Sputtering limits versus signal to noise limits in the observation of Sn balls in a Ga$^+$ microscope

V. Castaldo* and P. Kruit

Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, the Netherlands

Ion beams are not often used for imaging, because so far Scanning Electron Microscopes have given the best results in terms of resolution and ease of operation. However, the use of ions instead of electrons in scanning microscopy promises several advantages: new contrast mechanisms, larger depth of focus and perhaps higher resolution[1, 2]. Until now, the only reliable ion sources have been the Liquid Metal Ion Sources, which have the disadvantage of damaging and contaminating the sample under observation. Only in the last 2-3 years a promising new generation of ion sources, involving lighter ions, is appearing[3, 4]. There are some theoretical studies which investigate the limitations on the formation of Focused Ion Beam images[5]. Unlike SEMs, in which the limit to the resolution is essentially optical (aberration, diffraction), in the FIBs another fundamental limit exists, due to the continuous removal of sample material (Fig. 1): the amount of information that can be collected for each pixel is limited by the sputtering, which depends both on the sample and ion species.

In this paper, an experimental procedure to establish the limit of a FIB for imaging purposes is proposed. The procedure is based on the observation of the geometrical changes in a Sn-ball sample (balls' diameter range: $<5nm$-$30\mu m$) imaged with a Ga$^+$ beam. The sample is imaged in a dual beam system, with a nominal ion current of $1pA$ (such a low current has been chosen in order to keep the sputter rate as low as possible); the energy of the beam is typically $30keV$. Series of images have been captured with different sampling times (from $6s$ up to $163s$ for a single image) and magnification between $50kX$ and $100kX$. The screen resolution of each image is the highest allowed by the machine (1024x954pp). Each area of the sample has been imaged for a total time of 1000-2000s, after which all the features smaller than 100-200nm have completely disappeared. Plotting the balls' diameter versus the irradiation time (Fig. 2) gives a straightforward visual evaluation of the time allowed for the observation of a single feature before it is "changed into another one" by the sputtering effect. For each particle, the curve, together with the error band connected with the imaging process, gives the maximum value of accuracy that can be achieved for the particle. Once the accuracy is set, a family of such curves for different particles allows the determination of the smallest observable feature, i.e. the actual resolution of the imaging process.

Together with simulations and theoretical studies, the described procedure will be able to confirm the effectiveness of the new ion sources.

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*Electronic address: `v.castaldo@tudelft.nl`

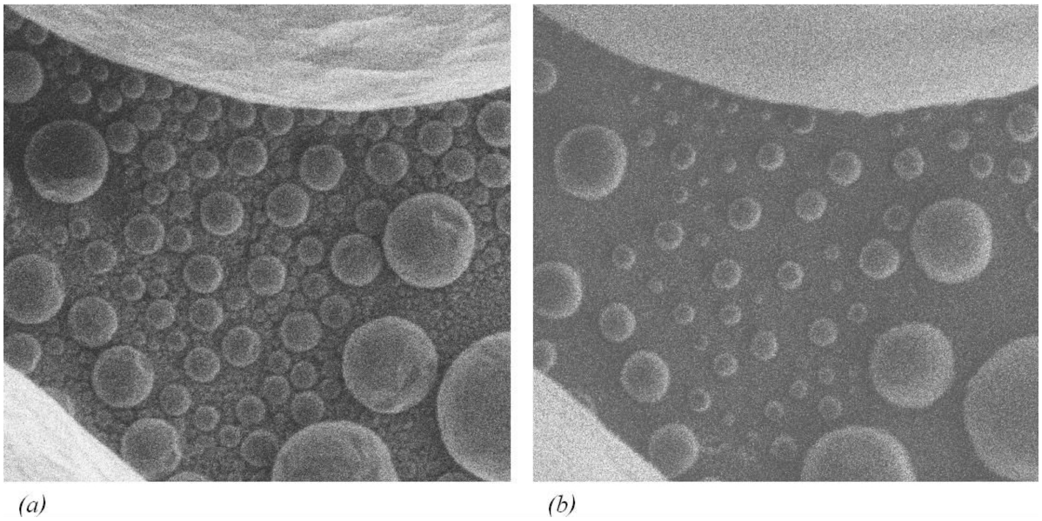

FIG. 1: Comparison between two ion-induced SE images: *(a)* after few seconds of observation, *(b)* after 1500s (*I=1pA, E=30kE, M=50kX*). A smoothing filter has been applied to both images in order to reduce the pixel noise.

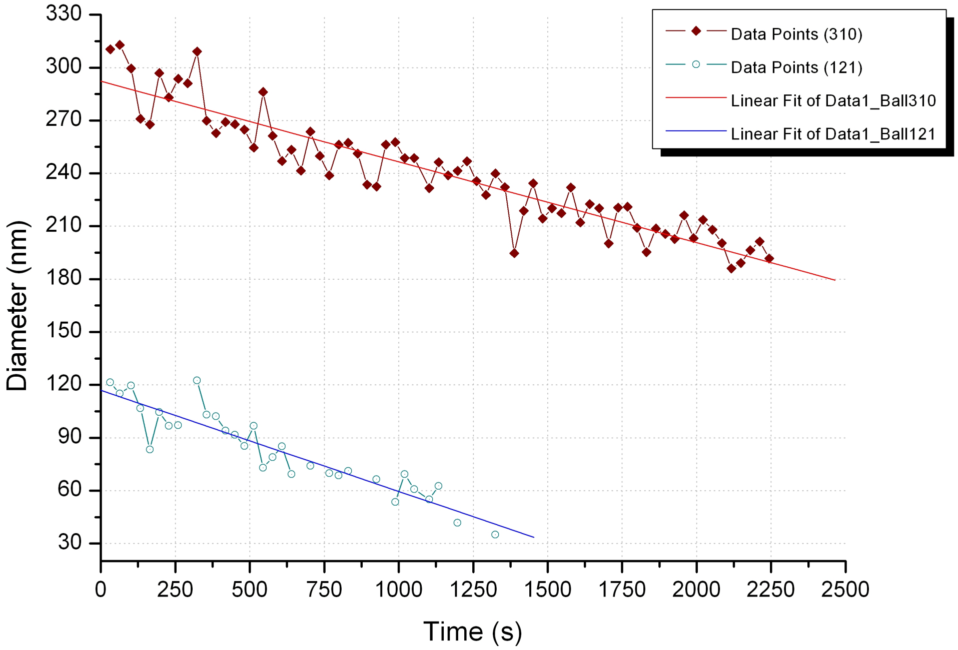

FIG. 2: Balls' diameter versus irradiation time for two Sn balls of initial diameter 300nm and 120nm.