Gentle Beam: Improving low voltage performance

Latest Innovation in our FE SEMs

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One of the main imaging artifacts generated during specimen observation in SEM is specimen charging. The effect of charging manifests itself either via 'flattening' of the image due to the beam deflection close to the source of charging, or extremely high or low contrast and image distortion. This artifact can be substantially reduced by either application of conductive coating to the sample or by lowering the primary beam voltage. Contemporary FE-SEMs have the ability to produce nm size spot sizes even at 1kV and below, paving the way for high resolution imaging and analysis of nanomaterials and surfaces without the need for conductive coating.

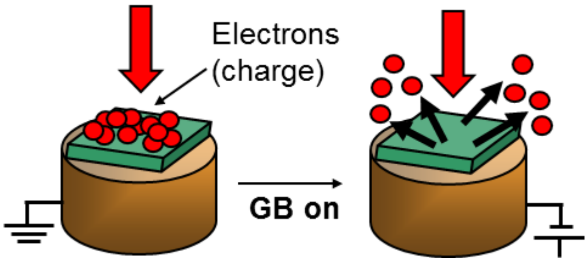

Figure 1: Gentle Beam principle.

In order to further improve FE-SEM performance at low voltages, JEOL employs a beam deceleration function, called Gentle Beam. Fig. 1 shows Gentle Beam mode configuration in JEOL FE-SEM. Beam deceleration not only helps with charge balance but also effectively reduces lens aberrations thus improving overall image resolution. Gentle Beam works by retarding the primary beam voltage using a negatively charged stage bias to a lower landing energy. The landing voltage ($E_{landing}=E_{gun}-E_{bias}$) can be varied with a combination of electron source voltage and specimen bias to achieve the necessary charge balance as well as high resolution performance at ultra-low voltages. The typical values for specimen bias are 0-2kV, though better performance can be obtained with bias values up to 5kV.

Beam deceleration also serves as a form of aberration correction; the aberration coefficients (both spherical and chromatic) are reduced when the ratio $E_{landing}/E_{gun}$ is reduced for a fixed E_{gun}, meaning larger specimen bias enhances image resolution at ultra-low kVs. The use of Gentle Beam function thus preserves all the advantages of high kV imaging (gun brightness, small probe size) with added advantages of reduced charging, reduced specimen contamination and improved surface detail.

Fig. 2 shows an example of polymer crystal imaged at 0.5 kV with and without beam deceleration. The images clearly show that even at 0.5 kV, any surface detail is completely obscured by specimen charging. Application of specimen bias in this case dramatically improves the imaging conditions and allows high resolution observation of the crystal surface.

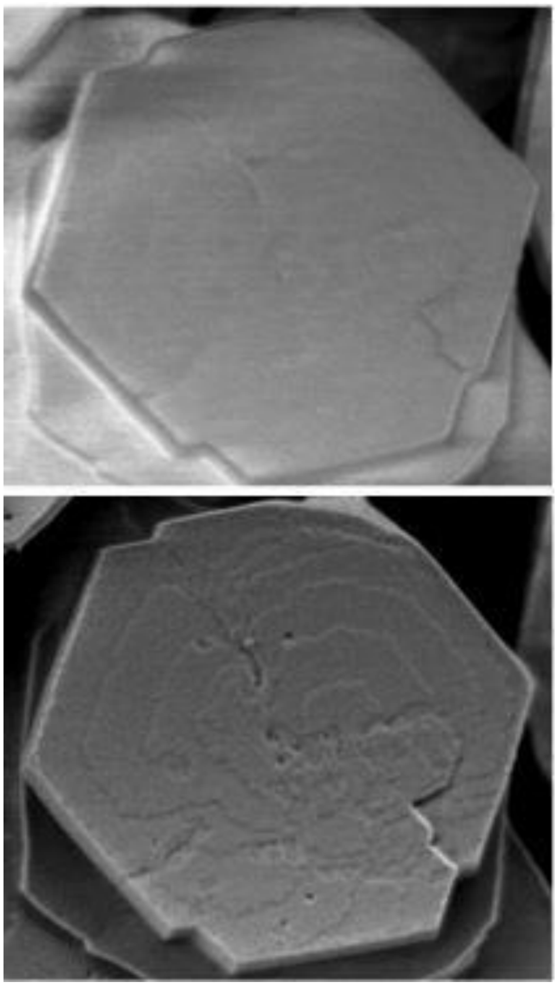

Figure 2: Example of polymer crystal imaged without (top) and with (bottom) Gentle Beam mode.

Several other examples are shown in Fig. 3 – toner particles imaged at 30V, Anopore filter observed at 200V, and graphene sheets imaged at 50V.

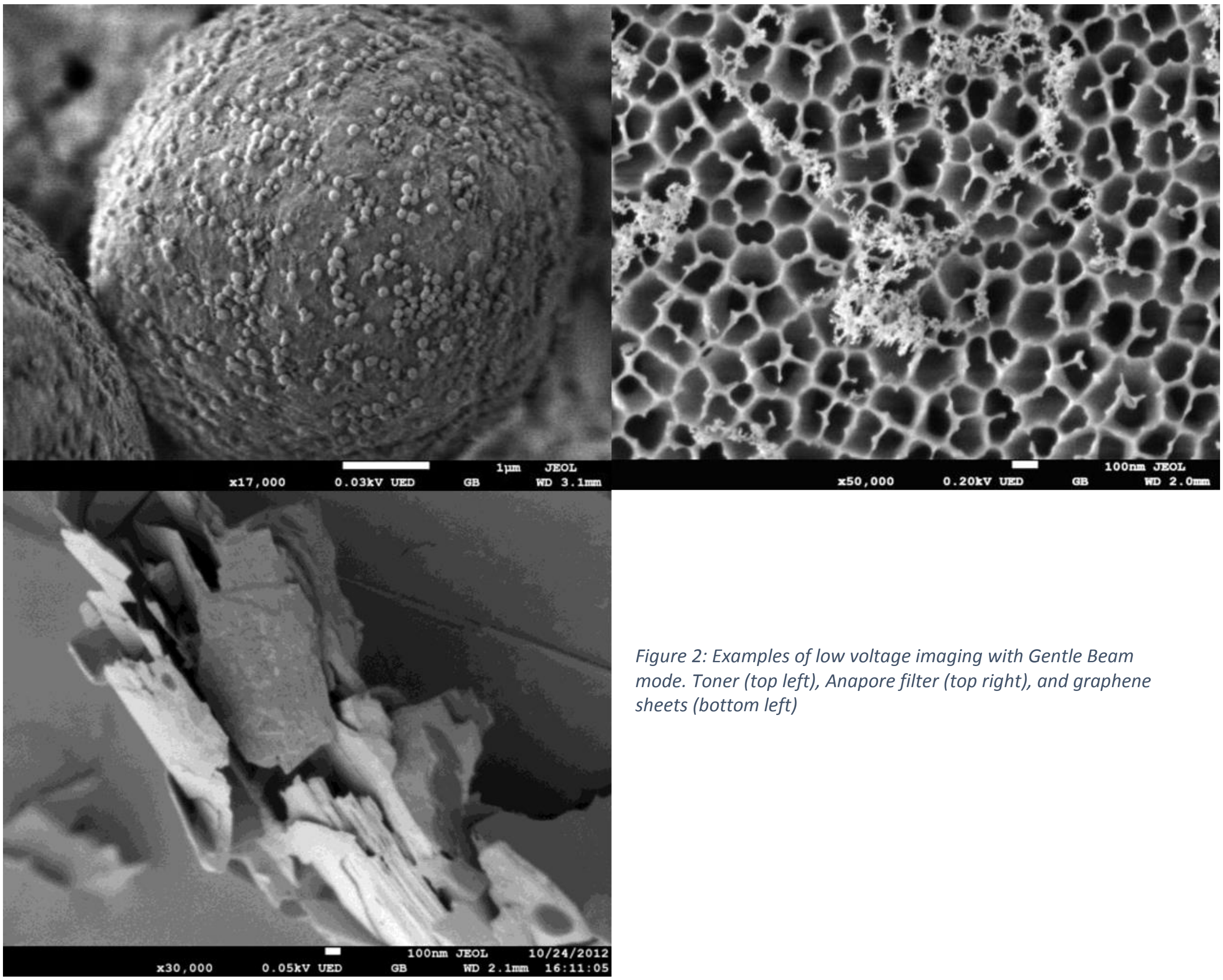

Figure 2: Examples of low voltage imaging with Gentle Beam mode. Toner (top left), Anapore filter (top right), and graphene sheets (bottom left)

Although beam deceleration is an excellent approach when the specimen is relatively small and flat (or comes in a form of a fine powder), it becomes somewhat problematic when the specimen has large topography variations or is tilted with respect to the incident beam. In such cases even small movements across the sample change the characteristics of the localized field created by the specimen bias and will require some operator adjustments of the alignment parameters