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Brief description on the applications of Thin Film Electrodes

Veronica Lodge*

Editorial office, ChemXpress, United Kingdom

***Corresponding author**: Veronica Lodge, Editorial office, ChemXpress, United Kingdom, Email: chemXpress@tradescience.org

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Abstract

ASV is a powerful electrochemical analytical approach for detecting and measuring a wide spectrum of metal ion species in aqueous fluids at extremely low concentrations. While early ASV tests relied on macroscopic electrodes such Hg drop electrodes to provide plating/stripping-ready surfaces, more recent work on the approach has relied on thin film metal electrodes made in situ to replace these electrodes. Such electrodes are plated with the analyte species onto the surface of a primary electrode, resulting in a composite metal electrode from which the analyte(s) may be extracted, identified, and quantified.

Keywords: ***Electrochemical analytical approach; Macroscopic electrodes; Electrolytes; Heavy metals***

Introduction

The relative simplicity and broad application of MTFEs and ASV assays have led to their employment in a variety of domains, including environmental monitoring, soluble metal species measurement in battery electrolytes, and even detecting the number of biomolecules in human serum. We've included an overview of several recent MTFE and ASV implementations in these and other disciplines below.

Environmental Studies

ASV is often used to detect and measure the concentration of various heavy metals (Pb, Cd, Zn, Tl, Ni, etc.) in the environment since it requires substantially less sample preparation and equipment to properly quantify metals in a wide range of sample medium. An in situ Bi MTFE was used to measure Tl concentrations in lake water samples, with a LoD of 0.021 nM for Tl and a linear range of 0.05nM–5 nM. This degree of precision necessitated the addition of a second preconcentration phase to the method, which concentrated the Tl in the solution greatly, allowing detection at ultra-trace quantities even in complicated media. Bi MTFE deposited on GaN achieved a 2.72 nM LoD for Cd with a linear range of 8.9nM–1,334.5nM. During the ASV experiment, GaN provided an inert, highly conductive substrate on which the Bi MTFE could be placed, and the composite electrode demonstrated great Cd recovery efficiency from a variety of diverse matrixes, including natural fluids and others. Finally, a 3D printed stainless steel electrode was used to produce an ex situ Bi MTFE for Cd and Pb ASV measurements. The researchers showed that bespoke electrodes could be made and used to do electrochemical experiments, with LoDs of 17 nM and 83 nM for Pb and Cd, respectively, and linear ranges of 200 nM-3000 nM.

Batteries and Energy Applications

ASV has also been used to investigate and characterize alkaline battery systems, most notably in the investigation of metal ion migration through polymer separators used in Zn/MnO_2 batteries. During electrochemical cycling, soluble Zn species formed at the Zn anode can react with the MnO_2 cathode, creating $ZnMn_2O_4$ irreversibly and lowering the cell's capacity. Zn^-impermeable separators can inhibit this reaction in addition to electrical short circuits; however finding potential polymers using typical ICP-MS crossover studies is time and processing intensive. Our lab has recently demonstrated that ASV employing MTFEs may replace ICP-MS and greatly simplify Zn permeability measurements, and has utilized the assay to assess a variety of commercial and bespoke battery separators. A LoD of 24.5 M for Zn in a 35 wt/% solution of KOH was produced using in situ Bi MTFEs with Pb and Cd additions, with a linear response range of 45.8 M–305.9 M. This result was identical to the LoD of ICP-MS (115 M) in the

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same KOH solution, but it could be done in the concentrated alkaline electrolyte instead of requiring extensive dilution and neutralization.

Medical Applications

The use of MTFEs for ASV is limited to medical tests, where the electrodes' sensitivity and tolerance for complex matrices make them perfect for identifying medically important species. Pb is utilized to catalyze various chemical processes during medication production, and trace amounts can be left in the final consumer product despite its toxicity. The scientists achieved a LoD of 103 M in an aqueous solution containing caffeine, with a linear range of 188 M–939.4M, without the need for time-consuming digesting processes. It was discovered that combining Cd and Pb increased the sensitivity of the Pd measurement. These species may be crucial in attaining low LoDs using Bi MTFEs, according to this finding. Organic species such as quinolones and peptides have also been quantified utilizing MTFEs and ASV.

Ex-situ Bi MTFE evaluated two different quinolones in both buffer solutions and caducean crustacean culture medium in an experiment, reporting a LoD of 1 nM for moxifloxacin and a linear range of 2.99 nM–87.2 nM for other quinolones. This allowed the researchers to employ ASV to demonstrate a link between molecular breakdown and crustacean death, implying that comparable mechanisms may occur in nature. The Crooks group has combined Ag MTFEs with peptide-specific antibodies for N-terminal prohormone brain natriuretic peptide to assess complicated heart-failure related peptides (NT-proBNP). During the test, both an ex situ Au MTFE and an in situ Ag MTFE are sequentially stripped and galvanic exchanged to create an in situ Ag MTFE that may be utilized to measure the amount of peptide in solution. The Ag nanoparticles bind to peptide-specific antibodies, establishing a link between the amount of Ag detected during ASV and the amount of peptide in the sample. Scientists were able to acquire a LoD of around 0.58 nM and a linear range of 0.58 nM–2.33 nM using this test. Although the sensitivity is still insufficient for clinical use, the whole test may be done on a paper-based device, which promises to lower the costs and complexity associated with these sorts of assays.

A short sample of the numerous applied MTFEs in the literature demonstrates a wide range of MTFE-based ASV applications. They demonstrate the sensitive readings and chemical selectivity that MTFEs offer to electrochemical analysis, as well as the wide range of applications that such basic systems may be employed in, creating a convincing argument for MTFEs and ASV to be included in the conventional analytical toolkit.

Conclusion

MTFEs provide a number of advantages over HMDE and bulk electrodes for ASV analysis. MTFEs may be deposited in situ with the analyte species, resulting in highly concentrated electrode films with exceptional sensitivity over a wide range of concentrations. Many metals, including the conventional (but poisonous) Hg and less toxic alternatives like Bi or Sn, can be used to make MTFEs. This versatility allows the MTFE to be tailored for a specific test, resulting in electrochemically different bimetallic alloys with the species of interest, even when additional species of interest are present. These electrodes, when combined with the relative simplicity of ASV sample preparation, enable for greater throughput examination of materials ranging from natural water to blood serum. MTFE-based ASV assays have been used in a variety of systems recently, and they should continue to be a sensitive and valuable tool for chemical analysis in these and other applications in the future.

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