

# Modeling the Electroplating of Hexavalent Chromium

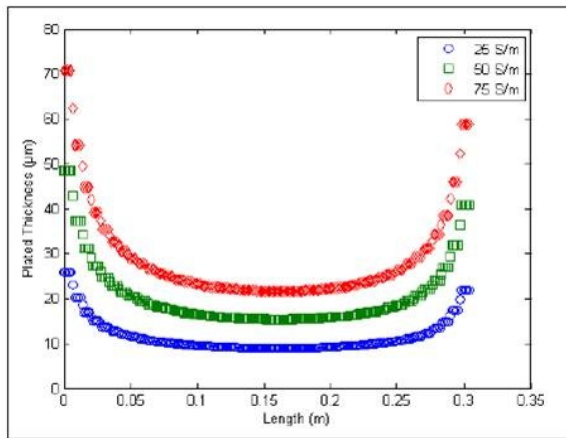
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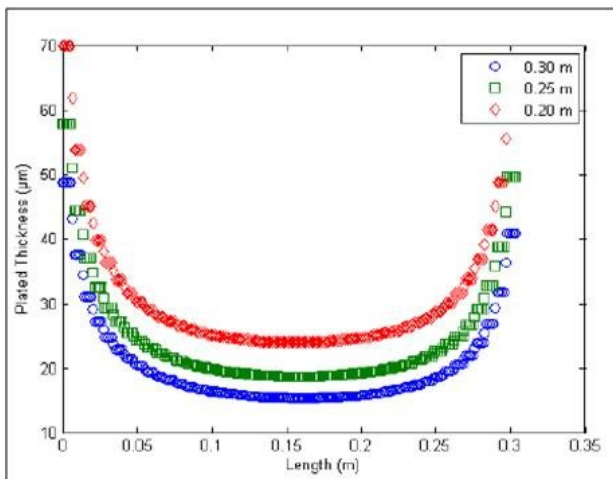
## Abstract

Chromium is often electroplated onto carbon-based components in order to increase the structural integrity of the product as well as increase its corrosion resistance. In industry, this process is conducted in a chromic acid bath where the component to be plated serves as the cathode. Although the chrome plating industry has been well-established for several years, the lack of understanding coupled with the lack of a mathematic model has been a hindrance for further process optimization. The purpose of this project was to model an industrial electroplating process, where the severe inefficiencies in the system resulted in an over-plating of over 300%, causing a corresponding increase in the cost of raw materials and excess energy consumption. The process was modeled via the Electrodeposition module offered by COMSOL Multiphysics® in a two-dimensional space. Through the simulation, the effect of solution conductivity (X1), electrode spacing (X2), and anode height (X3) were quantified using a two-level, three-factor design of experiment approach. A sensitivity analysis was used to study the effect of these variables on the absolute thickness value at the midpoint (Y1), as well as the non-uniformity of the plated surface (Y2). The results concluded that the three variables selected for this study had a substantial impact on the overall thickness value as well as the non-uniformity. The most to least significant variables were solution conductivity, anode-cathode spacing, and anode height, respectively. The simulation indicated that although higher solution conductivity caused an increase in the thickness values, it also resulted in higher non-uniformity in the overall coating. Increases in the electrode spacing caused an overall decrease in the thickness value while resulting in more uniform plating. Lastly, substantially higher anode height compared to the cathode would result in an increase in the non-uniformity. See Figures 1-3. The relationship between the variables was summarized in the following equations:  $Y1=17.22+14.34X1-11.31X2+0.43X3$  and  $Y2=8.36+8.34X1-4.22X2+1.61X3$ . It was also demonstrated that even an increase of 25 S/m in the solution conductivity could result in a decrease in the associated GHG emissions by approximately 111 tonnes of carbon dioxide equivalents per year. See Figure 4. Overall, this study demonstrated a strong correlation between the plating thickness and the three variables, whereby, the largest increase in plating thickness is obtained by increases in the solution conductivity and decreases in the electrode spacing.

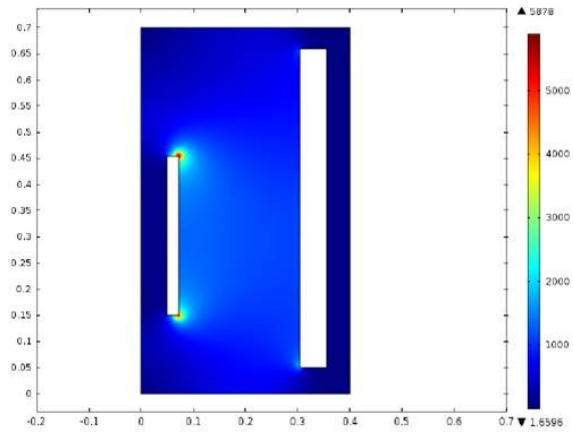
## Figures used in the abstract



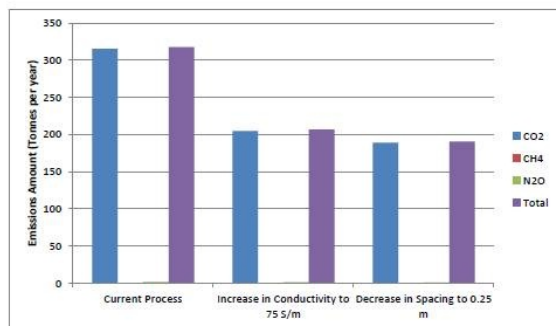
**Figure 1:** Effect of Solution Conductivity.



**Figure 2:** Effect of Electrode Spacing.



**Figure 3:** Effect of Anode Height on Current Distribution.



**Figure 4:** GHG Emission Reductions.