

Automated Optimization of the Electrodeposition of Alloy Thin Films using a Material Acceleration Platform (MAP)

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The rapid expansion of multi principal element alloys (MPEAs) has broadened the chemical landscape for designing materials with tailored functional and structural properties, while also enabling intelligent substitution strategies to reduce critical mineral content in alloys relevant to renewable energy technologies.[1,2] To create and explore such vast compositional spaces, electroplating poses an accessible tool that remains essential for corrosion protection and surface engineering across both conventional and emerging alloy systems. However, the complex interplay of bath chemistry, deposition parameters, and additives make the predictive process design extremely challenging - especially for multi component systems. To address this, we develop a fully autonomous optimization framework for electroplating transition metal MPEAs using a Material Acceleration Platform (MAP)[3,4] that integrates robotic sample handling, automated deposition, electrochemical testing, and machine learning based decision making.

As a proxy case study, we implement the MAP and demonstrate its capabilities through the autonomous optimization of electrodeposited nickel coatings on carbon steel. Nickel layers were deposited from an additive-free Nickel bath, with Bayesian optimization exploring deposition time and current density. The corrosion performance of the Nickel layers was evaluated using electrochemical impedance spectroscopy (EIS), linear polarization resistance (LPR), and chronopotentiometry (CP). Gravimetric weight determination data of the electrodeposit allowed for the determination of the deposition efficiency, leading to increased control of coating thickness with the progressing optimization runs. Promising candidates underwent additional morphological and thickness characterization, confirming that the MAP can independently generate and refine coatings with enhanced corrosion resistance.

Building on this validated workflow, the MAP is deployed for the autonomous exploration of multi component electroplating baths to electrodeposit MPEA coatings. Initial bath compositions are pre-

screened through literature-guided selection and high throughput Hull cell experiments to define feasible operating boundaries. The MAP then executes closed-loop optimization cycles in which electrochemical test results inform the next set of deposition parameters until user defined objectives are met. Selected optimized films that meet the objective are upscaled and subjected to long term stability testing, with detailed material characterization via SEM, ToF SIMS, GD OES, in situ AFM, PM IRRAS, and Raman spectroscopy to elucidate deposition mechanisms and additive-surface interactions.

Together, these studies highlight the power of autonomous, data driven workflows for accelerating the discovery and optimization of electroplated coatings—from single metal systems to complex MPEAs—and demonstrate how AI enabled MAPs can transform electrochemical materials development for corrosion resistant and energy relevant applications.

References

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Figures



Figure 1. Digital twin of the electrochemical MAP set-up.