Observation of molecular layers of dissolved gas at a graphite/water interface with non-contact atomic force microscopy

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The hydrophobic effect has been found to play an important role in diverse phenomena, such as protein folding, lipid aggregation, chemical self-assembly, etc. The hydrophobic/water interfaces have been under intensive study for decades, but the nature of this type of interfaces remains controversial [1].

Here a water/graphite interface is investigated with frequency-modulation (FM) and phase-modulation (FM) atomic force microscopy. We find that gas molecules dissolved in water may segregate and adsorb at the interface to form ordered adlayers. Nucleation and growth processes of the first adlayers are observed. Figure 1a shows bright patches caused by gas adsorption on a graphite surface in water taken with the FM-AFM mode. Figure 1b shows that only flat terraces of the graphite substrate are seen after switching to the tapping mode, and the bright patches cannot be seen. The subsequent adsorption process is found to resemble the layer-plus-island growth mode typically seen in heteroepitaxy.

Some three-dimensional structures have the appearance similar to AFM images of nanobubbles on hydrophobic solid surfaces reported in many previous studies [2]. This suggests that the surface nanobubbles might be soft nanostructures of a condensed state formed through aggregation of gas molecules at the water/solid interfaces. This picture may solve the long-standing puzzle about the stability of nanobubbles [2]. Theoretically, bubbles having a radius smaller than 1 μm are not thermodynamically stable and should dissolve on timescales far below 1 s due to a large Laplace pressure inside the bubbles. However, previous AFM observations indicate that nanobubbles are stable for days. Our work clearly demonstrates the importance for employing high-sensitivity AFM modes to reveal the subtle interfacial structures and to solve mystery at interfaces.

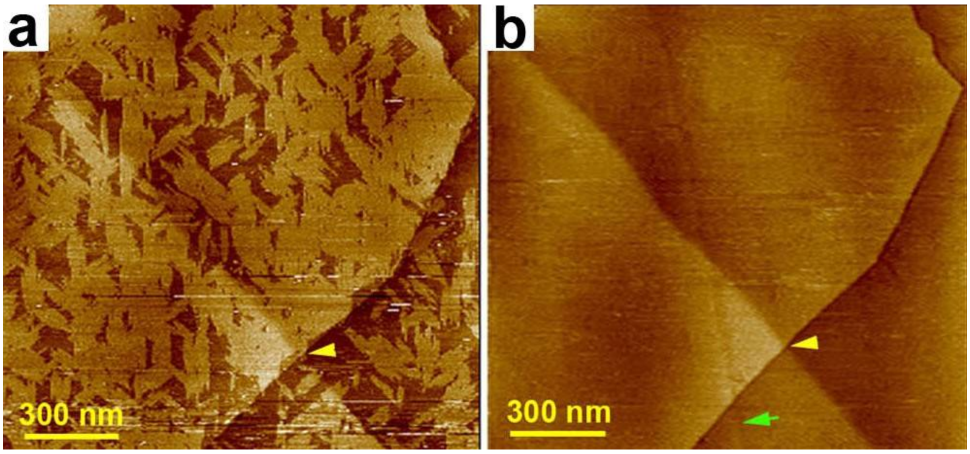

Fig.1 Graphite surface in pure water taken with the FM (a) and the tapping (b) modes.

References

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