Dr Mose Bevilacqua and Mr Sufyan Akram
School of Engineering and Computer Science
University of Hertfordshire

Comparative study of the magnetic behavior of Carbon-based materials

Purpose of this study

The discovery of anomalous magnetic and transport properties in Highly-Oriented Pyrolytic Graphite (HOPG) showed that significant research work is still needed to fully understand the basic properties of carbon materials. The study presented here attempts at further elucidating the arising of magnetic properties in HOPG through the application of various types of magnetic fields (MF) to HOPG. X-Ray Diffraction (XRD) and Atomic and Magnetic Force Microscopy (AFM and MFM) are used to monitor HOPG structural and magnetic properties.

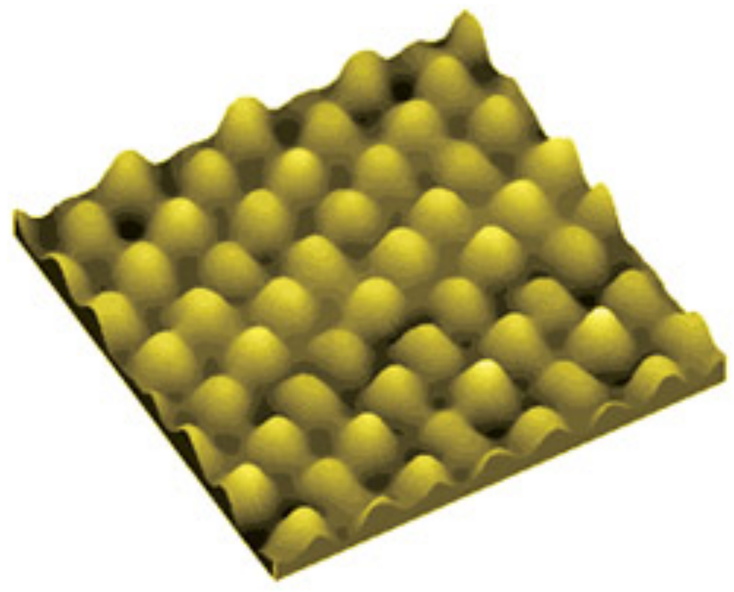

Fig. 1: Atomic lattice of HOPG. Image size: 1.7nm × 1.7 nm × 0.2 nm. Courtesy of Advanced Technology Centre (www.nanoscopy.net) [3]

Experimental strategy

HOPG samples in their as-grown state were exposed to two different types of magnetic fields of different intensities: type A: 4.5 Tesla, and type B: 1.5 Tesla. Structural and magnetic properties before and after treatment were monitored and compared with XRD, AFM and MFM.

Results

Type A MF

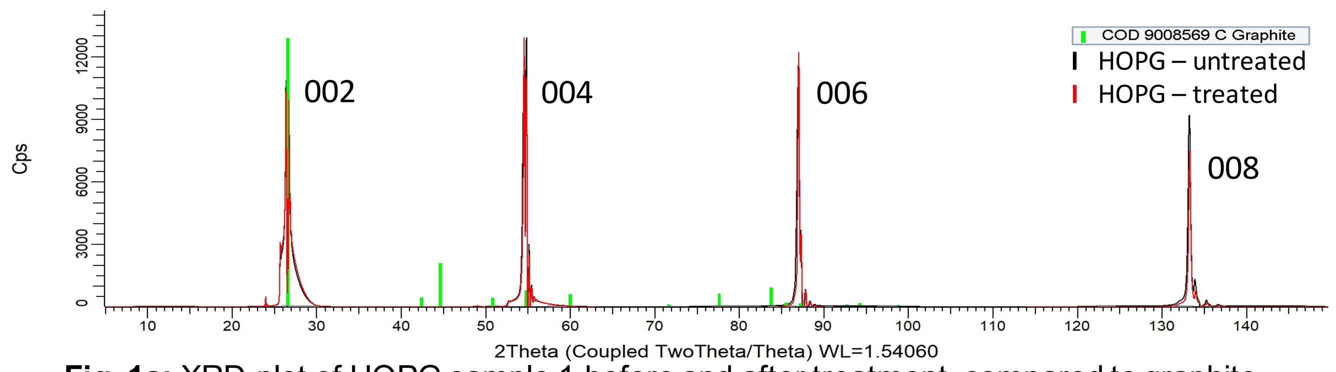

Fig. 1a: XRD plot of HOPG sample 1 before and after treatment, compared to graphite

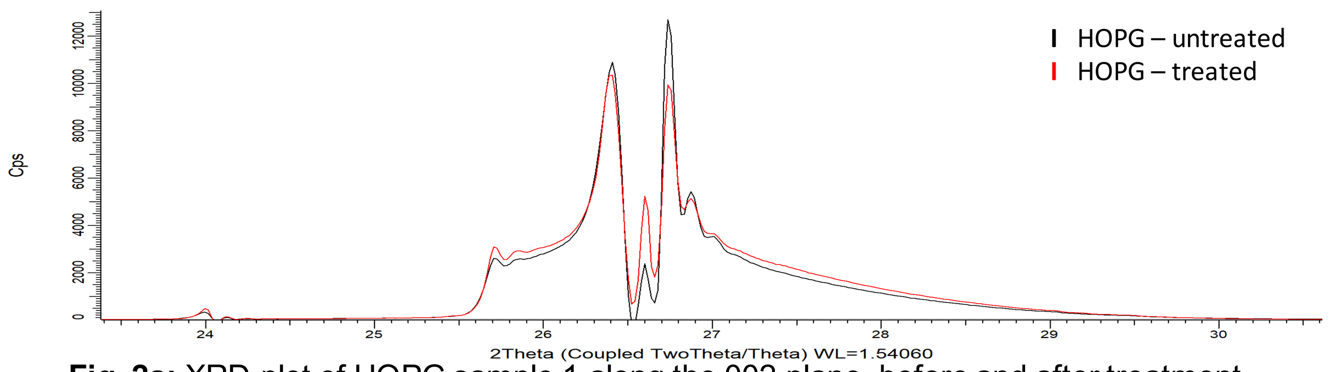

Fig. 2a: XRD plot of HOPG sample 1 along the 002 plane, before and after treatment

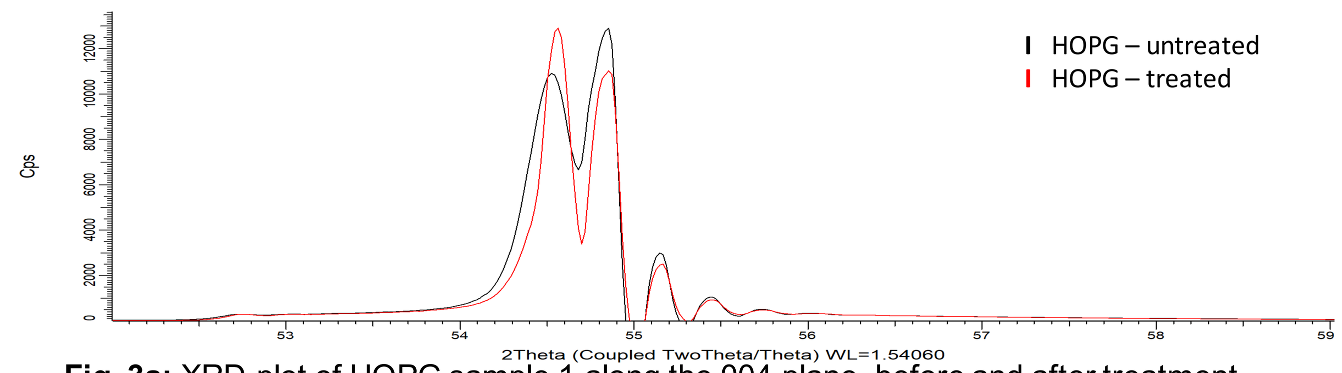

Fig. 3a: XRD plot of HOPG sample 1 along the 004 plane, before and after treatment

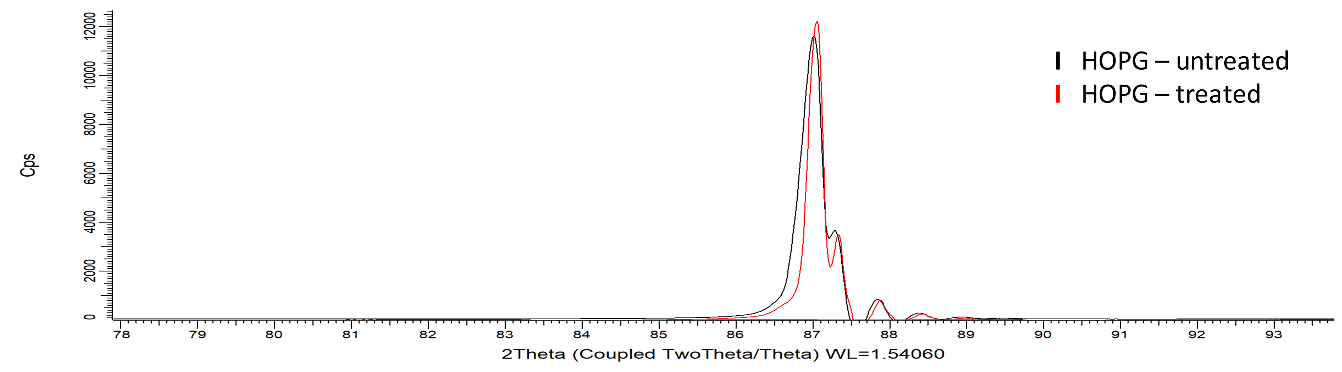

Fig. 4a: XRD plot of HOPG sample 1 along the 006 plane, before and after treatment

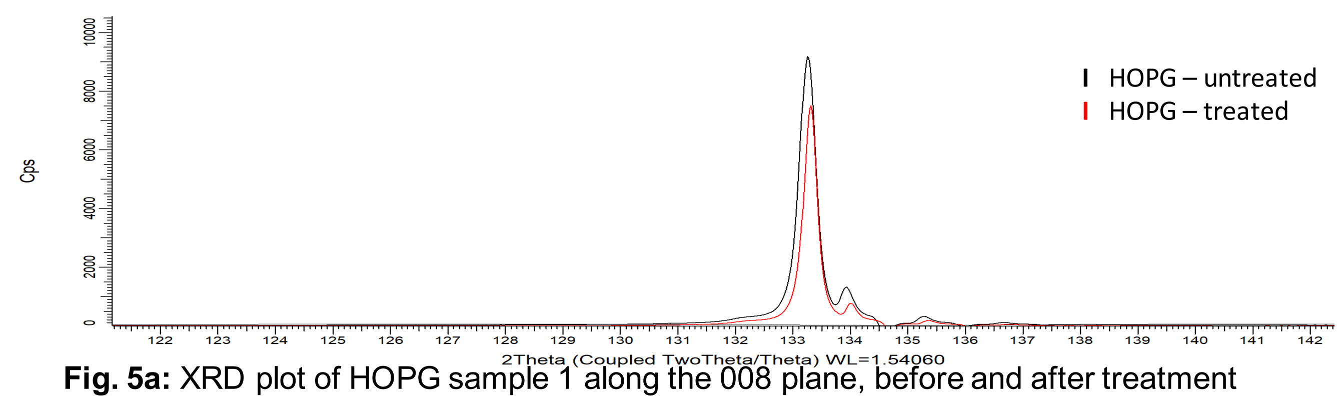

Fig. 5a: XRD plot of HOPG sample 1 along the 008 plane, before and after treatment

Type B MF

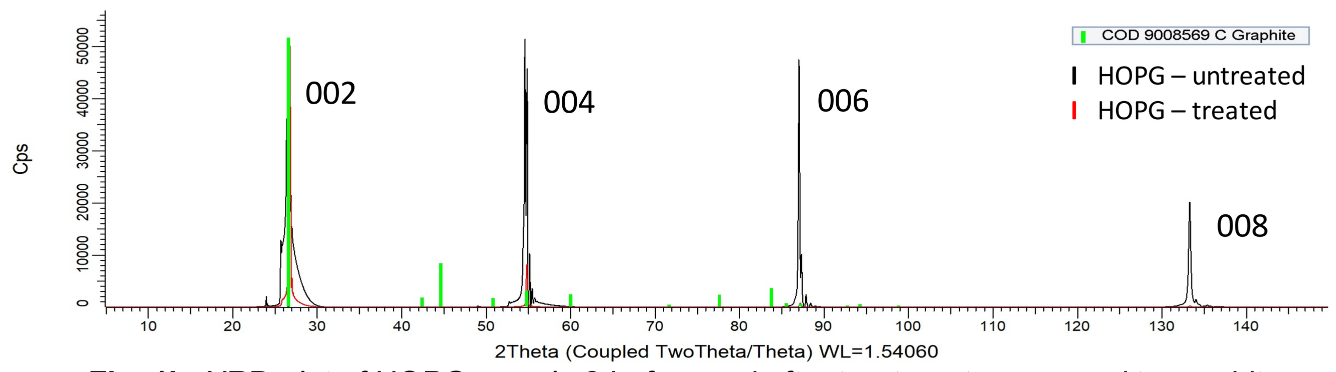

Fig. 1b: XRD plot of HOPG sample 2 before and after treatment, compared to graphite

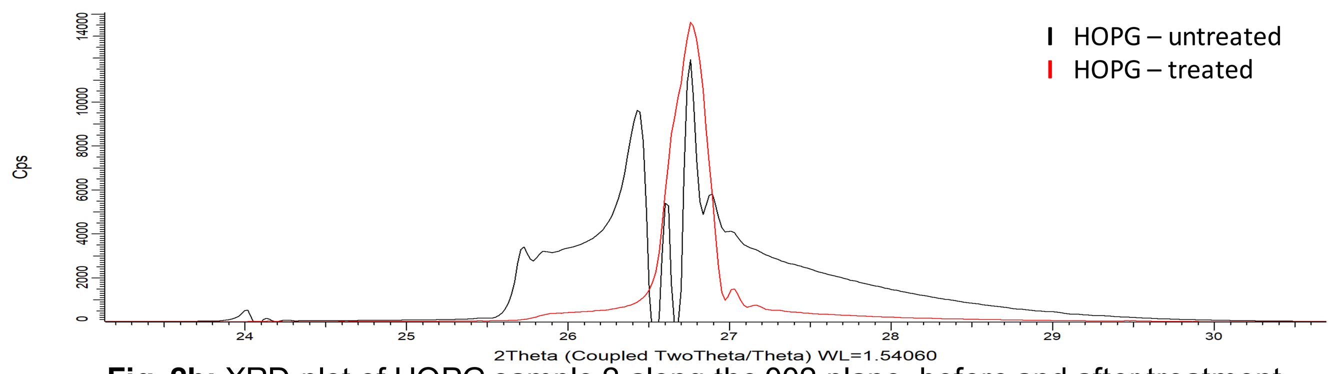

Fig. 2b: XRD plot of HOPG sample 2 along the 002 plane, before and after treatment

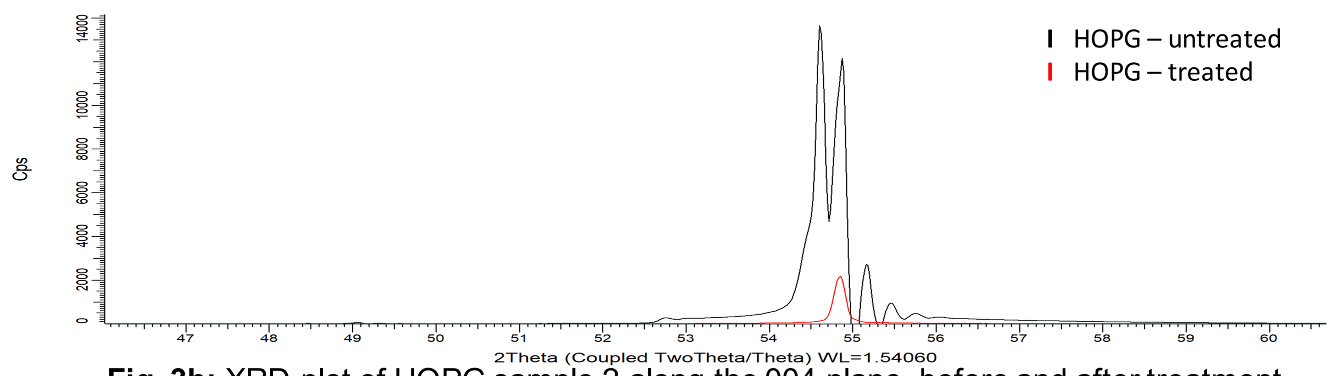

Fig. 3b: XRD plot of HOPG sample 2 along the 004 plane, before and after treatment

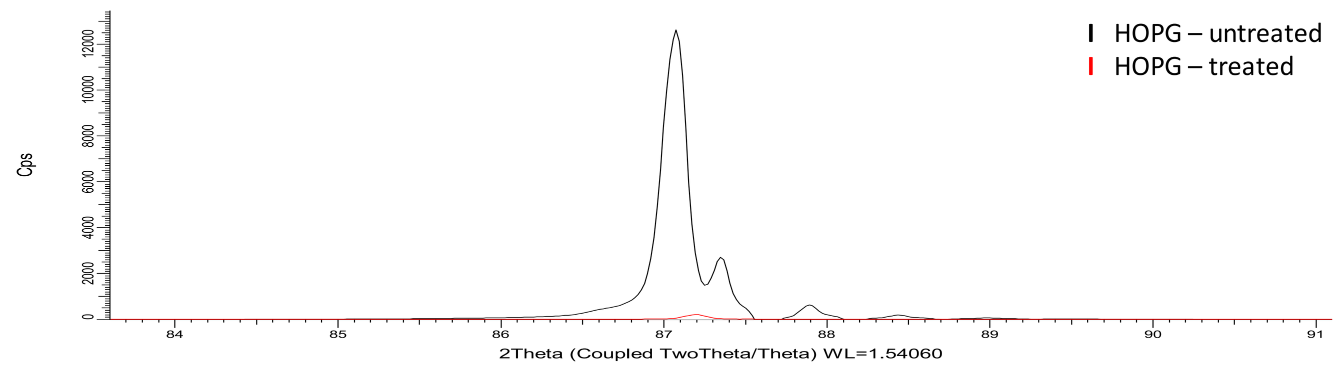

Fig. 4b: XRD plot of HOPG sample 2 along the 006 plane, before and after treatment

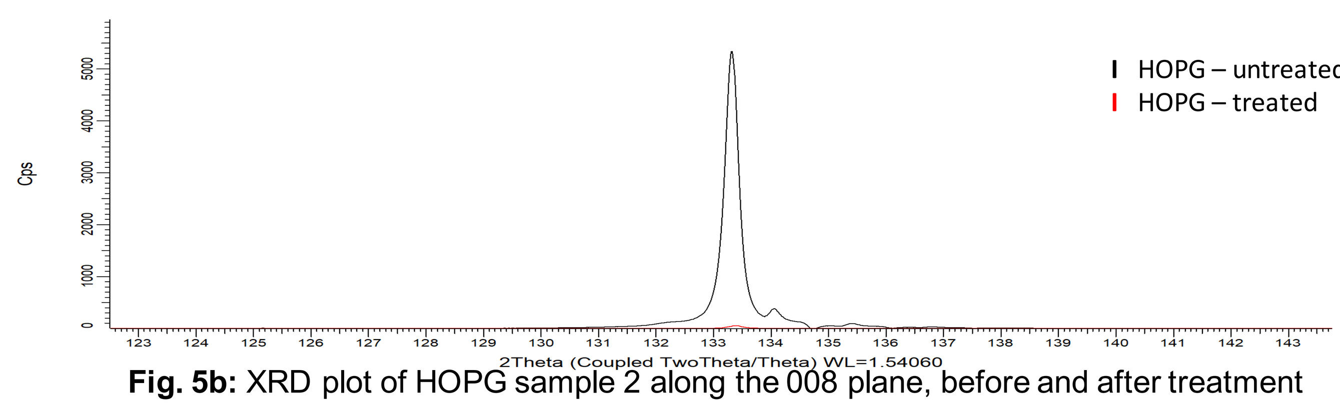

Fig. 5b: XRD plot of HOPG sample 2 along the 008 plane, before and after treatment

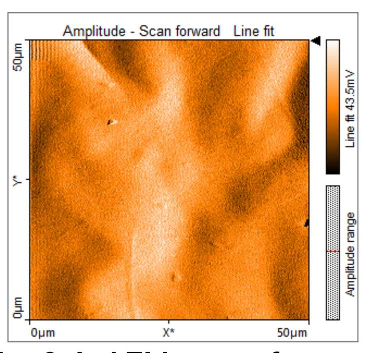

Fig. 6ai: AFM scan of sample 1 in its as-grown state

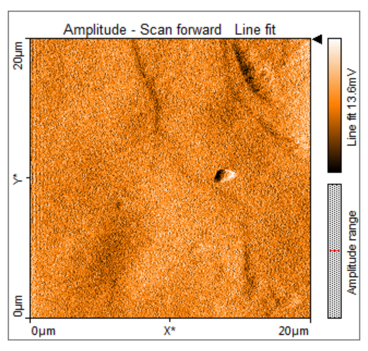

Fig. 7ai: AFM scan of sample 1 treated with type A MF

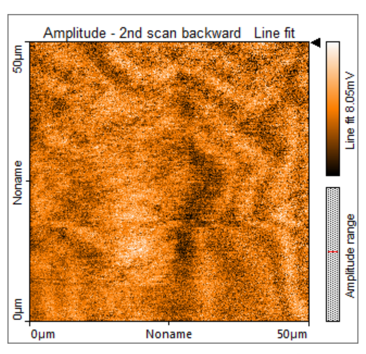

Fig. 6aii: MFM scan of sample 1 in its as-grown state

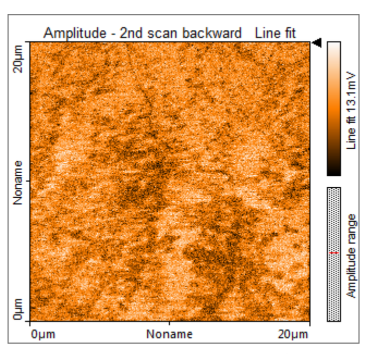

Fig. 7aii: MFM scan of sample 1 treated with type A MF

MFM plots show that the initial evidence of magnetic domains in the as-grown HOPG samples has disappeared following treatment with type A magnetic field, whilst it seems to have become more prominent following treatment with type B magnetic field

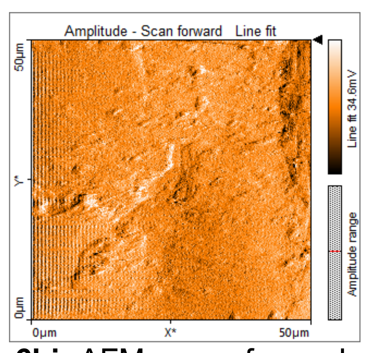

Fig. 6bi: AFM scan of sample 2 in its as-grown state

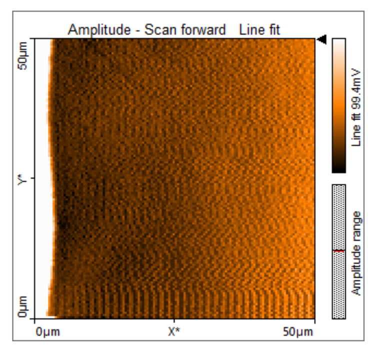

Fig. 7bi: AFM scan of sample 2 treated with type B MF

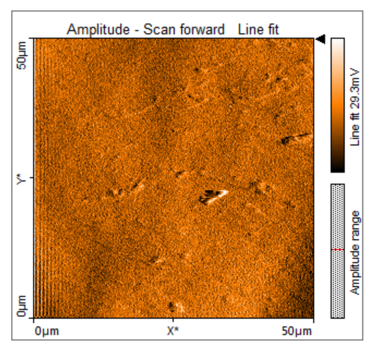

Fig. 8i: AFM scan of sample 2 treated with type B MF

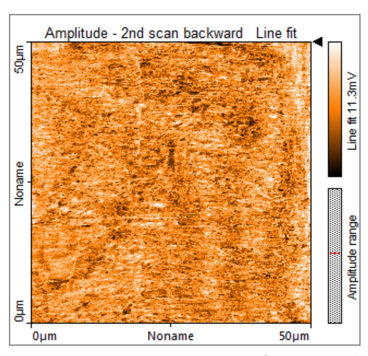

Fig. 6bii: MFM scan of sample 2 in its as-grown state

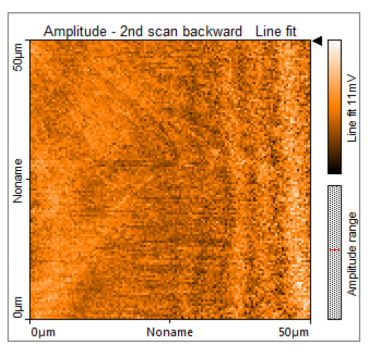

Fig. 7bii: MFM scan of sample 2 treated with type B MF

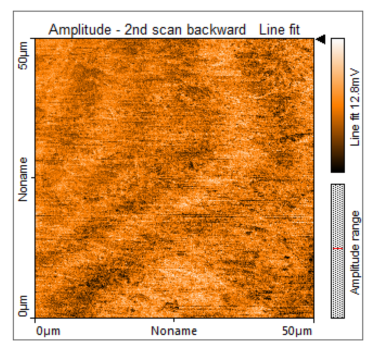

Fig. 8ii: MFM scan of sample 2 treated with type B MF

The initial evidence presented in this work suggest that changes in the preferential orientation of HOPG following magnetic field treatment may be related to changes in its magnetic properties. Research work is currently being carried out to characterize more precisely the mechanisms causing changes in the structure and magnetic properties in HOPG and related carbon materials. Whilst the application of magnetic fields on metals has been documented in detail [1, 2] , the role of such treatment on HOPG needs to be yet fully ascertained.

[1] A. Babutsky, A. Chrysanthou, M. Smelina, J. Stepanov, M. Zietara, Effect of pulsed magnetic treatment on the corrosion of titanium, Material Science and Technology, (2017), vol. 33, issue 12
[2] Akram S., A. Babutsky, A. Chrysanthou, D. Montalvao, N. Pizurova, Effect of alternating magnetic field on the fatigue behaviour of EN8 Steel and 2014-T6 Aluminium alloy (2019), Metals, 9 (9), 984
[3] Advanced Technology Centre, www.nanoscopy.net