Electronic Properties of Passive Films on Carbon Steel Rebar in Simulated Concrete Pore Solutions

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Abstract

In the highly alkaline environment of concrete, carbon steel rebar is protected against corrosion by a passive oxide/oxyhydroxide film. Understanding the characteristics of this passive film, and how it depassivates, is the key for mitigating problems associated with steel corrosion in concrete. Although a large number of electrochemical and analytical studies have been conducted on the passivity of steel in concrete, current mechanistic models do not explain all experimental observations about the chloride-induced depassivation process. One area that is not studied extensively is the electronic properties of semiconductive passive films such as those on steel rebar; a better understanding of these properties will provide additional information to improve the mechanistic models for chloride-induced depassivation of carbon steel in concrete. This thesis uses Mott-Schottky (M-S) analysis along with other electrochemical techniques to study the electronic properties of passive films that form on carbon steel exposed to simulated concrete pore solutions. Both passivation and chloride-induced depassivation processes are investigated, and changes in electronic properties during these processes are monitored. The main parameters of the study include the concrete pore solution composition, pH, and chloride amount. Challenges of using M-S analysis to study the electronic properties of passive films are also discussed. Results showed that the passive film on steel rebar is an n-type semiconductor with two discrete donor species. The space charge layer shows a thickness of around 0.4 nm at full passivation, a donor density on the order of $10^{21} \text{ cm}^{-3}$, and a flatband potential between -0.5 to -0.6 V vs. SCE. In addition to experimental investigations, numerical models used to describe the electronic properties of passive films are also investigated, and an optimal numerical model for simulating the steel rebar passive film is identified.

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