

# Determination of trace amounts of gold(III) by cathodic stripping voltammetry using a bacteria-modified carbon paste electrode

Communication

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A bacteria-modified carbon paste electrode has been prepared and used for the very sensitive and selective determination of trace amounts of gold(III). The modified electrode was able to detect a solution of 1.0 ppb Au(III) by applying cathodic stripping voltammetry. Advantages of the bacteria-modified electrode include high sensitivity, good stability, low cost and simple preparation. It could be a new class of modified electrode with practical value.

The determination of trace amounts of metal ions by electrochemical analysis can be improved by using chemically-modified electrodes in stripping analysis.<sup>1–5</sup> The use of bacteria-modified electrodes has been reported for the determination of enzyme<sup>6</sup> and BOD (biochemical oxygen demand).<sup>7</sup> Other biomasses such as lichen have been used to prepare modified electrodes for the determination of metal ions,<sup>8</sup> but there is no report on the use of bacteria-modified electrodes in the determination of metal ions. Here we introduce a novel method for the preparation of a bacteria-modified carbon paste electrode for the determination of gold(III). Previously, bacteria have been employed to adsorb the compounds of gold and other metals in order to recover the noble metals or treat waste water<sup>9,10</sup> since some bacteria are able to concentrate the metal ions. Now we adopt the bacteria to prepare an electrode with high sensitivity and selectivity for the determination of trace amounts of gold(III). Under the tested conditions, a good linear dependence between the peak current and the gold(III) concentration in the range of 10–85 ppm has been obtained. The preparation method is simple and the obtained electrode is stable.

## Experimental

The bacteria were isolated from the soil of mining areas. The bacterial biomass D01 was screened out from different bacterial biomasses because it has a strong ability for adsorbing Au(III) and grows well in a medium containing 600 mg l<sup>-1</sup> Au(III). The bacterial biomass D01 is gram-positive and was identified as *Bacillus megatherium* D01. It is easy to obtain and culture. The biomass D01 was cultured in a water solution containing beef gels, peptone and salt *etc.* It was separated by centrifugation and washed with deionized water and alcohol before use.

All of the detection experiments were conducted in a solution of KCl (0.1 M). The pH value of the solution was adjusted by 0.1 M HCl solution. Solutions of AuCl<sub>3</sub> at varying concentrations were used as standard samples. All chemicals were of analytical grade. Deionized water was further double distilled.

Voltammetric experiments were performed using a 8511A potentiostat (Yanbian Yongheng, China). To prepare the working electrode, 100 mg D01 was mixed with 1.4 g graphite and 0.2 g paraffin wax. The mixture was ground thoroughly in a mortar. This modified paste was pressed into a Teflon film

tube, with a copper stick providing electrical contact. The electrode was carefully polished and cleaned before use. Surface renewal was achieved by replacement of the superficial material with a small amount of freshly prepared modified paste. A saturated calomel electrode (SCE) was used as a reference electrode and a platinum electrode was used as a counter electrode for all experiments, thus potentials are quoted vs. SCE. The three electrodes were placed into a solution of AuCl<sub>3</sub> and pre-concentrated at +0.75 V for 10 min. The solution was purged with N<sub>2</sub> in order to remove the oxygen for 10 min, and then a voltage scan was conducted at a speed of 100 mV s<sup>-1</sup> from +0.75 V to -0.25 V.

## Results and discussion

Fig. 1 shows the cathodic stripping voltammetric curves obtained in a solution of 84.7 ppm AuCl<sub>3</sub> with a carbon paste electrode with and without bacteria-modification. One can see that there is a peak at 350 mV, corresponding to the reduction of Au(III). The peak current detected by the bacteria-modified carbon paste electrode is about 280 μA, which is much stronger than that detected by the unmodified one, which is about 110 μA. This result indicated that the bacteria-modified electrode is much more sensitive than the unmodified electrode. The cathodic stripping voltammetric curve obtained with the electrode for a solution of 1.0 ppb Au(III) is shown in Fig. 2. Although a background current (of about 3.0 μA) does exist, a peak with *ca.* 0.8 μA peak current appears obviously in the curve. In other words, the electrode can determine 1.0 ppb Au(III) in the solution. The sensitivity is much higher than that reported by other authors up till now.<sup>1,3</sup> Another experiment using the bacteria-modified electrode to determine a solution

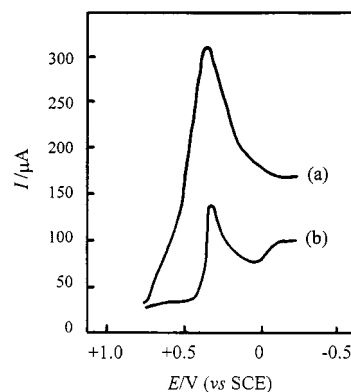
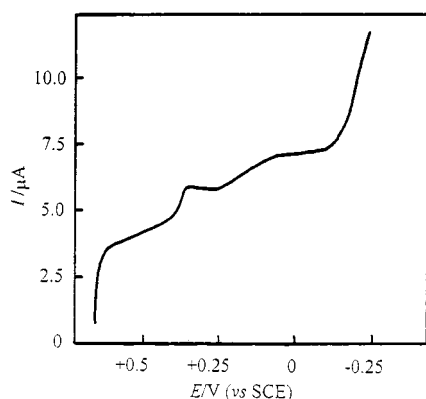
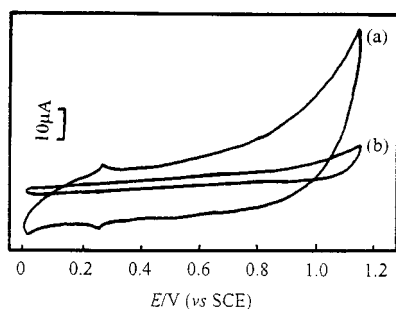


Fig. 1 Cathodic stripping voltammetric curve in a solution of 84.7 ppm AuCl<sub>3</sub> (pH 1.18) with (a) bacteria-modified and (b) unmodified carbon paste electrode.

containing Ag(I) or Cu(II) showed that there is no reduction peak corresponding to Ag(I) or Cu(II) in the detection range. These results indicated that the bacteria-modified electrode is both sensitive and selective for the determination of Au(III). In order to examine the reproducibility, the electrode was renewed with freshly prepared bacteria-modified paste before every test. A solution of 84.7 ppm Au(III) was detected 6 times. The relative standard deviation was 3.4%, showing that the electrode is precise. The electrode has also been used to determine solutions of Au(III) at varying concentrations. The results show that the position of the reduction peak is not changed with the concentration of Au(III), while the strength of the peak current is in good linear dependence with the concentration of Au(III). The relationship of the peak current ( $I_{pk}$ ,  $\mu\text{A}$ ) and the



**Fig. 2** Cathodic stripping voltammetric curve in a solution of 1 ppb  $\text{AuCl}_3$  with bacteria-modified electrode.



**Fig. 3** Voltammetric curves in a background solution of HCl at pH 4.0 with (a) bacteria-modified and (b) unmodified carbon paste electrode.

concentration of Au(III) ( $[\text{Au}]$ , ppm) can be described by the following equation:

$$I_{pk} = 3.165[\text{Au}] + 9.646$$

The relation coefficient is 0.99945.

The above results clearly show that we have obtained by a simple method a highly sensitive and selective bacteria-modified electrode. The role of the bacteria has been proved to be helpful for the adsorption and reduction of Au(III) on the electrode surface, thus increasing the sensitivity of the electrode. We have also demonstrated that the stripping current increased with both the pre-concentration time and the amount of bacteria (with bacteria < 7%). Furthermore, in a background solution of HCl at pH 4.0, a peak positioned at 0.25 V appeared in the voltammetric curve with the bacteria-modified carbon paste electrode. In contrast, there is no peak in the curve with the unmodified electrode (Fig. 3). This indicates that the biomass D01 itself is reduced electrochemically. The reduction potential (0.25 V) of D01 confirmed that the D01 is able to reduce Au(III). This is beneficial for the electrochemical reduction of Au(III) on the surface of the electrode. The concentration and reduction of Au(III) by the bacteria increased the sensitivity of the electrode in cathodic stripping.

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