

Disposable barrel plating nickel electrodes for use in flow injection analysis of trivalent chromium

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Abstract

We report a disposable barrel plating nickel electrode (Ni-BPE) coupled with a specifically designed electrochemical cell for use in flow injection analysis for the determination of trivalent chromium (Cr^{III}). The response of the activated Ni-BPE was found very sensitive under alkaline condition with a systematic increase in current signal upon successive addition of Cr^{III} . Under optimized conditions, the calibration curve showed a linear range up to 1 mM with a detection limit ($S/N = 3$) of 0.30 μM . Continuous hydrodynamic flow of 0.1 M NaOH at regular Cr^{III} injections verify the reproducibility of the present system. The proposed method was successfully used to detect the amount of Cr^{III} in environmental water to show its potential use in real applications.

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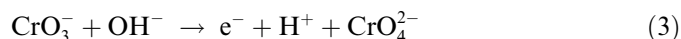
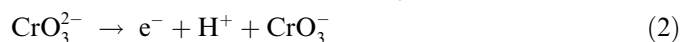
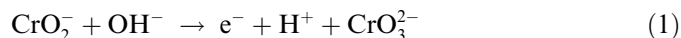
Keywords: Chromium; Nickel electrode; Disposable; Flow injection analysis

1. Introduction

Trivalent chromium (Cr^{III}) is an essential nutrient ion needed to maintain normal physiological functions. It is one of the essential trace elements in multivitamin with multimineral pharmaceutical formulations [1]. The detection of Cr^{III} that exists in many biological and industrial materials is of great interest [2]. Many methods, such as atomic adsorption spectrophotometer [3,4], plasma mass spectrometry [5], spectrofluorimetry [6], chemiluminescence [7–9], spectrophotometry [10] and electrochemistry in potentiometric measurement [11–17], have been employed for the determination of Cr^{III} . In general effective separation and preconcentration are both essential to obtain the best results, but the procedures are both complex and time consuming. Consequently, it is difficult to directly apply them *in situ* for monitoring Cr^{III} in aqueous environments.

Direct oxidation of Cr^{III} is promising in this regard and has been studied at platinum, stannum and diamond

electrodes [18–21]. Notably, the oxidation of Cr^{III} was examined at polycrystalline gold and Au(111) single crystal electrodes [22,23] and the following mechanism was proposed for the overall electrode reaction:



In this paper the electrochemical oxidation of Cr^{III} is studied at an activated barrel plating nickel electrode (designated as Ni-BPE). It is anticipated the reaction mechanism of gold electrode might also be accessible at the activated Ni-BPE. Our previous study introduces an engineering process of barrel plating technology for mass production of disposable-type electrodes [24]. The primary function of barrel plating is to provide an economical means to electroplate manufactured parts that meets specific finishing requirements [25,26]. Since the fabrication cost of the Ni-BPE is cheap, it is thus disposable in nature. It was found that the activated Ni-BPE coupled with a specifically designed electrochemical cell allowed us to obtain

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a distinctive voltammetric profile towards the oxidation of Cr^{III} in flow injection analysis (FIA). To validate the applicability, the developed method was applied to the determination of Cr^{III} in real water samples.

2. Experimental

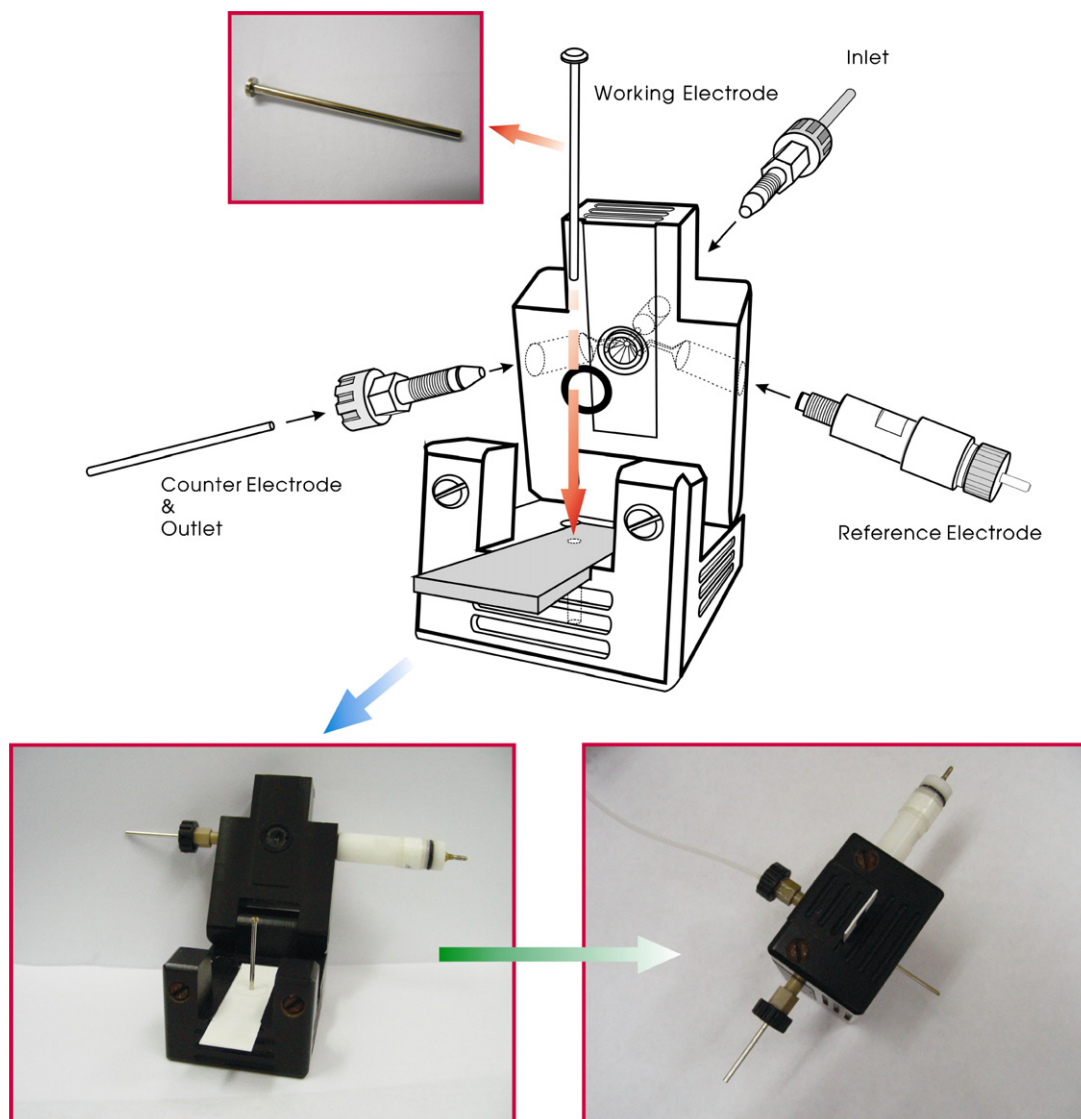
2.1. Reagents and chemicals

Chromic chloride (RDH, min. 96%) and sodium hydroxide (Showa, min. 96%) were used as received. All reagents were of analytical-reagent grade and prepared with high resistivity (18 M Ω /cm) de-ionised water. Natural water samples were collected in a polyethylene bottle from a lake at the campus of Chung Hsing University and kept under refrigeration below 4.8 °C and were filtered by 0.22 μm membrane (Millipore Inc.) before detection.

2.2. Apparatus and instrumentation

Cyclic voltammetric and chronoamperometric experiments were carried out using a CHI 900 electrochemical workstation (Austin, TX, USA). The three-electrode system consists of a Ni-BPE working electrode, an Ag/AgCl of reference electrode, and a platinum or stainless tube auxiliary electrode. The Ni-BPE (1.25 mm diameter, 31 mm length) with an average weight of 392.2 ± 0.5 mg ($n = 10$) was a special order from Zensor R&D (Taichung, Taiwan). The geometric surface area of the Ni-BPE was ~ 0.012 cm².

Scheme 1 shows typical pictures of the Ni-BPE working system used in this work. It consists of a Ni-BPE working electrode, a stainless tube counter electrode (outlet), an Ag/AgCl reference electrode. The flow injection analysis (FIA) system was equilibrated in 0.1 M NaOH carrier solution at +0.5 V until the current became constant. The



Scheme 1. Scheme and pictorial representation of the proposed flow injection electrochemical detector setup.

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