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ScienceDirect

Procedia Technology 27 (2017) 135 – 136

Procedia Technology

Biosensors 2016

Point-of-use simultaneous electrochemical detection of lead and cadmium using low-cost screen-printed transparency electrodes

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Abstract

In this work low-cost screen-printed transparency electrodes were fabricated and optimized for the simultaneous detection of lead and cadmium using square-wave anodic stripping voltammetry. Bismuth was employed in order to enhance preconcentration of the metals on the electrode surface. Transparency electrodes were integrated in sample vial caps for point-of-use detection, directly on the container where the sample is collected.

Keywords: Paper-based devices; Electrochemical detection; Point-of-use; Low-cost devices; Heavy metals.

Nowadays the detection of heavy metals is one of the most studied analytical problems due to the prevalence of these species in the environment and its adverse health effects [1]. Then, the development of devices for heavy metal detection with ideal characteristics such as low cost, portability, short analysis time and high sensitivity, is a constant concern. Electrochemical detection meets fairly well these criteria and has been established as a very promising tool to carry out heavy metal detection [2]. The latest trend is the development of low-cost paper-based electrochemical devices [3] that further reduce the cost of analysis and can be used in a disposable way. The aim of this work was to fabricate paper (or similar)-based low-cost electrochemical devices for the simultaneous determination of Cd and Pb.

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doi:10.1016/j.protcy.2017.04.059

The electrochemical performance of screen-printed carbon electrodes fabricated on low-cost substrates was evaluated. Chromatography paper, tracing paper, office paper and transparency sheets were employed as low-cost substrates (Figure 1a). A three-electrode system was screen-printed with the aid of a template onto the substrates. Commercial carbon ink was employed to generate the conductive pads, and was left to dry to remove any remaining solvent and stabilize the surface. A ring of insulating tape was cut and placed in the middle of the devices in order to delimit the electrochemical cell, with the exception of the chromatographic paper, where the electrochemical cell was delimited printing hydrophobic wax. These low-cost screen-printed electrodes were evaluated by cyclic voltammetry using hexamine ruthenium (III) as model species. Good electrochemical response was found for the different low-cost substrates, especially for chromatographic paper and transparency sheets.

Then, the performance of these electrochemical devices for the simultaneous detection of heavy metals such as Cd and Pb was evaluated using anodic stripping voltammetry. The best results were found using transparency sheets as substrate. Several experimental conditions such as the effect of bismuth, the effect of a Nafion® film or the buffer pH were optimized. Square-wave anodic stripping voltammetry was chosen as electrochemical technique and *in situ* deposition was the best method for modification with bismuth film. Calibration curves for simultaneous determination of Pb and Cd were carried out (Figure 1b), obtaining a linear response in the range 1-200 μg L^{-1} (Figure 1c). Adequate sensitivities for Cd and Pb were obtained, respectively, exhibiting a strong response of the transparency electrodes towards these metals. The analytical characteristics obtained for these low-cost devices allow detecting heavy metals at concentrations as low as 1 ppb, well below the legal limits established for drinking water. The relative standard deviation for different transparency electrodes was under 9% for both metals, suggesting a good reproducibility of the fabrication.

Transparency electrodes were successfully integrated in sample vial caps for direct point-of-use detection (Figure 1d). Adhesive copper tape was employed for the connection with the potentiostat through the septum of the vial cap. This system allows the determination of the analytes directly in the container where the sample is collected and was employed for the accurate determination of Cd and Pb in real samples such as river and estuary waters.

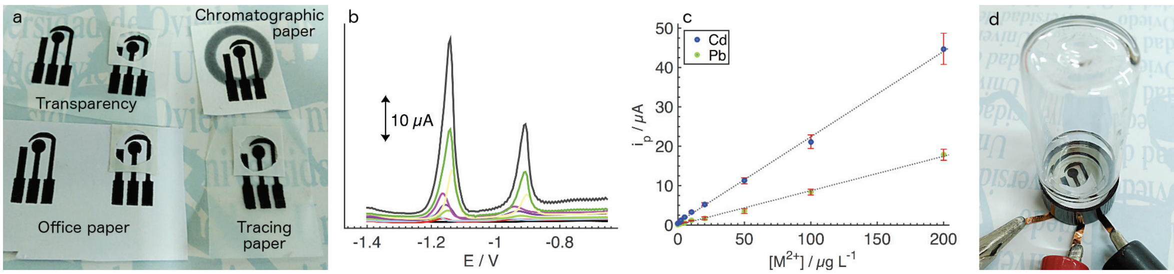

Figure 1. a) Picture of low-cost screen-printed electrodes on different paper-based platforms. b) Square-wave voltammograms obtained in transparency electrodes for increasing concentrations of Cd (II) and Pb (II). c) Representative calibration plots for Cd (II) and Pb (II). d) Picture of the point-of-use system, where a transparency electrode was integrated in a sample vial cap.

Acknowledgements

This work has been supported by the FC15-GRUPIN-021 project from the Asturias Regional Government and the CTQ2014-58826-R project from the Spanish Ministry of Economy and Competitiveness (MINECO). IAM acknowledges the EU's support under H2020-MSCA-IF-2014 grant agreement 660339 (eADAM).

References

[1] Jarup L. Hazards of heavy metal contamination. Br Med Bull 2003; 68, 167–182.
[2] Gumpu, MB, Sethuraman S, Krishnan UM, Rayappan JBB. A review on detection of heavy metal ions in water – An electrochemical approach. Sens. Actuators B 2015; 213, 515–533.
[3] Dungchai W, Chailapakul O, Henry CS. Electrochemical Detection for Paper-Based Microfluidics. Anal Chem 2009; 81, 5821–5826.