Environmental and In Situ SEM/TEM

IM.3.057
Nanoscale Dynamics in Liquids visualized with TEM

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Keywords: in situ TEM, interfacial water, nanofluidics, electron beam tweezers

Nanoscale imaging of frozen aqueous specimens and solid materials with transmission electron microscopes (TEM) has revolutionized our understanding in biological and material sciences. However, there is an ample number of important problems in life and physical sciences that occur only in liquid environments. Therefore, there is an incredible advantage of being able to image nanoscale processes directly in liquids. Recently we have developed a platform for imaging soft materials and biological samples in liquids using TEM (Fig. 1) [1-4]. This platform is also suitable to study liquid properties at nanoscale. Here we show that the properties of fluids at nanoscale dominated by interfacial interactions with the solid substrate surface and drastically differ from the expected bulk behavior. We found that diffusion of nanoparticles in of water is eight orders of magnitudes lower than in bulk. Also flow of water at nanoscale happens in stick-slip manner and not smooth as generally observed for bulk water.

In addition, we will also describe our new all-graphene nanofluidic device that enables high contrast imaging of nanoscale dynamic processes in liquids (Fig. 2). Using these graphene nanochannels we have for the first time to visualize the interface between water and graphene using TEM.

Lastly, we will introduce the concept of electron beam tweezers and demonstrate that by using tightly focused electron beam we can manipulate nanometer sized particles inside the nanochannels and move them over large distances (Fig. 1) [5].

These developments aimed towards imaging dynamics in liquids at nanoscale hold potential to transform how TEM's are used in future and can aide in unlocking properties of liquids and soft materials at atomic scale [1].

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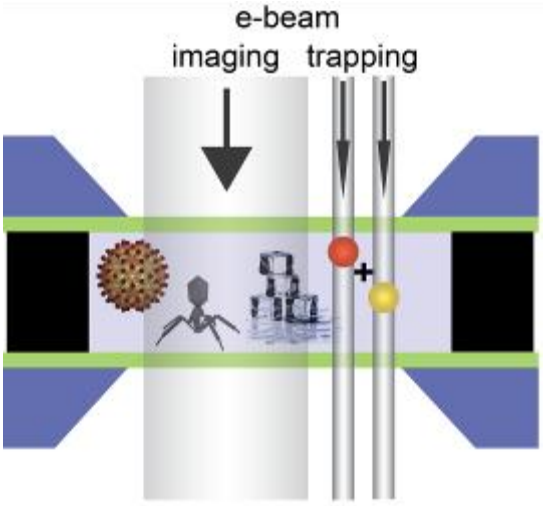

Figure 1. Schematic of the liquid cell encapsulates thin liquid sample between two ultrathin Si_3N_4 membranes (shown in green). Next liquid cell is loaded into TEM. Using this liquid cell we can image samples in native liquid environment. Electron beam is also use to manipulate nanoscale objects inside the liquid cell

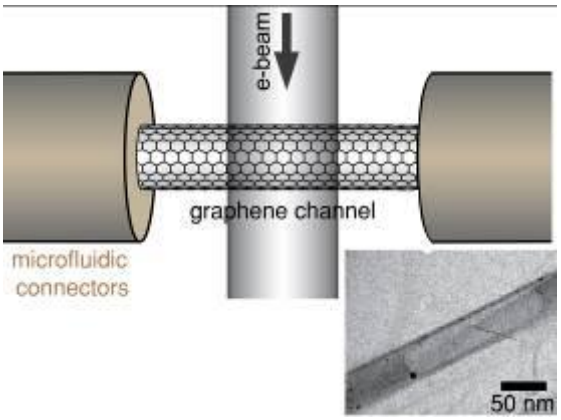

Figure 2. Schematics of graphene naofluidic device that enables high contrast imagin of liquid specimens with TEM.