

Supporting information for the paper: *Investigating carbon materials nanostructure using image orientation statistics*

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- Influence of image filtering

The image (76nm×76nm) of the ReL PyC has been filtered using four different filters: the two filters used in this study (the bandpass filter ($\alpha=1$) and the bandpass and angular filter ($\alpha=1$, $\sigma_\theta=50^\circ$)) and two freely available filters, the ABSF (Average Background Subtracted Filter) and the Wiener filter [1-2]. These two filters are available as a script (R. G. Mitchell, v1.3, February 2007) for Digital Micrograph. The parameters for the ABSF and Wiener filter were: Delta=2% , $BW_n=3$ (order of Butterworth filter) and $BW_{R_0}=0.5$ (radius of Butterworth filter in pixels).

Figure 1 shows the unfiltered image and the four filtered images as well as the local orientation and the orientation coherences. It can be seen that the bandpass filter, with $\alpha=1$, has little effect, mainly removing high frequency noise. The confidence maps of the unfiltered image and of the bandpass filtered image show some areas where orientation is badly estimated. These areas are located in the blurred areas of the image and indicate orientations at plus or minus 90° from the horizontal axis (blue areas in the local orientation maps). These orientations are obviously wrong, as in these images no fringes are oriented perpendicular to the preferential orientation plane. The three other filters show similar features: the determination of the orientation seems better as only one or two small areas exhibit low confidence. The last image (bandpass and angular filter ($\alpha=1$, $\sigma_\theta=50^\circ$)) is the smoothest. However it has the advantage to show homogeneous intensity along each fringe.

Table 1 shows that the orientation angles are smaller for the more heavily filtered images than for the unfiltered and the bandpass filtered images (from 10° for the more heavily filtered image to 12.6° for the unfiltered image). Moreover larger coherence lengths are also obtained for the heavily filtered images. The maximum values for L_{cMOD} and L_{aMOD} are obtained with the ABSF filter and the bandpass and angular filter ($L_{cMOD}\sim 1\text{nm}$ and $L_{aMOD}=0.51\text{nm}$) while the smaller values are obtained for the unfiltered image ($L_{cMOD}=0.84\text{nm}$ and $L_{aMOD}=0.46\text{nm}$). Interestingly the Wiener filter give intermediate values ($L_{cMOD}=0.92\text{nm}$ and $L_{aMOD}=0.49\text{nm}$) while its coherence map shows only few areas of bad determination of the orientation.

These results were expected because filtering the image removes the noise and improves the contrast in the blurred areas in which fringes exhibit weak contrast. These areas are also taken into account in the determination of the quantitative parameters; the orientation coherence maps allow reducing the weight of the defective areas in the results but this is not sufficient to obtain the same results whatever the filter is.

It can be concluded that the procedure can be successfully applied to unfiltered and filtered images; however for the sake of comparison the same filter must be applied to all images.

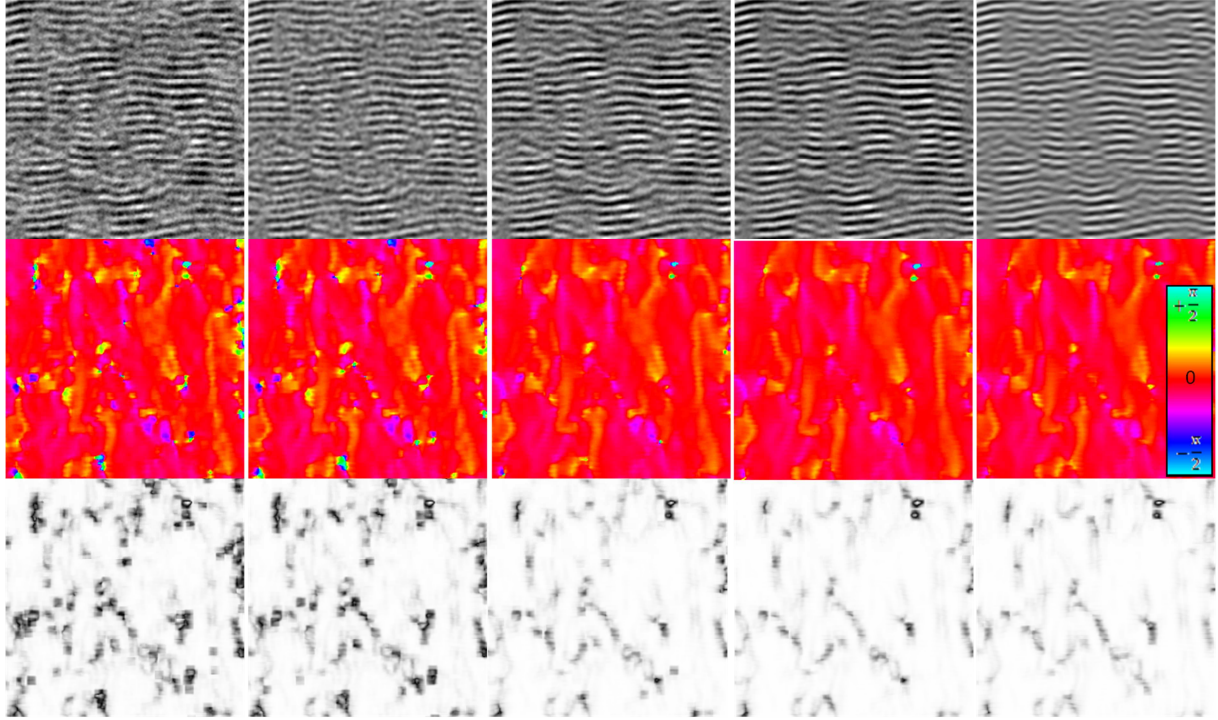


Figure 1: first row, zoom of the HRTEM image (unfiltered, bandpass ($\alpha=1$), Wiener filter, ABSF filter, Bandpass and Angular ($\alpha=1$, $\sigma_\theta=50^\circ$), from left to right), second row, corresponding local orientations and third row, orientation coherences. Images are 9.2 nm width (resolution 0.037 nm/pixel).

ReL PyC (76nm*76nm) image	$L_{cMOD}(nm)$	$L_{aMOD}(nm)$	L_{cMOD}/L_{aMOD}	β_{MOD}°
Unfiltered	0.84	0.46	1.8	12.6
Bandpass ($\alpha=1$)	0.86	0.46	1.9	12.4
Wiener	0.92	0.49	1.9	10.7
ABSF	1.00	0.51	2.0	10.1
Bandpass+Angular ($\alpha=1$,	0.99	0.51	1.9	10.0

Table 1: coherence lengths determined by the Mean Orientation Difference method, ratio L_c/L_a and average orientation angle β_{MOD} for the ReL PyC image unfiltered and filtered with various filters.

References

[1] Kilaas R. Interactive software for simulation of high resolution TEM images. Procs. 22nd Ann. Conf. of the Microbeam Anal. Soc., Kona, Hawaii; 1987; p. 293–300.

[2] Kilaas R. Optimal and near-optical filters in high-resolution electron microscopy. Journal of Microscopy, Vol. 190, Pts 1 / 2 , April/May 1998, pp. 45-51