AFM and TEM Studies on Nanobubbles

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Boiling is one of the most familiar phenomena and has been studied by numerous researchers for more than a century but its initial stage is still veiled. The very initial stage consists of very tiny gas phases in sub-micron scale and thus it is highly desired to understand the mechanism of their nucleation, stability and interaction for reliable application of boiling. We report our recent progress on experimental investigation of nanobubbles in water by using atomic force microscopy (AFM) and transmission electron microscopy (TEM). To treat the stability of nanobubbles at the liquid/solid interface, we employed the peak force quantitative nanomechanical mapping mode of AFM. Our results showed that the interfacial nanobubbles are prevented from dissolving into water mainly due to the pinning of the three-phase contact line, resulting in the very flat gas phase. The combination of hydrophobicity and hydrophilicity of the solid surface is also found to significantly affect the nanobubbles. For example, on the hydrophobic surface without hydrophilic domains, only a small number of nanobubbles are generated and then rapidly decrease in size, while on the hydrophobic surface with hydrophilic domains, the generation and stability of nanobubbles are enhanced by the hydrophilic domains, with bubbles remaining on the surface for up to three days. On the other hand, TEM is a promising technique for the investigation of the dynamic behavior of nano-world and the liquid cell electron microscopy has enabled the direct observation of nanobubbles in liquid. However, obtained TEM images there give only two-dimensional information, which are not enough for understanding the nanobubbles. We proposed and developed a new method, Fresnel fringe method, which enables us to determine the location of bubble from their two-dimensional images. By using this technique, we could observe the bubble nucleation on the 4-8 nm scale in real-time and found that all of the bubble generation in 600nm-thick water layer were heterogeneous nucleation even on the atomically-smooth SiN surface.

References:

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