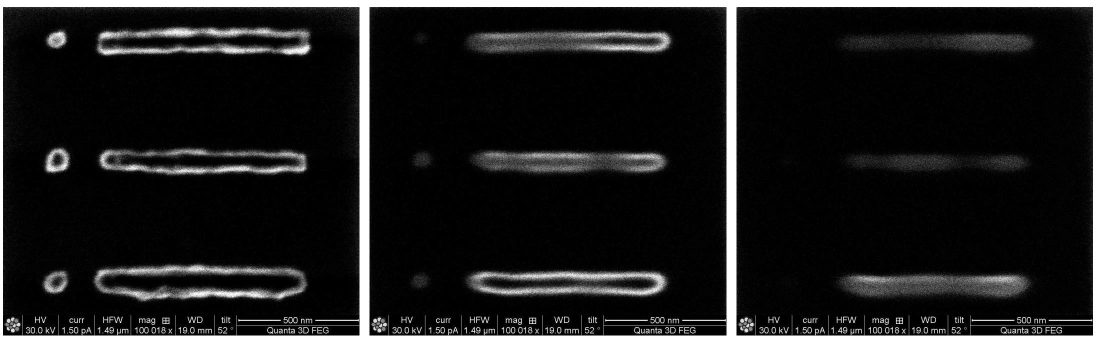


(a) (b)

FIG. 1: Evolution of Sn balls on a layer of C under ion bombardment (I=1nA, V=30keV, M=80kX, t_{scan}=90.5s), shown through the intensity level of the collected signal along a diameter. In this case the sputtering must be taken into account in the evaluation of the measurement accuracy, because the features might shrink. Comparision of fig. 1(a) and fig. 1(b) suggests that the size of the imaged objects also plays a role. In fig. 1(a) the initial diameter is ∼200nm: the profile can be fitted with a double gaussian down to a size of ∼70nm before being covered by noise, and the fade is neglegible. In fig. 1(b) the evolution of a smaller ball is showed (D_{in} ∼100nm): fitting is not possible without noise reduction, but a visual evaluation already suggests that the feature exhibits fading.



(a) (b) (c)

FIG. 2: Scannin Ion (Ga^+) Images: evolution of photoresist lines (thickness ∼100 nm) under ion bombardment (I=1.5nA, V=30keV, M=100kX, t_{scan}=9.2s); 2(a) after 2 scans; 2(b) after 17 scans; 2(c) after 26 scans. It is evident that in the case of planar geometry the features do not shrink, they fade instead; as a consequence, in this case the sputtering does not affect the accuracy of geometrical measurements, while still affects the ability of seeing small objects.