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Bubble Growth and Deformation Characteristics under Non-Uniform Electric Field

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Extended Abstract

The technique of the enhanced bubble dispersion by electric field has been widely applied to the chemical industry, which can dramatically decrease bubble size and intensify dispersion of the tiny bubbles with low energy consumption [1,2]. On this basis, the control of the bubble size and flow field by electric field have significance for optimizing the heat and mass transfer efficiency. Previous studies have mainly expounded the dispersion characteristics [3] and polarization motion in a non-uniform electric field [4]. The generation and motion of gas bubbles in the liquid phase are also important elements of discrete phase dynamics. In the present work, an electrostatic experimental system for bubble visualization is designed and constructed, and the high-speed camera is employed to investigate the microscopic visualization of bubble growth process. The high voltage direct current (DC) is applied to the capillary tube to form a non-uniform electric field around the bubble outlet position. As the electric field strength increases, the non-uniform Coulomb force induces interfacial fluctuations due to the partial accumulation of free charges at the gas-liquid interface. Consequently, the mechanisms of polarization and relaxation of space charges cause the bubble boundary to exhibit stretching and instability. By processing and analyzing the microscopic images of the bubble growth and detachment process obtained from the experiment, the dynamic characteristics of the bubble growth deformation and detachment were summarized.

The experimental results indicate that the bubble growth can be divided into four distinct patterns, including the dripping separation, cone separation, kink separation, and branching fragmentation. First, when the dripping separation turns into cone separation, the bubble is stretched to form a conical bubble growth substrate, and the size of the detached bubbles is sharply reduced. The growth and detachment occurs at the tip of the bubble cone, which has the similar characteristics to the typical electrified cone jet (known as the Taylor cone) [5]. The stretching height of the bubble cone increases with the electric field strength and is accompanied by instability fluctuation at the gas-liquid interface. The bubble cone instability can be attributed to the competition between surface tension force and electric stresses on the bubble surface [6,7]. Eventually, this equilibrium state will be broken by a continuously increasing electric force. The bubble cone is torn and broken into multiple unstable bubble branches. In the branching fragmentation mode, the bubble growth point is shifted toward the tip of each bubble branch. The bubble size is considerably reduced again and micro-bubble cluster is in an atomized state after separation from the capillary tube.

This study summarizes the modes of bubble growth by analyzing the bubble detachment size, frequency, and interfacial fluctuation, and then achieves the macroscopic control of bubble characteristics in a DC electric field. In addition, based on visualization studies, developed the dynamic identification of bubble boundaries to describe the instability mechanisms at gas-liquid interfaces.

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