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In-situ Cryo-TEM Investigations of Ice Crystallization from Supercooled Water and Interactions between Solid/Liquid Interface and Nanoparticles

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Water is the most common and valuable constituent in our lives. Water has a wide variety of solid-state (ice) polymorphs under diverse temperature and pressure conditions. Water-ice phase formation and transitions play crucially important roles in many fundamental phenomena, from materials science to atmospheric science, and have attracted intensive research interest in the past decades [1-5]. However, many basic issues including the mechanisms of ice nucleation, solidification, and microstructural evolution are still not well understood. At ambient pressure, water commonly crystallizes into a stable hexagonal structured phase and a metastable cubic phase. These two ice phases have very similar physical properties as well as formation energies [6]. A variety of techniques have been applied to characterize ice crystallization [7], but direct observation of the process at the nanoscale is still of lacking. The present work develops a temperature controlled cooling system for an enclosed environmental cell in the TEM. The apparatus combines a cold finger, resistive heating, and a thermocouple-based temperature feedback system. The technique enables the in-situ characterization of ice crystallization with good temporal (~100 ms) and spatial resolutions (~5nm). At low freezing rates, the ice crystallizes in the hexagonal phase growing with <-1100> growth facets, as shown in Fig. 1. This approach provides a variety of new opportunities to investigate the water-ice system at the nanoscale and has relevance to a number of scientific and engineering disciplines.

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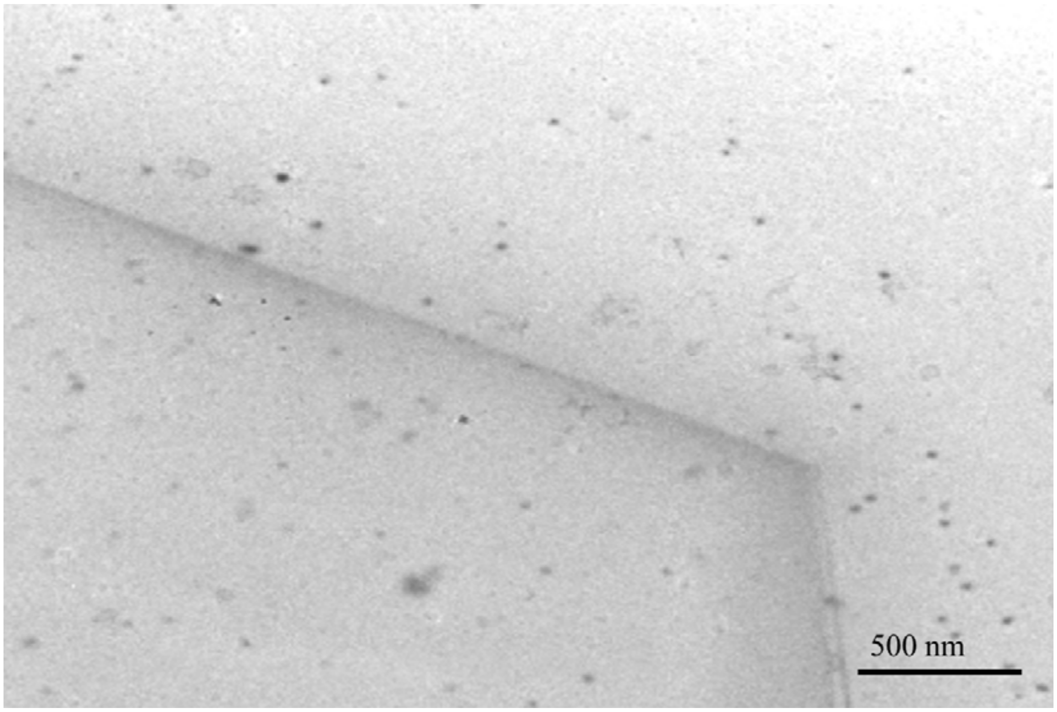

Figure 1. In-situ TEM image of the hexagonal phase of ice during crystallization surrounded by 30 nm Au particles.

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