Dynamic Nucleation in Supercooled Liquids and Measurement of Viscosity and Surface Tension

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Abstract

The major topics of interest of this research project are the study of dynamic pressure as a means to induce solid phase nucleation in the undercooled liquid state and the development of novel methods of measuring the surface tension and viscosity of deeply undercooled liquids with *moderate and high* viscosity. The experimental approach is based on previously developed single droplet positioning/levitation methods combined with the ultrasonic technique of trapping and driving gas bubbles into large amplitude volume oscillations. The same single particle levitation approach will be implemented in the development and validation of a rotation-based method to measure the surface tension and viscosity. The ultimate goals of this study are to experimentally verify the hypothesis that large dynamic pressure excursions can trigger the liquid-solid phase transition, and to gather surface tension and viscosity data for deeply undercooled melts to test current theories for the liquid state. The required high intensity fields for sample levitation and trapping in 1 G and the modification of sample positions due to gravity introduce substantial error in the measurements of the relevant parameters. The performance of microgravity investigations will not only lead to more precise measurements, but it will also allow theoretical modeling of the actual experimental conditions.

The first approach using a dual-frequency technique for trapping and driving radial oscillations of a bubble in a supercooled liquid host was extensively tested by combining a 23 kHz standing wave with a 150 kHz (and even up to 400 kHz) resonance to drive high-amplitude radial oscillations of a trapped air bubble. This was proved to be effective for bubble radii down to about 15 mm. In order to investigate the stationary region of sonoluminescence and large-amplitude oscillations, however, smaller bubbles of about 7 mm in radius are required. To accommodate this requirement, a new method was devised using thin-wall small-volume liquid cell and a single 23 kHz sound wave. This was proved to be successful, and we have already demonstrated dynamically-induced solidification in water supercooled to -8 ^{o}C by an oscillating bubble in the radial mode. The magnified video observation has allowed us to correlate the onset of dendrite growth of ice crystals with the exact position of the vibrating bubble. The measurement of the dendrite growth velocity in supercooled water has also provided some initial data showing deviation from available theoretical predictions.

Initial experimental measurements of the dynamics of rotating levitated viscous drops relaxing from a state of near fission have demonstrated the capability of controlling the acoustic torque in order to allow the observation of the dynamic behavior of a stretched liquid column. By using high-speed photography, we plan to model and to measure the relaxation rate of the stretched column in order to deduce the value of the viscosity. Initial results using water and glycerin levitated droplets have shown the ability of resolve the difference in viscosity. Theoretical analysis is being carried out in order to determine the effects of differential rotation in the relaxation process of the drop shape.