



Contents lists available at ScienceDirect

## Waste Management

journal homepage: [www.elsevier.com/locate/wasman](http://www.elsevier.com/locate/wasman)

# Electrochemical extraction of gold from wastes as nanoparticles stabilized by phospholipids

Hiroshi Moriwaki<sup>a,b,\*</sup>, Kotaro Yamada<sup>a</sup>, Hisanao Usami<sup>c</sup>

<sup>a</sup> Shinshu University, Faculty of Textile Science and Technology, Division of Applied Biology, 3-15-1, Tokida, Ueda 386-8567, Japan

<sup>b</sup> Shinshu University, Division of Instrumental Analysis (Ueda branch), Research Center for Supports to Advanced Science, 3-15-1, Tokida, Ueda 386-8567, Japan

<sup>c</sup> Shinshu University, Faculty of Textile Science and Technology, Division of Chemistry and Materials, 3-15-1, Tokida, Ueda 386-8567, Japan

## ARTICLE INFO

## Article history:

Received 7 April 2016

Revised 7 July 2016

Accepted 7 July 2016

Available online xxxx

## Keywords:

E-waste

Gold extraction

AC voltage

Phospholipid

Gold nanoparticles

## ABSTRACT

A simple one-step method for the extraction of gold from wastes as nanoparticles stabilized by phospholipids is demonstrated. This is achieved by applying an AC voltage for 5 s to the gold-containing wastes, which act as the electrodes in a buffer solution containing a dispersed phospholipid (1,2-dioleoyl-*sn*-glycero-3-phosphocholine, DOPC). This is an environmentally friendly and rapid method for recovering gold from wastes. The extracted gold nanoparticles have significant potential as a catalyst or biomedical material.

© 2016 Elsevier Ltd. All rights reserved.

## 1. Introduction

Gold has been widely used in various electronic components because of its high electric conductivity, ductility, and resistance to oxidative corrosion (Akçil et al., 2015; Vats and Singh, 2015). However, the average grade of gold ore has shown a declining trend; thus, the sustainability of gold has become a concern (Mudd, 2007). Under such circumstances, the establishment of a technique to recover gold from gold-containing wastes is needed. The conventional technology for the recovery of gold from wastes is pyro-metallurgical processing. However, this process is expensive due to the requirement for the exhaust gas treatment and the massive amount of energy required (Cui and Zhang, 2008; Jadhav and Hocheng, 2012). On the other hand, hydrometallurgical treatments for the recovery of gold from wastes generally use toxic reagents, such as strong acids, cyanide, and thiourea (Córtes et al., 2015). Consequently, a reduction of the environmental burden for this process is recommended (Birloaga et al., 2013).

Gold has been frequently used in electronic components and also as a catalyst. Because of the unique catalytic properties of gold nanoparticles (Chowdhury et al., 2006; Turner et al., 2008), various production methods have been developed. Most gold nanoparticles

are prepared by mixing chloroauric ions ( $\text{AuCl}_4^-$ ) with a reducing agent, such as borohydride, citric acid, or ascorbic acid, and a stabilizing agent. Various compounds, such as amine compounds and amino acids, have been used as the stabilizing reagent (Aslam et al., 2004; Selevakannan et al., 2003).

Recently, a method was developed for the preparation of gold nanoparticles, which involves applying an AC voltage to metal electrodes in an electrolyte solution containing a water-soluble polymer dispersant and a reducing agent was developed (KR Pat., 2010).

In this study, a method for the extraction of gold from waste electrical and electronic equipment (WEEE) as nanoparticles stabilized with phospholipids is suggested. The method is very simple. An AC voltage is applied for 5 s to a pair of electrodes formed from wastes containing gold in a 4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid (HEPES) buffer solution containing 1,2-dioleoyl-*sn*-glycero-3-phosphocholine (DOPC). The gold is then extracted from the wastes without using any expensive equipment or applying toxic reagents. Finally, gold nanoparticles stabilized by the DOPC are obtained.

## 2. Materials and methods

### 2.1. Materials

Sodium chloride, HEPES, and DOPC were purchased from Wako Pure Chemical Industries (Osaka, Japan). Pure water was prepared

\* Corresponding author at: Shinshu University, Faculty of Textile Science and Technology, Division of Applied Biology, 3-15-1, Tokida, Ueda 386-8567, Japan.

E-mail address: [moriwaki@shinshu-u.ac.jp](mailto:moriwaki@shinshu-u.ac.jp) (H. Moriwaki).

using an automatic water distillation apparatus (MQ Academic A10, Millipore, Billerica, MA, USA).

## 2.2. Method for the extraction of gold

A schematic of the system used for the extraction of gold in this study is shown in Fig. 1. Both the positive and negative terminals of a variable autotransformer (RIKO-Slidetrans RSA-10, Tokyo Rikosha Co., Ltd., Tokyo, Japan) were connected to a pair of gold wires or wastes containing gold. The variable autotransformer plug was inserted in the socket of an AC source at 60 Hz. The DOPC suspension (10 mM) was extruded 25 times through a 50 nm polycarbonate filter, using a mini-extruder (Avanti Polar Lipid, Alabaster, AL, USA) to form a lipid bilayer (Miyano et al., 2010). The DOPC suspension was diluted with an HEPES buffer aqueous solution (HEPES; 10 mM, NaCl; 0.15 M) to a concentration of 500  $\mu$ M. The obtained liquid (4 mL) was poured into a 3 cm diameter petri dish. The gold electrodes were immersed in the liquid with a distance of 0.8 mm between them. An AC voltage of 100 V was then applied to the pair of gold electrodes for 5 s. During the energizing process, gas bubbles were generated, and the color of the liquid turned purple. On the other hand, the surface color of the gold electrodes did not change at all, while the temperature of the liquid increased from 19 to 44 °C. In addition, the pH of the reaction liquid was not significantly changed by energizing for 5 s. The pH of the liquid was around 7.4 before and after energizing. All the processes were carried out in fume hoods.

## 2.3. Characterization of gold nanoparticles

The UV spectrum of the liquid by power distribution was measured using a UV–visible spectrophotometer (300–800 nm, V-630 spectrometer, JASCO Corporation, Tokyo, Japan). The particle size distribution of the suspension was measured by dynamic light scattering using a Zetasizer NanoSeries (Malvern Instruments Limited, Worcestershire, UK). After centrifuging the suspension at 12,000 rpm (11,800g) for 3 min (MCD-2000, Hsiang Tai, New Taipei, Taiwan), the residue was washed once with distilled water and dried. The obtained solid was placed on a specimen support and visualized under low-vacuum conditions by scanning electron microscopy (SEM; JSM-6010LA; JEOL, Tokyo, Japan). In addition, the elemental composition of the sample was measured by energy dispersive X-ray fluorescence analysis (EDX). The particle diameter of the prepared gold nanoparticles was determined by TEM using a JEM-2100 (JEOL, Tokyo, Japan) at an operating voltage of 200 kV. The sample was dispersed in distilled water by ultrasonic irradiation. The suspension (10  $\mu$ L) was dropped on a carbon-coated

copper grid (200 mesh, JEOL, Tokyo, Japan), followed by drying. The gold concentration in the deposit was measured by ICP atomic emission spectrometry (SPS 3100; SSI Nanotechnology, Tokyo, Japan).

## 3. Results and discussion

### 3.1. Formation of gold nanoparticles from gold wires by energizing AC voltage

The UV–vis spectrum of the liquid obtained from gold wires using the presented method is shown in Fig. 2. A peak value of 540 nm, assignable to the absorption by the surface plasmon resonance of the gold nanoparticles, was observed. A deposit was obtained by centrifuging, and the deposit was dispersed by adding distilled water and subjecting it to the ultrasonic irradiation. The obtained purple suspension was analyzed by dynamic light scattering, and the size distribution was found to be  $17.4 \pm 4.21$  nm. After centrifuging the suspension again, the supernatant was discarded. The residue was then freeze-dried. The weight of the solid substance was 1.4 mg. The solid was dissolved in nitrohydrochloric acid, and the gold concentration of the solution was analyzed by ICP. The content of gold in the deposit was 5.7 wt%. In addition, the deposit was analyzed by SEM-EDX. The results showed that the deposit included gold and phosphorus (Fig. 3). The other component of the deposit was the DOPC surrounding the gold nanoparticles.

Fig. 4a and b show TEM photographs of the obtained deposit. Nanosized particles were observed by TEM. These particles were spherical, and the mean diameter was 13.9 nm with a standard deviation of 5.7 nm (Fig. 4a). The diameter obtained from the TEM measurement was similar to that from the dynamic light scattering technique. In addition, lattice fringes of 0.23 nm were observed, which are consistent with those of the Au(1 1 1) crystal plane (0.235 nm, Fig. 4b). Therefore, it was concluded that the obtained solid contained gold nanoparticles. In addition, there is a section, where a diffraction pattern does not appear around the gold nanoparticles (Fig. 4b) but was suspected to consist of non-metallic substances. This result indicates that the gold particles are included in the phospholipid bilayer of the DOPC. Previously, gold nanoparticles formed on the surface of a bilayer of DOPC have been reported (Sau et al., 2009). However, to the best of our knowledge, no reports on the preparation of gold nanoparticles capped by a bilayer of DOPC have been published. The purple suspension

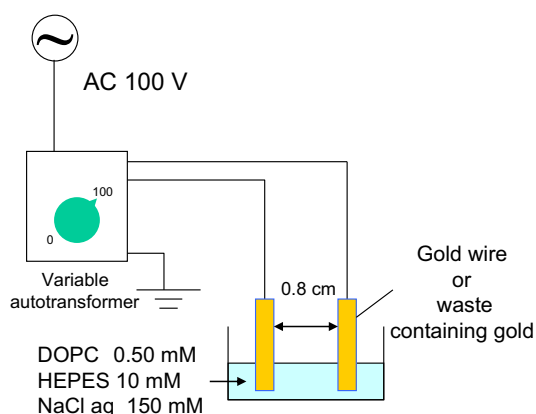


Fig. 1. A schematic of the system used for the extraction of gold.

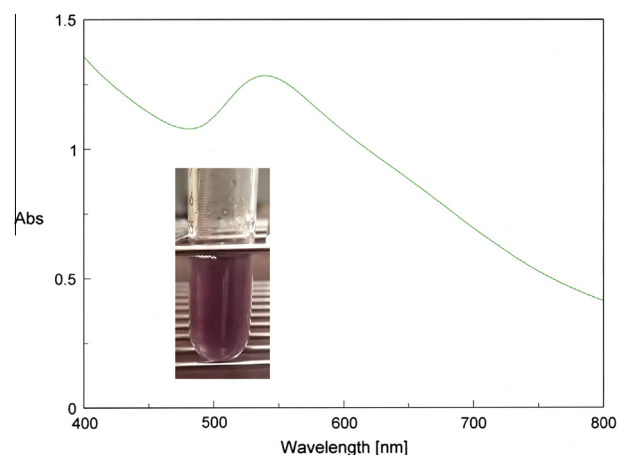


Fig. 2. UV–vis absorption spectrum of the gold nanoparticle suspension (The electrolyte solution: 500 mM DOPC, 10 mM HEPES, 150 mM NaCl). The inset shows a picture of the obtained suspension.

Download English Version:

<https://daneshyari.com/en/article/5756819>

Download Persian Version:

<https://daneshyari.com/article/5756819>

[Daneshyari.com](https://daneshyari.com)