

Trace Metal Detection Using Carbon and Boron-Doped Diamond Microelectrodes

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Environmental monitoring makes more and more use of low-power and real-time technologies to achieve portability. This trend is driven by several requirements, among them the need to reduce costs and to shorten the monitoring cycle time by performing the measurement at the point of sampling and not in the laboratory. Devices based on electrochemical detection methods, such as anodic stripping voltammetry (ASV) ^[1], are potentially capable of fulfilling many of the requirements of field portable systems including low power consumption, small size, low weight, and unattended operation.

The use of microelectrodes for the detection of metals brings a number of advantages such as being able to perform the measurements in low conducting media as well as eliminating the need for stirring during the metal concentration step. Until now, the analysis of metals by stripping voltammetry has required a layer of mercury on the electrode for pre-concentration of the metal analyte. However, due to increased regulation pressure of the environment, along with the lack of availability of mercury electrodes have led to the development of mercury-free sensors for trace metals analysis. The metallic and screen-printed carbon microelectrodes reported to date often lack reproducibility and stability, which are a prerequisite for field tests. The use of thin-film carbon and boron-doped diamond (BDD) microelectrodes for trace metal detection shows promising results, which are described hereafter.

The microelectrodes consist of a hexagonal array containing 200 disks, 5 μm in diameter and separated by 100 μm ^[2]. The measurements are performed in a three-electrode cell in a Faraday cage to avoid external noise. The reference electrode is an Ag/AgCl protected by an additional bridge of 0.1 M NaNO₃ to avoid contamination with Cl ions. Differential pulse ASV experiments are carried out by using a low-power versatile miniaturized potentiostat controlled by LabviewTM.

Figure 1 shows stripping voltammograms corresponding to Ag⁺ detection in water using carbon microelectrodes. A detection limit of 1 ppb for Ag⁺ in drinking water using a concentration time of 10 min has been demonstrated. The detection of Cu²⁺ using BDD microelectrodes is shown in Figure 2. Good stability and reproducibility of the measurements are obtained. The results demonstrate the application of both carbon and BDD microelectrodes in mercury-free detection of trace amounts of metal ions in water. Due to their chemical inertness, durability, and low background current, BDD microelectrodes hold promise for the on-line monitoring of metal ions in difficult media such as natural waters. The development of this application is currently under way.

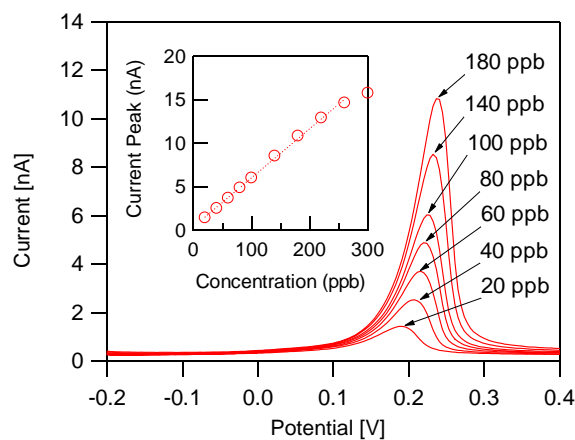


Figure 1
Anodic stripping voltammograms recorded at carbon microelectrodes for various Ag⁺ concentrations in a 0.2 M KNO₃ electrolyte. Concentration potential and time were -0.2 V and 3 min respectively.

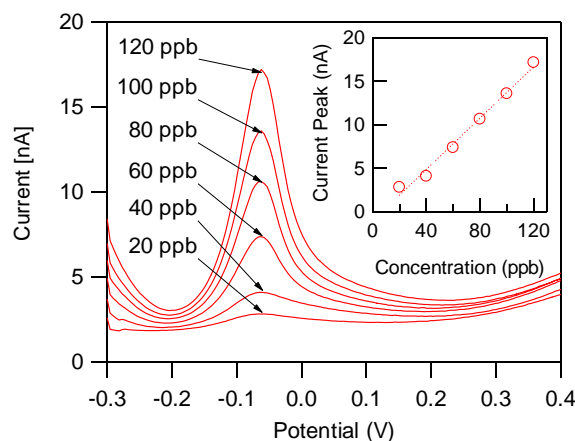


Figure 2
Anodic stripping voltammograms recorded at BDD microelectrodes for various Cu²⁺ concentrations in a 0.2 M KNO₃ electrolyte. Concentration potential and time were -0.4 V and 2 min respectively.

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^[1] J. Wang, "Stripping Analysis: Principles Instrumentation and Applications", VCH, Deerfield Beach, FL (1985)

^[2] X.M. Tang, N. Skinner, G.C. Fiaccabrino, M. Koudelka-Hep, "Chemical Analysis Using Microstructured Thin-Film Amorphous Conducting Carbon", ECS Meeting Abstracts, MA 96-2 (1996) 895