A drift measurement tool for TEM/STEM

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Drift is an omnipresent issue in high resolution transmission electron microscopy (TEM), especially aberration-corrected scanning TEM (ac-STEM). Most spectroscopic mapping software incorporates dynamic drift compensation. Various post-processing methods to correct for the shearing effects of drift on serially-acquired images have been developed (1,2). However, the ideal approach is to eliminate the sources of drift, of which there are many (3). The software tool presented here (Drift Measurement), is a script developed for Gatan's DigitalMicrograph software (4). It enables periodic drift monitoring and can be used on any microscope in either TEM or STEM modes, provided a Gatan CCD camera (TEM) or DigiScan hardware (STEM) is/are present. The script can be freely downloaded from the internet (5).

The method works by periodically capturing images from a high contrast, nanoparticulate specimen (Au on C). The drift is measured by computing the cross-correlation between subsequent images. Fig. 1 shows a screenshot of the script in operation. This was taken 165 minutes after switching the microscope (STEM mode) from 80 to 200kV operation. The large change in heat output from the lenses was countered with a reduction in the chiller temperature to keep the column temperature nearly constant. The initially high drift rate arises from stage movement and coarse focusing during setup. After about 5 minutes, these effects die away and the drift rate settles to 1nm/min, declining very gradually thereafter. In this condition the system may be quite usable for imaging/mapping at perhaps 500kx magnification, but atomic resolution work (>5mx), will necessitate overnight stabilisation of thermal and magnetic drift to reach the drift floor (<0.2nm/min).

Fig.2a shows the effect of a temperature imbalance between the holder and the column (instrument drift specification: <0.5nm/min within 60mins of holder insertion). The blue plot (Unbalanced) resulted from a holder retrieved from a vacuum storage station in an adjacent room (4 °C temperature imbalance) and showed large and persistent unidirectional drift due to thermal expansion of the holder in the microscope. Relocation of the storage station to the microscope room, and adjustment of the chiller water temperature to balance the column internal temperature with that of the room, produced a large reduction in drift (Fig. 2a Balanced) with a drift rate of <0.5nm/min within 40mins of holder insertion. Fig. 2b shows the steady-state drift rate many hours after holder insertion where any stage movement/thermal imbalance effects have died away. The red plot shows a sinusoidal component to the drift, fluctuating about zero. Superimposed in blue is the temperature of the chilled water cooling the microscope, which also shows a very small (+/- 0.05 °C) sinusoidal fluctuation. The frequency of the two is identical albeit with a phase shift. The corresponding room temperature variations (not shown), were also cyclic, but of a much longer period, showing that the chilled water temperature variations were driving the cyclic drift. Revision of the cooling system helped eliminate this problem entirely.

This drift measurement tool is an invaluable aid to measuring, understanding and resolving the various issues which can give rise to drift in TEM/STEM.

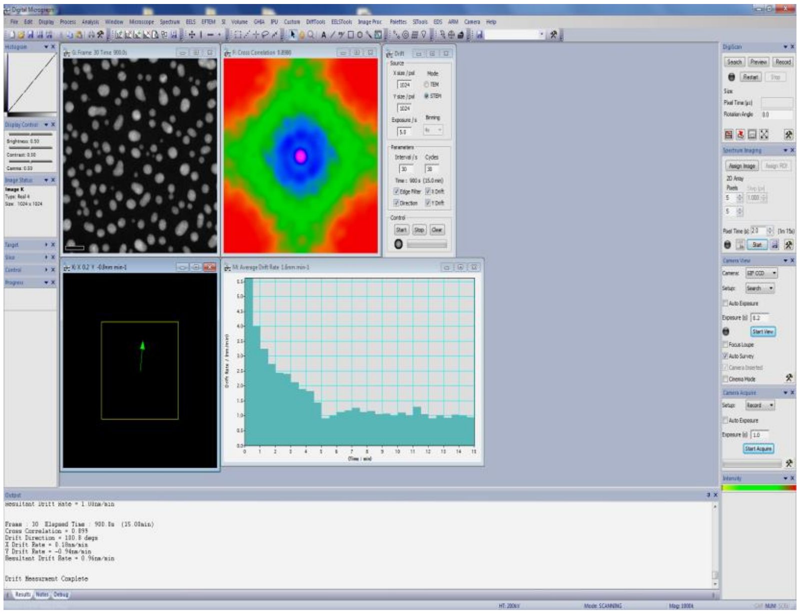
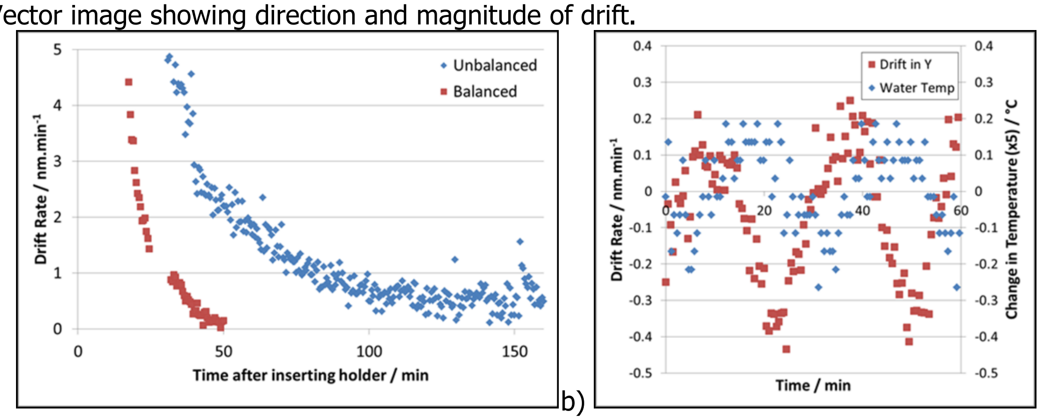


Fig. 1 Screen shot of the Drift Measurement tool in operation (STEM mode, 165mins after switching from 80kV operation to 200kV). Clockwise from top left: HAADF image of test specimen (Au on C); cross-correlation between current and preceding images; Drift Measurement tool; Drift plot over a 15min measurement period (30 measurements). The initially high drift rate (5nm/min) is from stage movement/coarse focusing. After 5mins, steady-state drift (1nm/min) is reached which declines gradually as thermal and magnetic equilibration occurs; Vector image showing direction and magnitude of drift.

a) 

b)

Fig. 2 Effect of various parameters on drift: a) A 4 °C temperature imbalance between the TEM holder and column results in persistent drift for several hours after holder insertion (Blue - Unbalanced). Balancing the holder and column internal temperature results in <0.5nm/min drift within 40mins of holder insertion; b) Microscope chilled water temperature (blue) and instrument steady-state drift (red) have the same frequency (with a phase shift). Chiller modification eliminated this cyclic drift.

References

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