Pitfalls in the Measurement of FIB Beam Size

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Focused ion beam (FIB) resolution is a difficult quantity to measure, partly because of the destructive nature of the beam. For this reason, instead of resolution beam size is often chosen as a metric of instrument quality. Beam size is usually measured by sweeping the beam across a "knife edge" and determining the distance over which the beam current changes from one level (e.g., 20% of full intensity) to another (e.g., 80% of full intensity) by measuring the change in the secondary electron current generated by the ions. This rise distance defines the beam size. Clearly, if instruments are to be compared there needs to be some standard way of doing the measurement. We have found some pitfalls in the procedure that need to be taken into account to avoid errors.

The difficulties that may be encountered in a rise distance measurement come from several sources. One is the effect of statistical fluctuations in beam current when the beam size - and hence the beam current - is small. In a scanned image there are only a few ions in any given pixel that is part of a single line of the image, so if the beam size measurement does not involve averaging over many lines (an image will contain ~ 1000 lines, typically), then by a judicious choice of the data a rise distance as small as ½ (or even less) of the average result may be found. Such a result would give a fictitious picture of the capability of the FIB (see Figure 1). This problem is trivially solved by averaging.

A potentially more serious issue, at least in terms of being able to correct for it, is the effect of the knife edge shape on rise distance results because of the varying secondary electron yield (the well known "edge effect" in SEM). We have found by simulation and experiment that, because the secondary electron yield depends strongly on the angle of the ion beam relative to the normal to the specimen surface, a rise distance measurement can be distorted by the finite radius of curvature of the knife edge. We have found that as the radius of curvature of a knife edge becomes large compared with the beam size (e.g., the FWHM), the measured rise-distance can decrease by as much as 30% compared to the case where the knife edge is small compared to the beam FWHM (see Figure 2). For focused beams of a few nm FWHM, or less, this becomes a problem as the concept of a knife edge with a 0.1 nm radius of curvature is not meaningful. A comparison of experimental results with simulations will be presented and a way of removing this difficulty will be shown.

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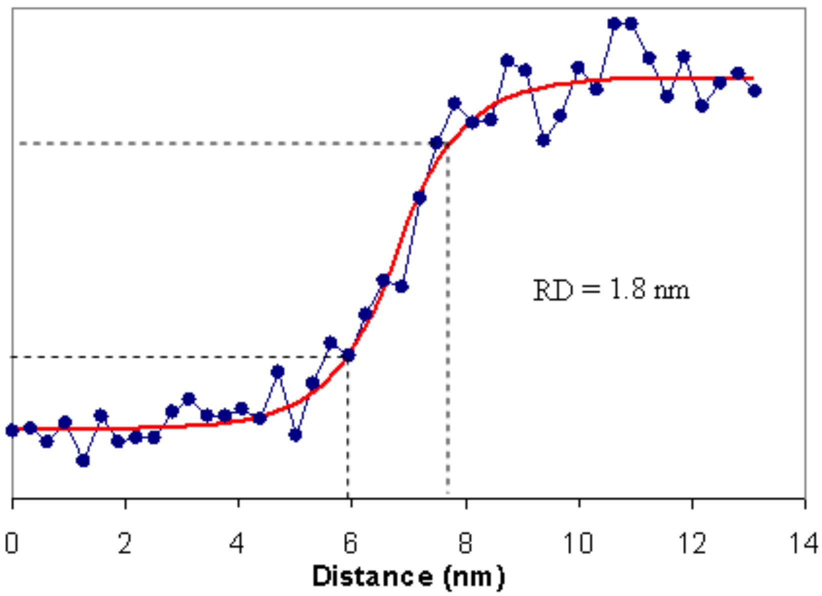

Figure 1. A rise distance measurement taken from a micrograph of a graphite specimen with a 1 pA Ga^+ ion beam. The data represent a single line taken from an image. The smooth curve is a fit to the data and indicates a 20% - 80% rise distance of 1.8 nm. This measurement shows how by careful data selection an unusually good result can be obtained. It was chosen from several thousand that had an average rise distance of ≈ 5 nm.

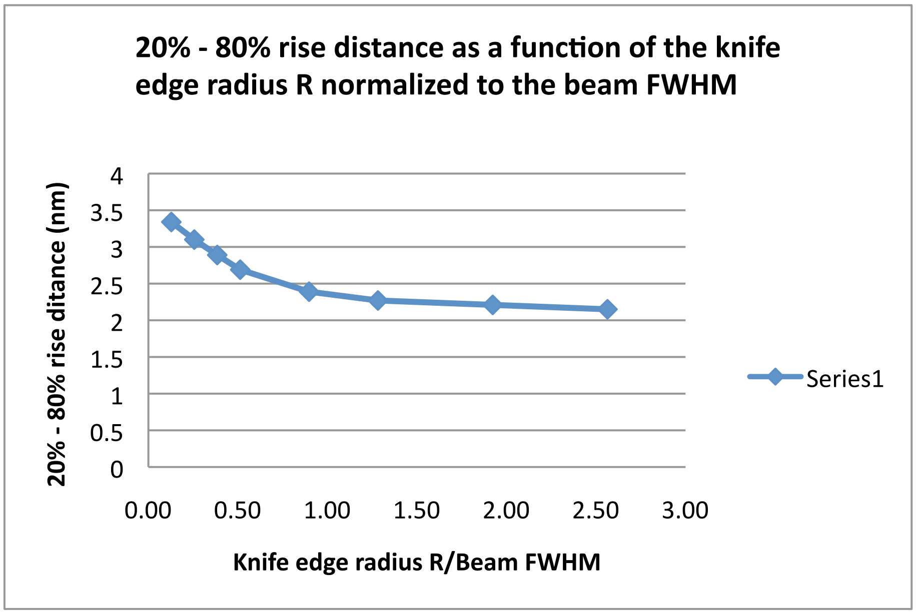

Figure 2. The 20% - 80% rise distance of an ion beam was simulated for a series of knife edges of increasing radius of curvature R (Series 1). The simulated beam had a current density distribution FWHM of 3.1 nm. As the ratio of the knife edge radius of curvature R to the Beam FWHM increased from 0.13 to 2.56, the 20% - 80% rise distance dropped by 36% from 3.3 to 2.1 nm. This points up the importance of having a knife edge that is "sharp" relative to the beam size.