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Effect of bubbles coverage in gas evolving rotating disk electrodes

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Introduction

In some electrochemical reactions, gases are one of the products. The bubbles formed, during the gas evolution reaction, on the electrode surface will affect the active area of the electrode, which in turn will increase the overpotential and also alter the mass transfer of the species interacting at the electrode surface.

The mass transfer process leading to the bubble formation on the electrode surface has been recognized to be analogous to the nucleate boiling heat transfer [1,2]. The flux of non-volatile species, in the absence of reactions in the liquid phase, remains constant throughout the diffusion layer boundaries [3]. The gas, product of the electrochemical reaction at the solid-liquid interface, also diffuses through the liquid in the form of dissolved gas. However, if the concentration of the dissolved gas in the vicinity of the electrode surface increases beyond the saturation limit [4,5], then bubbles start to grow on active nuclei sites [5]. The mass transfer of the dissolved gas faces two competing mechanisms: molecular diffusion to the bulk of the liquid, and mass transfer from the liquid phase to the growing bubbles [6,7].

The gas coverage on the electrode can be defined in terms of the bubble population density as shown in Equation 1 [8].

$$\theta = \frac{z}{At_r}\int_0^{t_r} \pi (K_1 R_d)^2 \, dt \qquad (1)$$

where t_r is the mean residence time, z is the number of bubbles attached to the surface, A is the electrode surface area, R_d is the detachment radii of the bubbles, and K_1 is a constant that accounts for the surface interaction between the electrolyte, the gas bubble, and the electrode surface [3]. The solution for Equation 1 is obtained through the mass balance of the gas evolved from the electrode surface to the diffusion layer boundary [9]. Parameters such as t_r, R_d, and K_1 can be obtained from the mass transfer equations that describe the bubble growth along with the balance of forces on the bubbles [10]. Hitherto, several research works have been published describing the effect of bubble coverage in horizontal and vertical electrodes, both in the absence and presence of convective flow [8,11,12].

In this present study, a mathematical model for a gas evolving rotating disk electrode (RDE) system will be developed. The RDE system allows the suppression of natural convection with a full description of the hydrodynamic factors that can affect the bubble coverage and formation on top of the electrode. The model outcome for hydrogen evolution in alkaline media will be compared against the experimental results and presented in terms of the gas coverage and flow velocity effects as a function of the current density.

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