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Where is SEM Resolution Reality in 2006: How do we Measure it and What are the Limits?

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Modern SEM are stated by their manufacturers to have resolution capabilities to sub-nanometre levels, even at low primary electron beam energies. Exciting data from aberration-corrected SEM have recently been reported, with values of 1.0 nm at 1 kV and 0.6 nm at 5 kV published for the JEOL 7700F [1]. Non-corrected field emission SEM performance is also reported to be impressive with operational specifications of 1 nm resolution at 15 kV and 1.7 – 2.0 nm resolution at 1 kV for the current flagship FESEM instruments from FEI, Hitachi and Zeiss (data from company web-sites in February, 2006).

Our experience is there remain a number of difficulties with all of these data. The challenge remains to provide a reproducible result that is meaningful and acceptable from the (practical) applications perspectives and also that has the necessary financial accountability. The latter aspect is increasingly significant.

The resolution measurement is sensitive to a wide variety of factors (fig.1) [2]. A particularly important factor with digital instruments is how the image is colected (fig.2). Some these factors affecting resolution in an image are completely independent, e.g. sample, method and site, but many of the remainder share some degree of independence. This complexity of sources of image degradation commonly leads to debate.

Our study of a number of recent installations supports the repeatedly stated fact that there is an urgent need to develop a robust, generic protocol. Our resolution measurements show, for example, that whilst 'SMART' FFT resolution measurement [3] may yield sub-nanometre resolution values the images show a horizontal fringing of the order of several nanometres. The use of filters will reduce the visibility of the fringing but these filters will degrade the image resolution (fig.2) This specific fringing artefact has now been observed on a number of similar instruments and comprehensive vibration spectroscopy suggests a stage –related problem.

At this point in time there seems to be little definitive evidence for sub-nanometre resolution in SEM at medium to low primary beam energies. This observation is consistent with recent modelling that gives values of informtation cut-off at 1 kV of ~ 2.0 nm for conventional FESEM and 1.4 nm for aberration-corrected FESEM [4], values greater than the reported resolution data.

References

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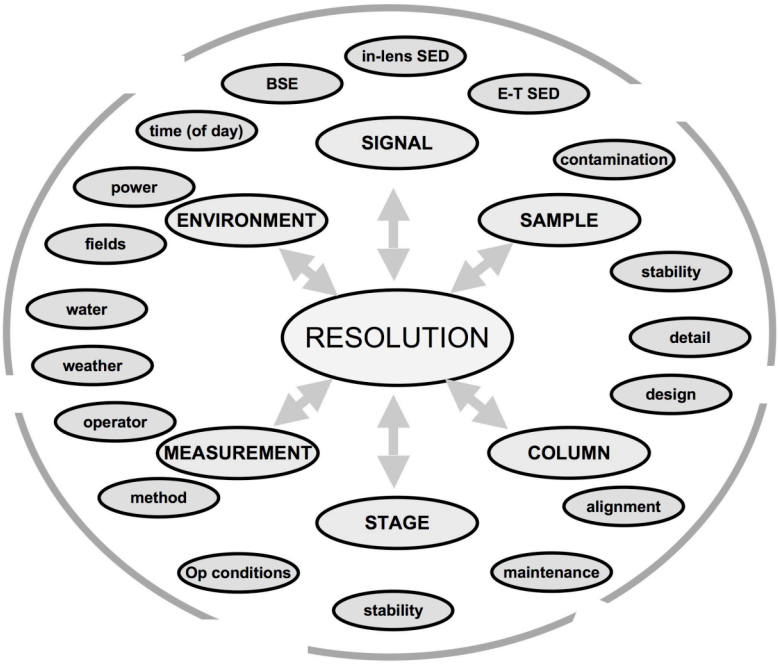

Figure 1: Schematic summary of key factors affecting the 'resolution' of an image. The outer band links associated parameters to the general area

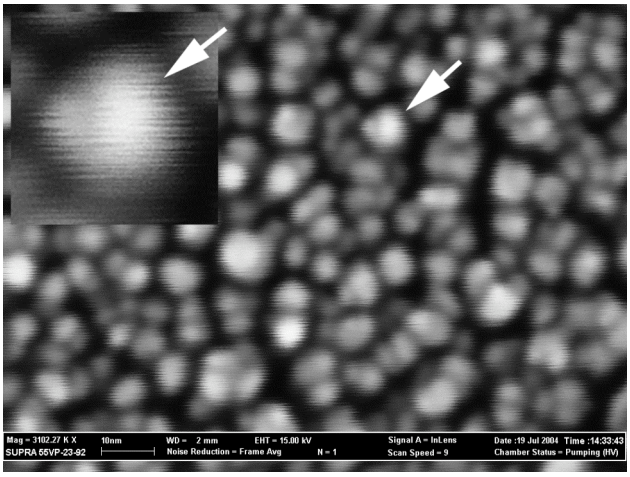

Figure 2(a): Single frame image of a Pt coating at 15kV and maximum magnification showing a 2-3 nm horizontal fringing.

The 'SMART' resolution value is 0.8 nm.

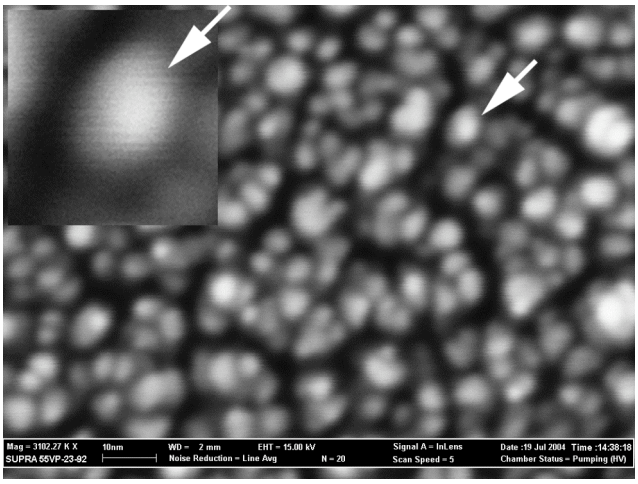

Figure 2(b): A 20-frame line-averaged image of the same Pt coating. Total image collection time is the same as for 2(a). The filtering minimises the fringing but introduces blurring of detail.

The 'SMART' resolution value is 1.3 nm.

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