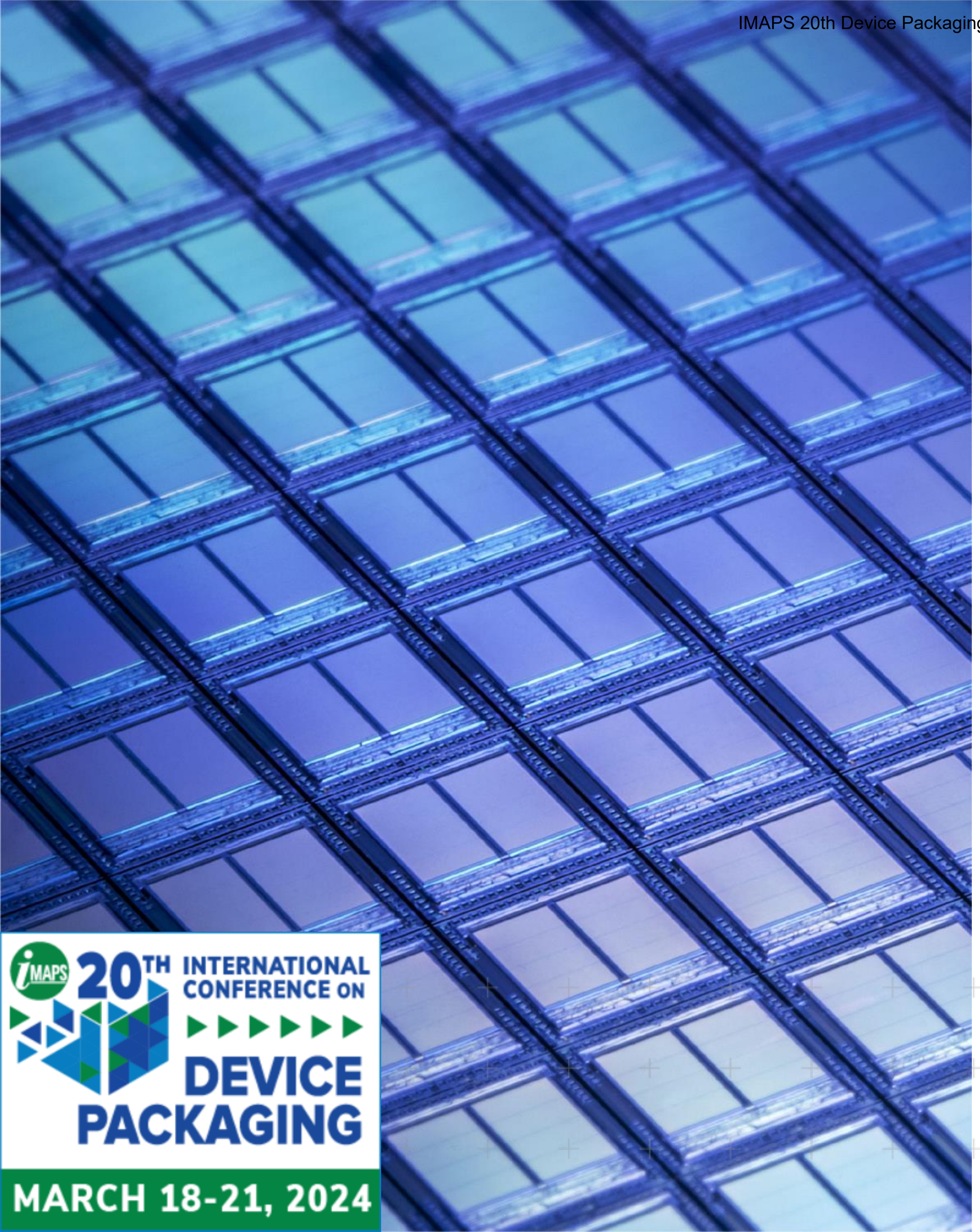

Metrology of Electrodeposition of New Iron-alloy Barrier Layers in Packaging

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Outline

Introduction

- Under bump metallization (UBM)
- Role of barrier
- CoFe plating bath

Analysis of components of CoFe plating bath

- CVS
- Metal ions (Co(II), Fe(II), Fe(III))
- Additives (Accelerator, Suppressor)

Conclusion

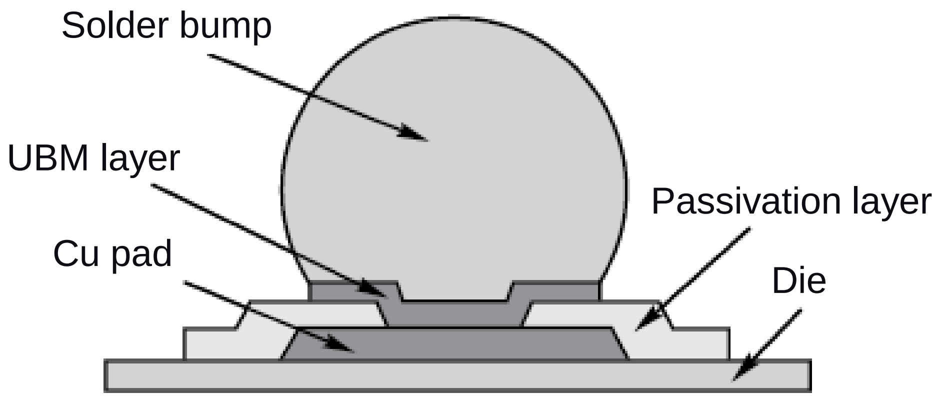
- Summary of analyses
- Key takeaways

Introduction

Under Bump Metallization (UBM)

Purpose

- Under bump metallization is a process employed in flip chip packaging where a thin film of metal is laid between the solder bumps and copper pads or pillars in order to provide an electronic interconnection between the die and package substrate
- The metal layer provides a barrier between the solder bumps (commonly Sn or SnAg) and pad that would otherwise react with one another to create an intermetallic compound (IMC) that severely degrades performance of the electronic package.



Source: Practical Components

Under Bump Metallization (UBM)

Role of barrier layer

- Traditionally, Ni barriers were used for older, macro-scale interconnects
  - As bump size has shrunk (<25um), Ni becomes unsuitable as a barrier layer due to poor diffusion characteristics that can form an undesirable intermetallic compound (IMC)

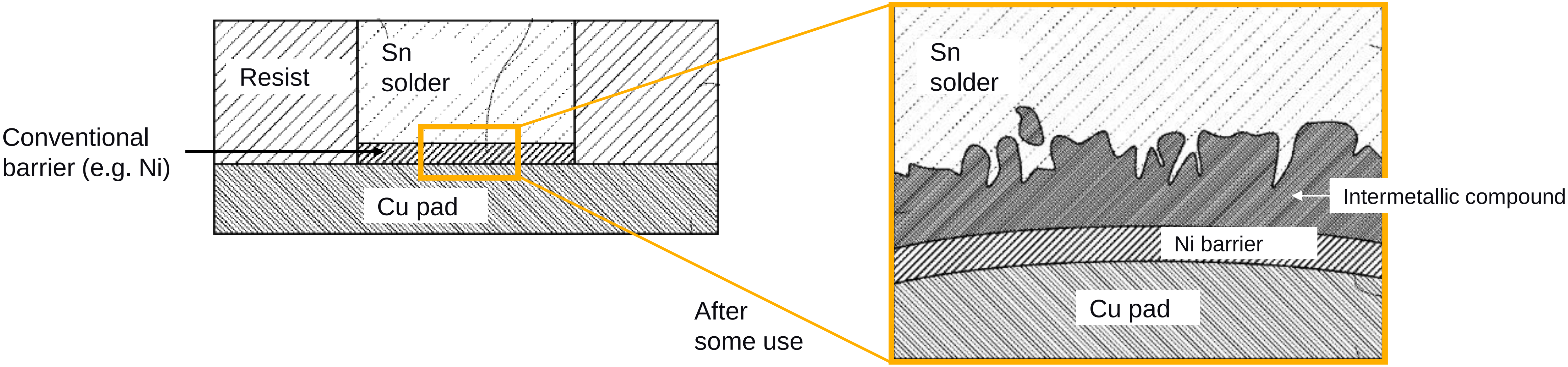
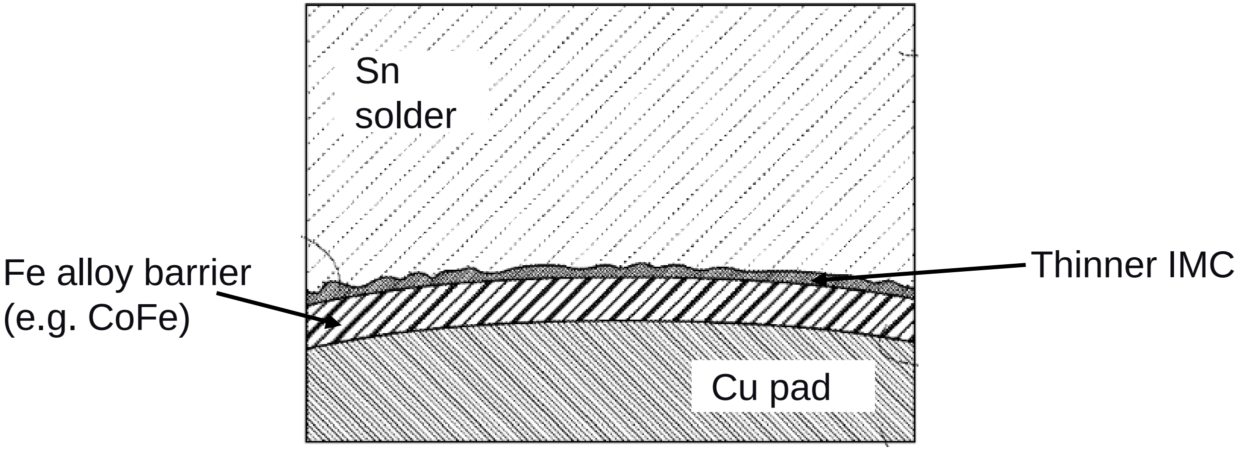


Image source: US20230091379

Under Bump Metallization (UBM)

Role of barrier layer

- Traditionally, Ni barriers were used for older, macro-scale interconnects
  - As bump size has shrunk (<25um), Ni becomes unsuitable as a barrier layer due to poor diffusion characteristics that can form an undesirable intermetallic compound (IMC)
- FeCo and other Fe-alloys are being investigated as a new material for barriers for micro-scale bump UBM
  - FeCo forms thinner layer and a more reliable intermetallic



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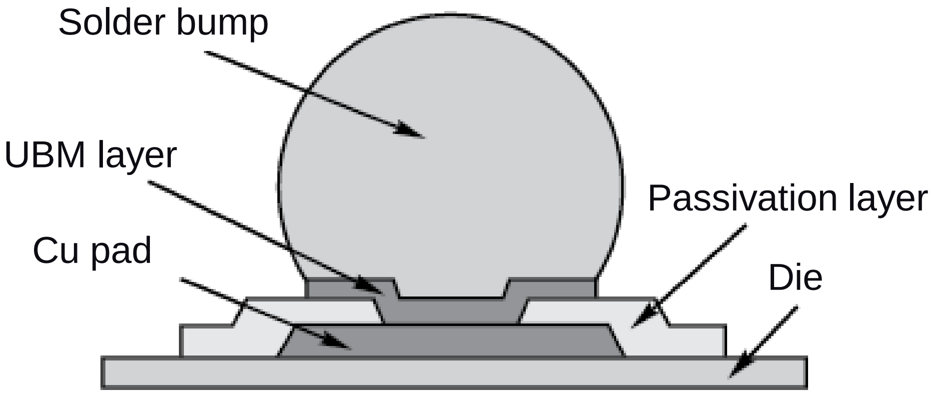
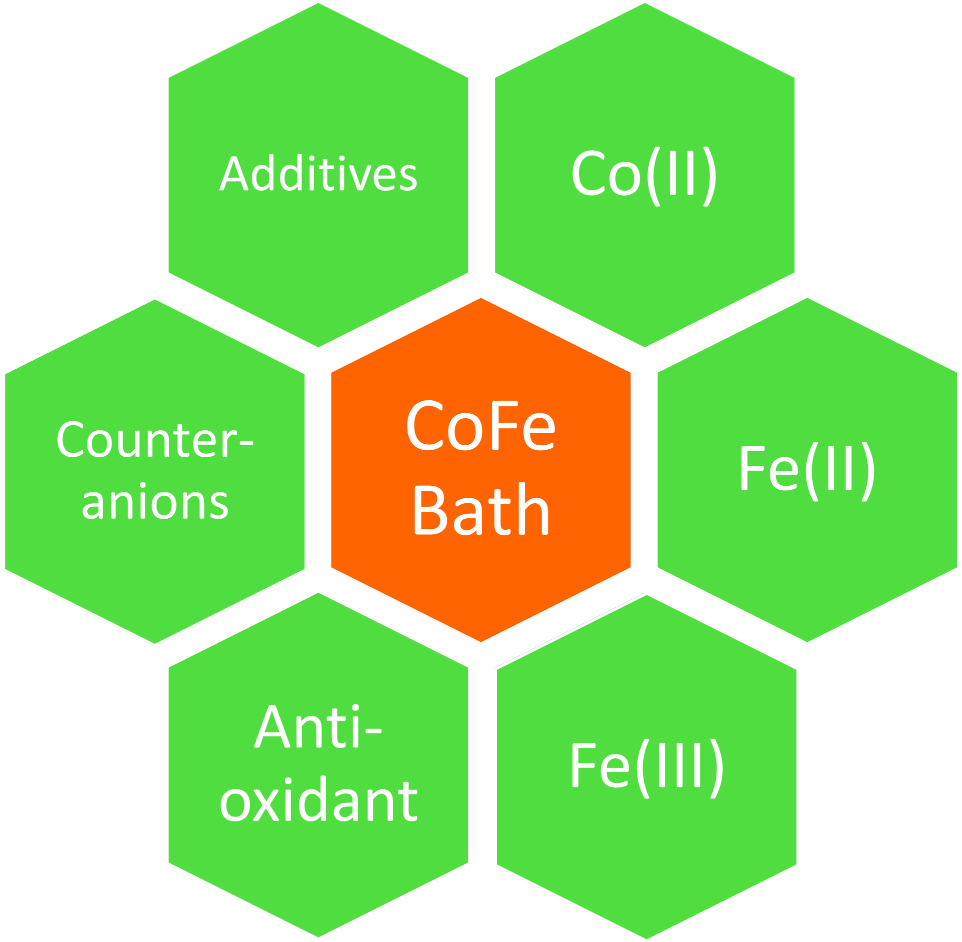


Source: Practical Components

CoFe plating bath solution

Formulation



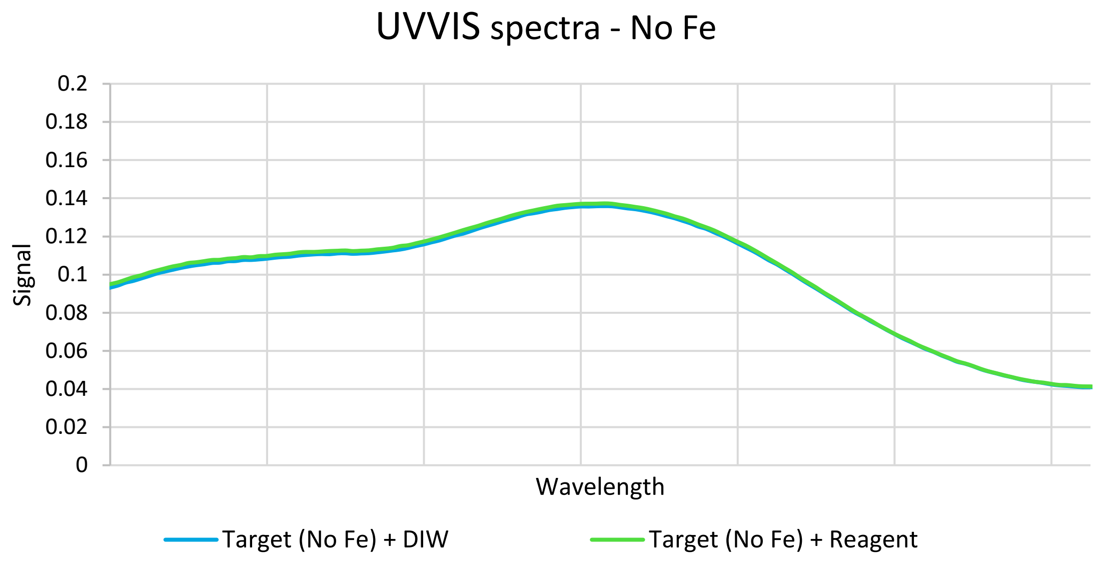
- Precise levels of components in plating bath are critical to proper electrodeposition and deposition characteristics
- Components are consumed during electroplating process, causing their concentrations to continuously change
- Analyses for metal components and CVS-based methods for additive analysis are needed

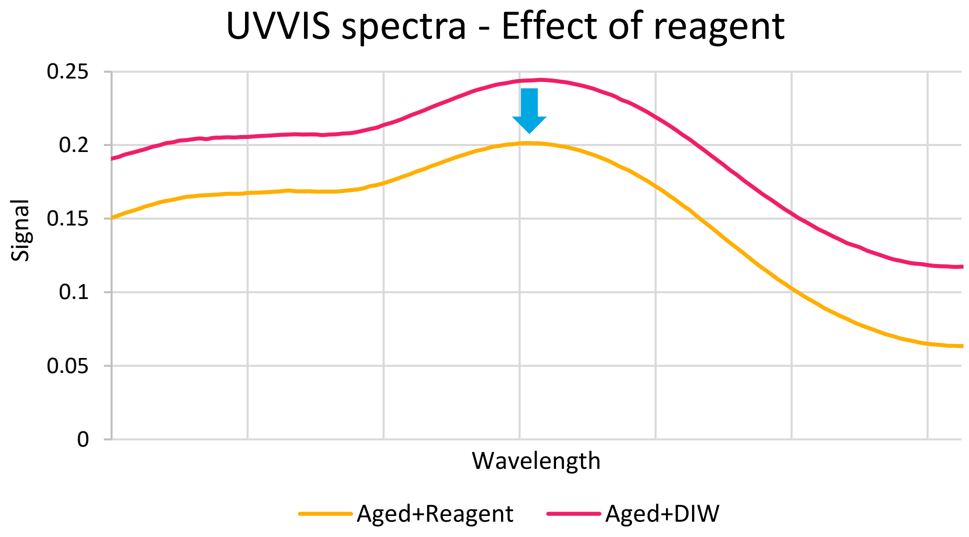
Analysis

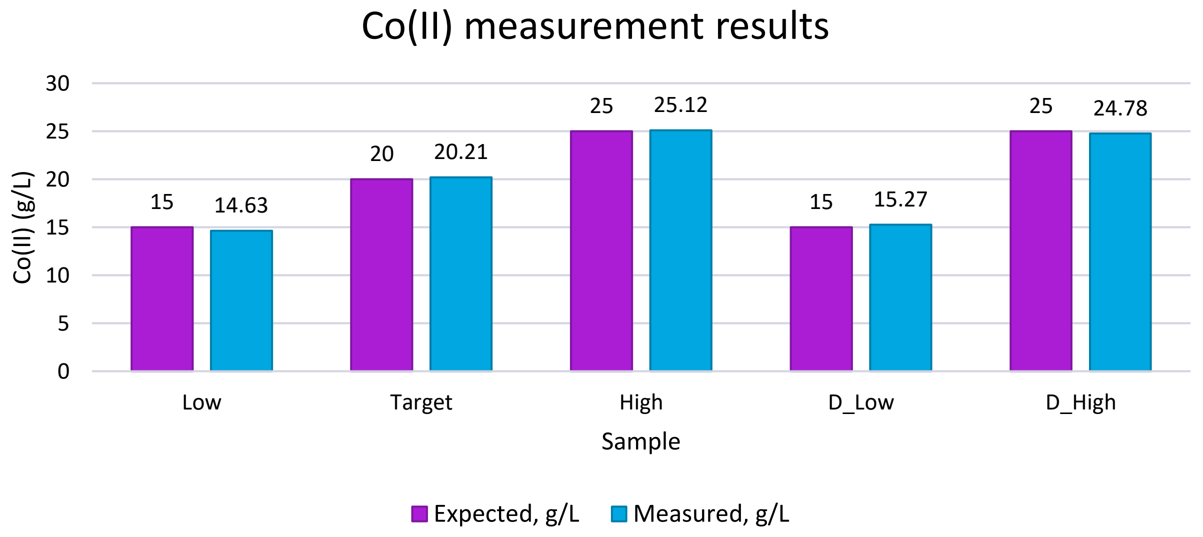
Performance

Co(II) analysis

- Co(II) is measured by ultraviolet-visible (UVVIS) spectroscopy
- Analysis time: <10 min
- Accuracy, RSD: <3% each



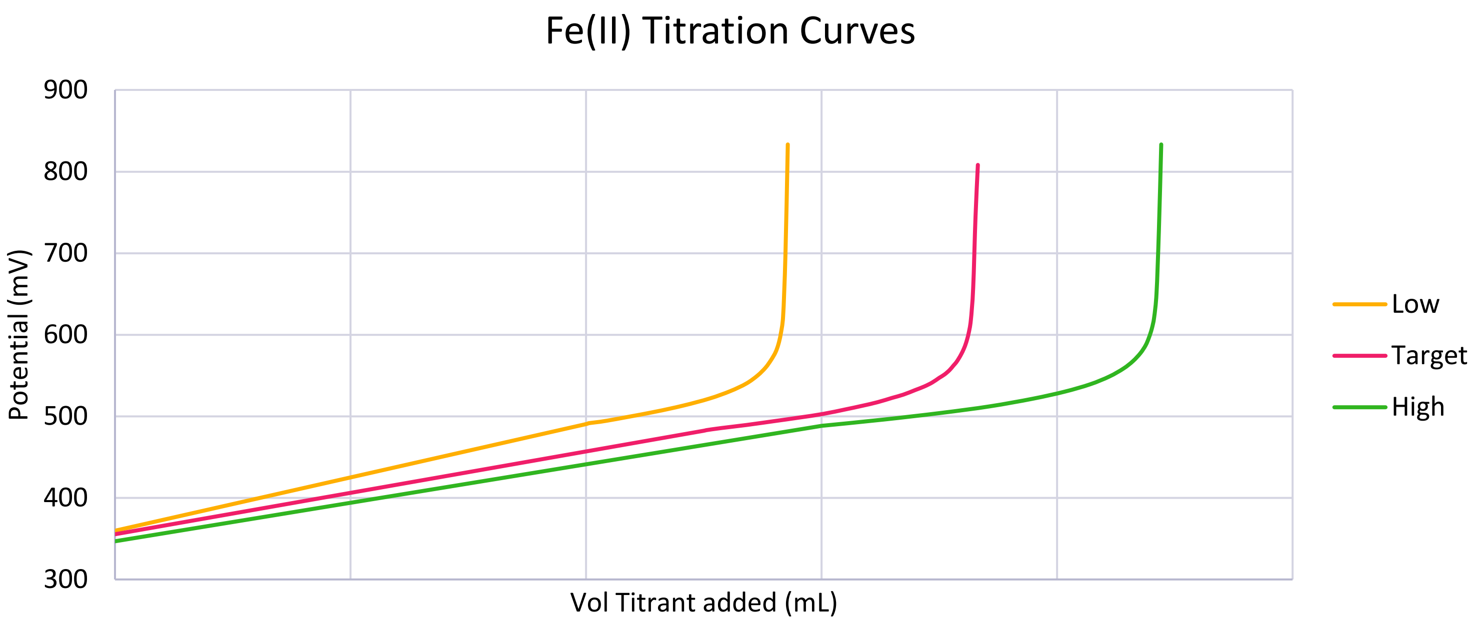


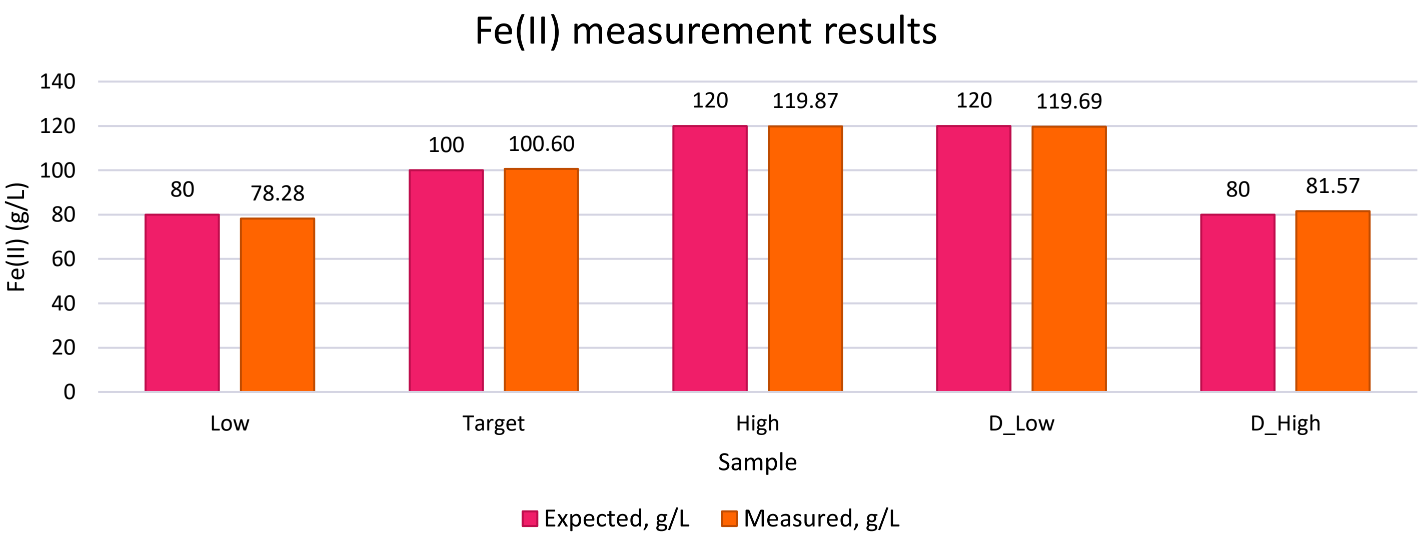


Performance

Fe(II) analysis

- Fe(II) is measured by redox titration
- Analysis time: ~15 minutes
- Accuracy, RSD: <3% each

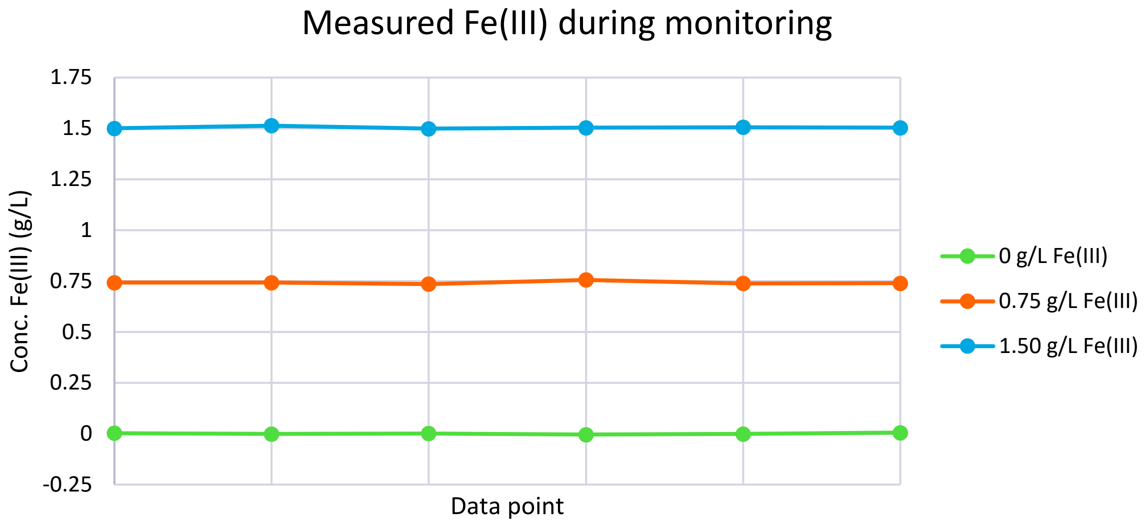


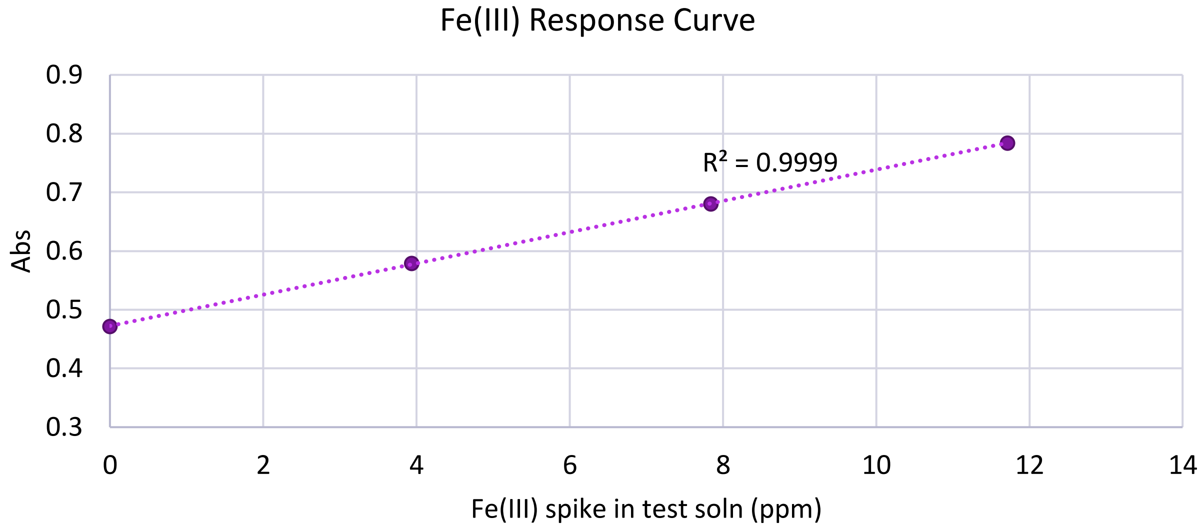


Performance

Fe(III) detection

- Fe(III) is generated in plating bath due to Fe(II) being oxidized by O_2 over time.
- Fe(III) is measured by reagent spectroscopy that is selective to Fe(III).
- Accuracy of Fe(III) is demonstrated by spiking known amount of Fe(III) into tank sample.
- Analysis time: ~ 15 min

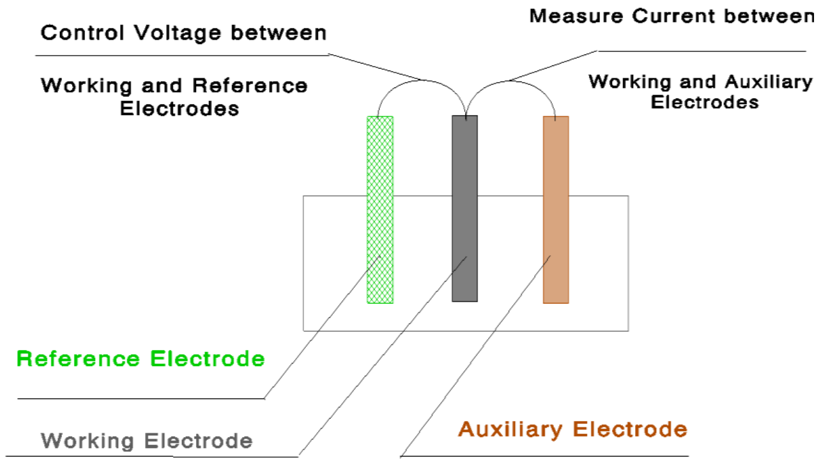


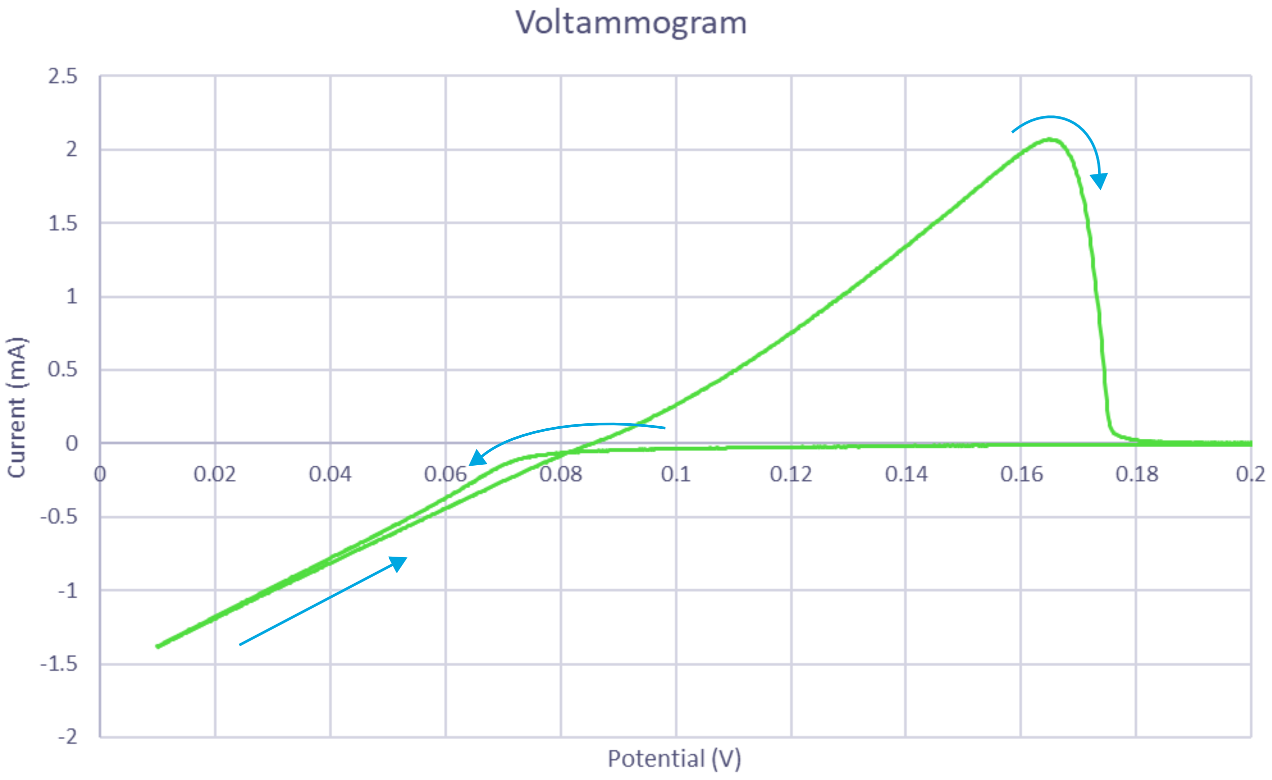


Cyclic Voltametric Stripping (CVS)

Overview

- Voltage is swept to the cathodic region where metal plates, and back toward the anodic region where the plated metal is stripped off
- Additives can affect stripping area, forming basis of analysis





Additives

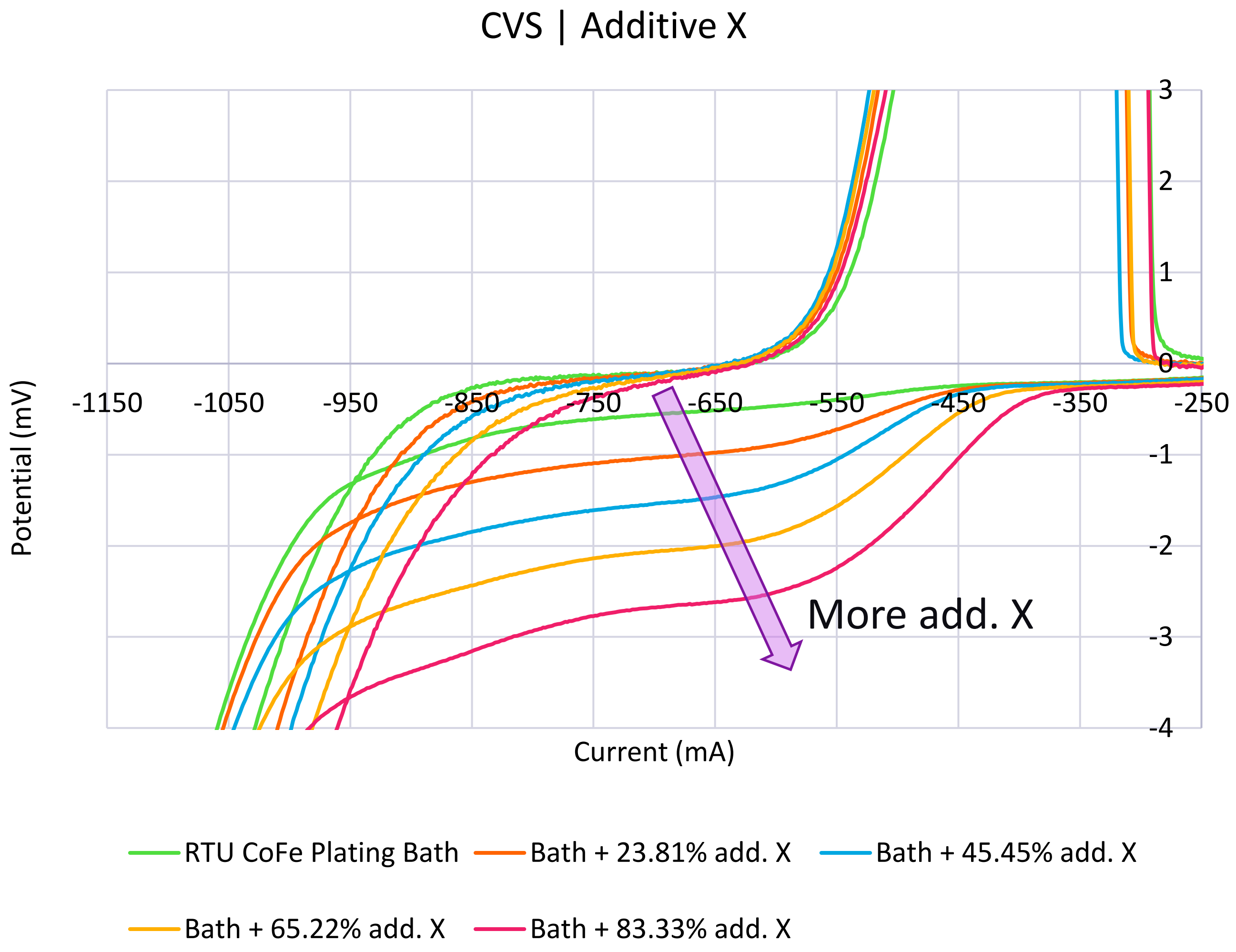
Accelerators and Suppressors

- Small molecule organic additives are often added to plating bath solutions to modulate plating behavior
- Two types investigated
  - Accelerator – catalyzes metal electrodeposition
  - Suppressor – inhibits metal electrodeposition
- Additives are analyzed by cyclic voltametric stripping (CVS), where their effect on the stripping areas of plated metal is measured

Performance

Additive X analysis

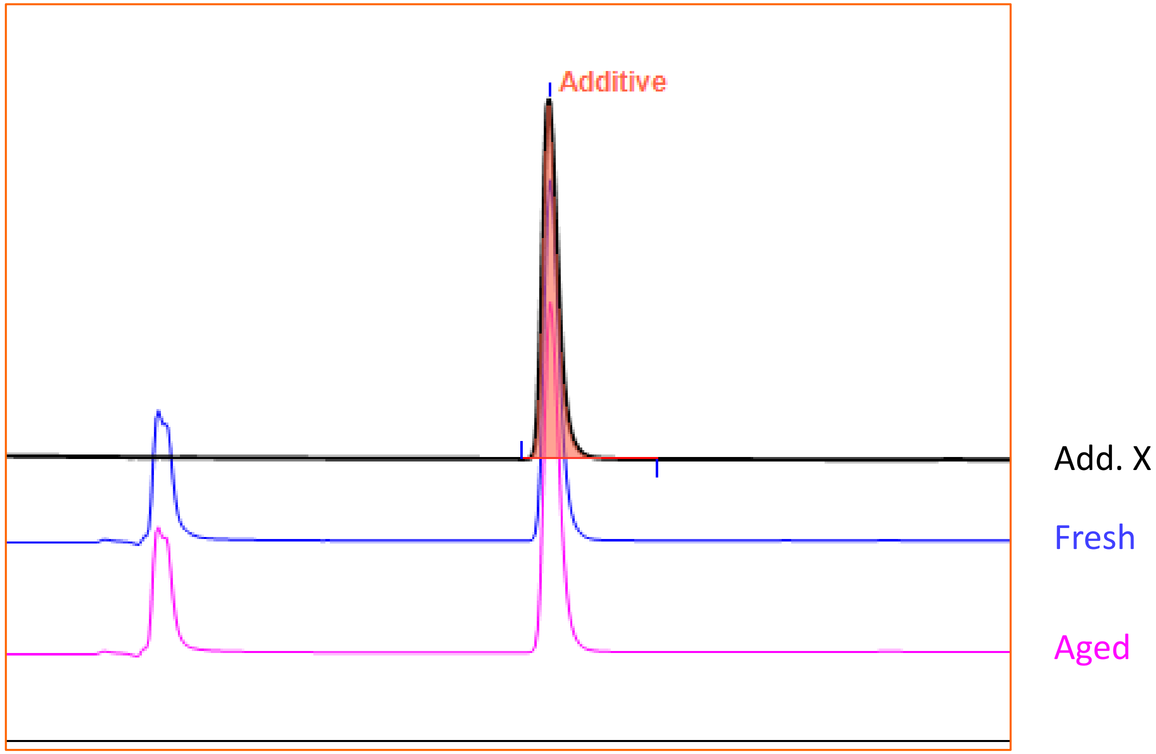
- “Additive X” was tested in CoFe plating solution
- Additive X causes metal to plate at more positive potential, demonstrating it accelerator effect



Performance

Additive X analysis

- "Additive X" was tested in CoFe plating solution
- Accelerator is measured unambiguously by HPLC
- Results confirm CVS analysis



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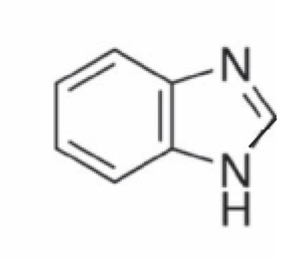
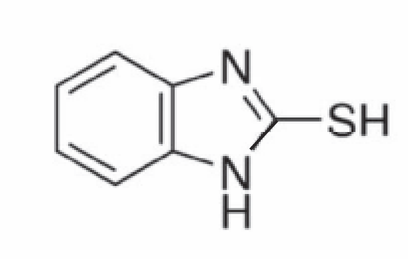
Suppressors

Compounds tested

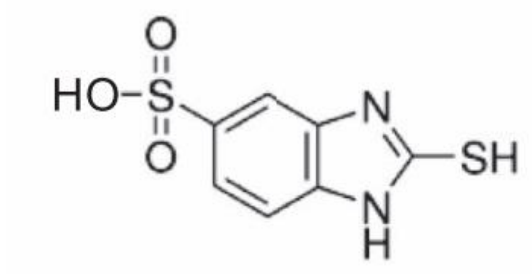
- Several suppressor molecules from the same family (i.e. benzimidazole) were tested, all sharing an imidazole moiety and some containing mercapto groups:
  - Benzimidazole (BZI)
  - 2-Mercaptobenzimidazole (MBZI)
  - 2-Mercapto-5-benzimidazolesulfonic acid (MBZISA)
- Suppressors were characterized by cyclic voltammetry stripping (CVS)



Benzimidazole



2-Mercaptobenzimidazole



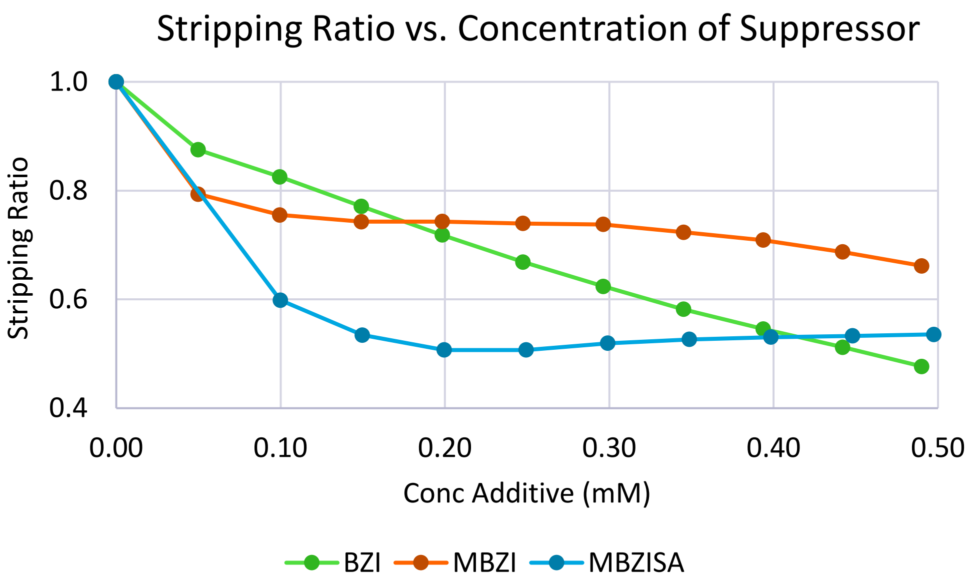
2-Mercaptobenzimidazolesulfonic acid

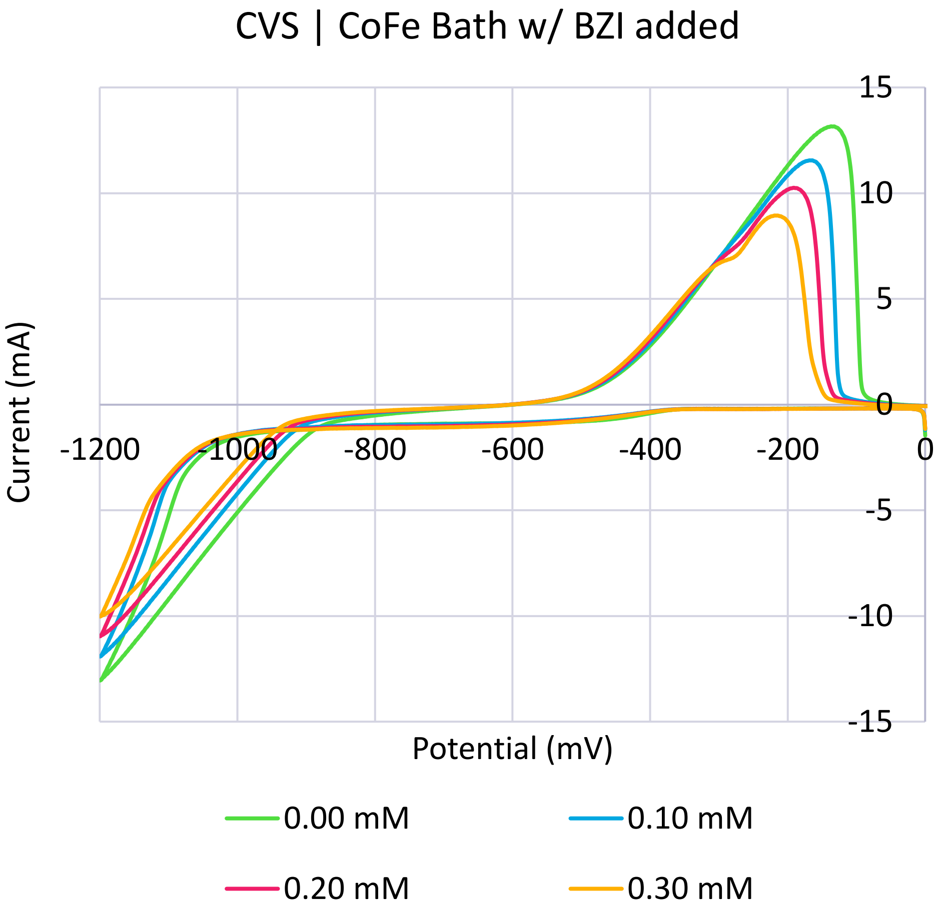
Source: US10487410

Performance

Suppressor analysis

- Increasing concentration of suppressor shrinks stripping area
- All suppressors showed shrinking stripping ratios, with the effect leveling out in MBZI and MBZISA, but not in BZI





Conclusion

Summary

What have we learned?

- Precise level of components in plating baths is critical to control deposition of barrier layer to desired thickness and morphology
- All components of CoFe plating bath solution are capable of being measured to high accuracy and precision, free of interference from matrix effects
- Total analysis time for Co(II), Fe(II), and Fe(III) analyses is 30 minutes or less
- Voltammetry-based analyses for additives are also fast, able to achieve an analysis time of ~20 minutes

Libra analyzer

Thank you!

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