Formation of water ice clusters on graphite

Frederik Doktor S. Simonsen, Signe Kyrkjebø, Richard Balog and Liv Hornekær
Center for Interstellar Catalysis (InterCat) & Department of Physics and Astronomy, Aarhus University, Denmark
Prashant Srivastava and Karina Morgenstern
Faculty of Chemistry and Biochemistry, Ruhr-University Bochum, Germany

In cold regions of the interstellar medium (ISM) icy mantles may form on the surface of cold dust grains and act as heterogeneous catalysts for the formation of complex organic molecules (COMs) [1].
In recent years the "onion model", which describes icy mantles as thick layered structures of polar molecules underneath apolar molecules, has been challenged by several groups, e.g. [2][3]. Arguments are made for partly ice-covered grains with exposed bare grain surfaces which themselves are complex and porous structures, stressing the importance of the grain-ice interface. The structure of the grains and their ices will likely impact the COM production as diffusion, adsorption and possible reaction barrier characteristics are influenced [4].

Here we examine sub-monolayer water ice formation on highly oriented pyrolytic graphite (HOPG), using a low-temperature scanning tunnelling microscope (LT-STM) functioning at 5 K. Sub-monolayer amounts of water were deposited onto an HOPG surface kept at ≈ 40 K.
Presented in Figure 1 is an example of water ice clusters grown at 40 K via molecular deposition on the HOPG surface. We argue for diffusion limited aggregation (DLA) [5] growth which is visible from the fractal structure of the clusters, both near step edges and for individual nucleation sites.
DLA leads to low densities and an amorphous and porous structure which with growth may form the reputed amorphous solid water of icy grain mantles.
Finally, water was deposited at varying surface temperatures, offering a unique look into non-heat-treated water ice clusters formed under slightly different, but controlled, conditions.

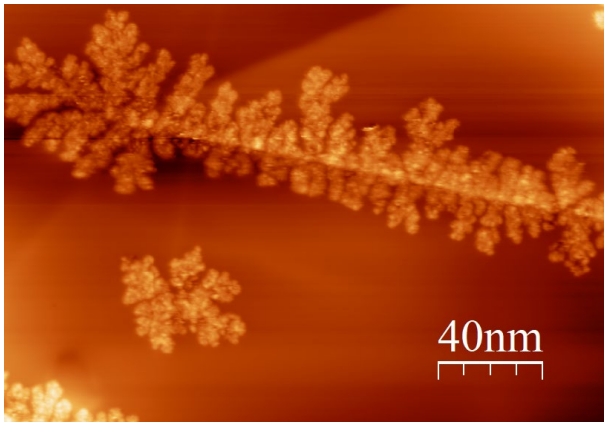

Figure 1: LT-STM image of water ice clusters on HOPG (4.5 V, 15 pA). The image shows a cluster on the terrasse of HOPG and aggregation of water along a step-edge on the HOPG surface.

References

[1] Abplanalp, M. J., & Kaiser, R. I. (2019), PCCP 21(31), pp. 16949-16980
[2] Rosu-Finsen, A., et al. (2016). PCCP 18(46), 31930-31935.
[3] Potapov, A., Jäger, C., & Henning, T. (2020). PRL, 124(22), 221103.
[4] Karssemeijer, L. J. et al. (2013), ApJ 781(1), 16
[5] Witten Jr, T. A., & Sander, L. M. (1981), PRL 47(19), 1400