Bubble aggregation by thermocapillary motion during electrolytic gas evolution

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Bubble coalescence on an electrode surface during electrolytic gas evolution has long been identified as an important phenomenon. Studies of the electrolytic evolution of oxygen bubbles from the back side of a vertically oriented transparent tin oxide electrode in alkaline electrolyte revealed a characteristic behavior of bubbles termed “specific radial coalescence.” Large “collector” bubbles appeared to attract smaller bubbles in their vicinity.

A model based on thermocapillary flow was proposed to explain the phenomenon. A temperature gradient perpendicular to the electrode, arising from reaction irreversibility and ohmic heating, creates a surface tension gradient at the bubble-liquid interface. This surface tension gradient engenders a shear stress that pumps adjacent fluid away from the plate. Bubbles within a proximity of a few radii are mutually entrained in this flow, which explains their apparent attraction. In order to confirm this bubble aggregation mechanism, an experiment that focused on the behavior of adjacent bubbles in temperature gradients near walls was developed. The results showed that the thermocapillary model successfully accounts for lateral motion of adjacent bubbles at a liquid solid interface where the temperature of the solid is greater than the temperature of the bulk liquid.

A general theory of how thermal and electric fields directed normally to a surface can produce two dimensional motion and self-assembly of bubbles and particles on the surface was developed. The origin of the motion is fluid convection driven by the field acting on the surface of the bubble or particle. We solved the quasi-steady field and hydrodynamic equations for two bubbles in a thermal field and two particles in an electric field. The result is a quantitative, predictive model for the relative velocity between two bubbles or particles as a function of the distance between them and the gap of fluid between them and the surface. Interactions between the bubbles and particles significantly increase the velocity of each, which might be considered counter-intuitive. The two-body theory explains the experimentally observed increased rate of attraction between bubbles and particles as they approach each other.