Thesis Project Portfolio

Electrochemical Post-Processing of Zn-Ni Deposition on Steel Substrates for Reliable Composition

(Technical Report)

Identifying Pitfalls of Regulating Cadmium in Technology

(STS Research Paper)

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Sociotechnical Synthesis

My STS research came about after asking why my capstone project was necessary. Cadmium has been useful for sacrificial environmental coatings, but its toxicity has led to increasing regulations and research into viable replacements such as Zn-Ni alloy. This problem seemed to beg the question of why cadmium was used in the first place despite it being a carcinogen, so I wanted to investigate why cadmium is useful for technology, the course of toxicity research concluding cadmium to be carcinogenic, and the regulations for managing cadmium exposure.

The initial mission of this project was to develop a +/- 0.25% tolerance band of Ni content in a Zn-Ni electroplated deposit on steel panel substrates with the intention of mitigating stress corrosion cracking in high-stress field conditions. While the aim of this project remains to reduce stress corrosion cracking behavior in a Zn-Ni electroplated deposit on steel panel substrates in high stress field conditions, the direction of the project shifted to optimizing the composition of the Zn-Ni coating within a range of 12-15 wt% Ni. We intended to ensure that the Zn-Ni coating potential will fall within the immunity region by tailoring the Ni content through Zn dissolution. Two of the steel plates received by Rolls Royce were sectioned into 0.75" squares. The coating on the flat sides of the samples were selectively dissolved with corrosion cells to narrow down ideal processing parameters. Samples were mounted in a cross-section orientation, ground and polished, and sputter coated prior to SEM characterization. The capstone team made multiple attempts to identify a replicable selective dissolution process to reach the potential range of interest. For the conditions used, it appears that the coating was completely dissolved from the substrate. The change in OCP was not from the selective dissolution of Zn from the Zn-Ni coating. It seems more likely that the exposure of the more noble substrate material led to the OCP being within the potential region of interest. Suggestions to improve the experiment include using thicker coatings, using coatings with higher initial Ni contents to start, or accepting the use of lower current densities albeit leading to longer treatment times.

In my STS paper, I argue that while the toxicity and potential of replacing cadmium has become understood, elements of uncertainty have led to risk management where regulation keeps pace with technological readiness more than scientific knowledge. Despite research on health risks of cadmium exposure beginning over a century ago, government and industrial interests have only enacted regulations in recent decades and still have allowed notable instances of cadmium exposure. I researched why it has taken decades to establish meaningful regulation to protect people from excessive cadmium exposure. I examined journal articles on cadmium toxicity and documents covering important regulations and technologies featuring cadmium. The main STS framework I used was Pinch and Bijker's Social Construction of Technology because technology tends to only be developed linearly in hindsight, and the meaning of cadmium varies from the perspective of different relevant social groups. Data has been collected on cadmium toxicity among humans over decades and has its share of weaknesses in definitively establishing causality, but nonetheless scientific consensus provides workable guidelines for how much cadmium exposure is acceptable. Actually regulating cadmium is somewhat arbitrary as exampled by variations between countries (Sweden being a notable example of banning cadmium in the early 1980s), and even within the US, states like California and Minnesota have passed standards more stringent than from the federal level. This was highlighted by OSHA's current standards for cadmium exposure which set allowable concentrations and exposure times while accepting that there is no completely safe amount of exposure. A lawsuit against the EPA also showcases conflict between perspectives of science and industry as the agency relaxed some cadmium standards for water without consulting relevant agencies for protecting wildlife. Cadmium has been difficult to consistently regulate because it remains useful enough to justify its continued use even in applications with suitable substitutes such as with NiCd batteries, CdTe solar panels, and the environmental coatings prompting my capstone project. I hope that this research shows how the difficulties of building science and developing technology can inform regulation as policymakers attempt to best decide acceptable amounts of cadmium. Just as engineering often works with changing knowledge, policy is arbitrarily made attempting to best account for current information and needs in principle.

The capstone project helped me personally witness how science and technological development can be long and arduous work. Broadly, I saw some of the interplay between researchers/engineers who are intimately involved with a project and stakeholders who want to see results from one project and integrate them with other work. Specific to electrodeposition work, I have seen why replacing an established technology can be difficult even if a material should be viable. Replacing cadmium for corrosion-resistant coatings has been years in the work due to technological readiness alone, and it may be years more before Zn-Ni can completely phase it out assuming it ever does. Altogether I can see the conflict between a desire for replacing cadmium and the technological limits standing in the way.