Asymptotic Approximation for the Current-Voltage Relation in the Electrochemical System of the Molten Calcium Fluoride Slag Operating Under a DC Voltage

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Abstract

Electrically resistive CaF2-based slags are extensively used in many metallurgical processes such as electroslag remelting (ESR). The required thermal energy is supplied into the process by passing electric current through the resistive slag layer (Joule heating). In addition, several chemical and electrochemical reactions occur in the slag aiming at further purification of the alloy during the process. In fact, the slag is an ionic salt (electrolyte) in which the electric current is conducted by means of the movements of ions such as Ca+2 or F- within the electrolyte. Meanwhile, the electric current is delivered to electrodes through redox (Faradic) reactions taking place at the electrolyte-electrode interface. Here, a typical electrochemical system is considered including two parallel, planar electrodes (pure iron) and a completely dissociated electrolyte (molten calcium fluoride) operating under a DC voltage. The asymptotic behavior of the system is captured by solving the dimensionless formulation of Poisson-Nernst-Planck (PNP) equations including electro-migration and diffusion of ions [Bazant, 2004]. The Finite Volume Method (FVM) is used for the numerical solution of the PNP equations. Mass conservations of inert ions (here anions e.g. F-) are automatically satisfied that is the advantage of using FVM method. Additionally, the non-linear Butler-Volmer equations are implemented to describe the boundary condition for reacting cations (Ca+2 or Fe+2) at electrode-electrolyte interface. Spatial variations of concentrations of ions, electric current density and electric potential across the electrolyte are analyzed.

References

1. M. Z. Bazant and K. Thornton and and A. Ajdari. Diffuse-charge dynamics in electrochemical systems. Phys. Rev. E 70 (2004).