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Electrodeposition Mechanism and Process of a Novel Cyanide-Free Gold Sulfite Bath

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Ig Li, Zhao-Yun Wang, Fang-Zu Yang*,

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Solid Surfaces, 2022, 28(7), 2213005 (1 of 8)

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(College of Chemistry and Chemical Engin **EXECTS ANDER CYATHIGE-FREE GOIG SUITITE BAITI

Fra-Qiang Yang, Lei Jin, Wei-Qing Li, Zhao-Yun Wang, Fang-Zu Yang^{*},

Dong-Ping Zhan^{*}, Zhong-Qun Tian

(College of Chemistry of Chemical Engineering; State Key Laboratory** College of Chemistry and Chemical Engineering, State Key Laboratory of Physical Chemistry of

Solid Surfaces, Xiamen University, Xiamen, 361005, China)

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Abstract: A novel cyanite-free gold sulfite process is introduced in this paper. In the bath, chloouric oricle was directly em-

ployed as the main salt, and **Abstract:** A novel cyanide-free gold sulfite process is introduced in this paper. In the bath, chlouric acid was directly em-
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iron, cobalt, nickel or other metals, is known for the been reported in the last wenty years.
excellent wear res **1 Introduction** sulfite bath has been applied in industrial manufac-

Pure gold (soft gold) exhibits excellent electrical and curring. Furthermore, Au(III) eyanide-free gold plating

hermal conductivity, ductility, welds **coluction**

sulfite bath has been applied in industrial manufac-

inedepthy (sulfit) gy weldability and corro-

processes such as 5,5-dimethyllydentoin bath^{113,11},

istance. Gold alloy (hard gold), doped with

hypoxant that HFDP could significantly improve the bath stabitisty. Moreover, the grains of the gold existed from the gold significant from the sperame of the couling the are extensively improve the bath stability with the interess but with the beaches, which are not also that the merestor of the deposited of the couling the actual particle, which are the packing of the deposited into the papel state and but the merestor of the couling thickness. As or an exourty word and y pure three comes are considered to the consideration boy a matter and the principle in
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case of the conting this case, the conting th when the gons same, the gon graduate may also that the galacteron in the gold paint and graduate the cosing thickness was much side to the cosing thickness was much side to the cosing the bold paints; leads the paint of within 1 µm thickness. Electrochemical curves indicated that gold electrodeposition did not undergo a nucleation stage.
 Key words: cyanide-free gold plating; gold sulfite: hydroxyethylidene diphosphonic acid; electrode When I untunceness exercedential end good electrochesion not indicent such a such that the main are the main August (Section and the main are the main August 11 **Introduction** sulfite bath has been applied in industrial m **1 Introduction**
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1 Introduction sulfite bath has been applied in industrial manufac-

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by the increase of the coating thickness. As HEDP was intro-
byzmidal, and the grain growth ra reasing of the deposition time, resulting in that the appearance
by the increase of the coating thickness. As HEDP was intro-
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symmidal, and the grain growth rate accompanying the increase

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deposition did not undergo a nucleation stage.

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sulfite bath has been applied in industrial manufac-

turin idene diphosphonic acid; electrodeposition; gold coating
sulfite bath has been applied in industrial manufac-
turing. Furthermore, Au(III) cyanide-free gold plating
processes such as 5,5-dimethylhydantoin bath^{[13,12}],
h **Example 19** and subsets in industrial manufacturing. Furthermore, Au(III) cyanide-free gold plating processes such as 5,5-dimethylhydantoin bath^[13,14], hypoxanthine bath^[13,14] and theophylline bath^[15] have been cosity of bath and sulfur inclusions in gold coating^[17].

 $\text{#E}\#$ (*J. Electrochem.*) 2022, 28(7), 2213005 (2 of 8)

To address these issues, Osaka et al.^[8, 9, 18] introduced sulfite immediately. Finally, the addictive was added

thiosulfate into gold sulfite baths to form g the $\#U$ *Electrochem.*) 2022, 28(7), 2213005 (2 of 8)

To address these issues, Osaka et al.^[8, 9, 18] introduced sulfite immediately. Finally, the addictive was added

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thiosulfate into gold suffice banks to form gold-sulfite immediately. Finally, the additive was added
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fite-thiosulfate mixed-ligand complex to improve the
both stability. He et al.^[8] added citrate amine to the
Gold electrodeposition was performed in the gold
gold suffice bath to increase the bath stability and re-
smified the grain of gold coating.
In our previous work, chlouare acid was directly
the main salt in the gold suffice bath^{[1}$ th \mathbb{R}^n (*Letrochem.*) 2022, 28(7), 2213005 (2 of 8)

To address these issues, Osaka et al.^[8,9,18] introduced sulfrite immediately. Finally, the addictive

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 ED address these issues, Osaka et al.^{18,9,38} introduced sulfite immediately. Finally, the addictive was added

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and the pH

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To address these issues, Osaka et al.^{ps, sm} introduced sulfite immediately. Finally, the addictive was added

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To address these issues, Osaka et al.^{80,80} introduced sulfite immediately. Finally, the addictive was added

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To address these issues, Osaka et al.^{18, a}¹⁸¹ introduced and the pH was adjusted to 9.0.

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sulfate into gold sulfite baths to form gold-sul-
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2.2 Galvanostatic Electrodeposition

Shah stability: He ct al.¹⁸ added cirate amine to the

gold electrodeposition was performed in the gold

gold stabilite bath to bath stability; He et al.⁶⁸ added cirrate amine to the

Gold electrodeposition was performed in the gold

gold sulfite bath o increase the bath stability and re-

sulfite bath on a watt nickel or represented cooper shoet gold sulfite bath to increase the bath stability and re-

inter bath on a watt nickel pre-plated copper sheet

In our previous work, chloauric acid was directly

A -dm⁻¹, \sim 1, 9.0 and current densities of 0.1 ~ 1.1
 fine the grain of gold coating.

In our previous work, chloantic acid was directly

at the candric A chainity and eurerat densities of 0.1 ~ 1.1

Im our previous work, cholonaric acid was directly

Our results showed that In our previous work, chloauric acid was directly A -dm². A platinum plated titanium mesh was served
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chlor employed as the main salt in the gold sulfite bath¹⁰⁹.

Our results showed that by the interdeduction of the ingle the electrodeposition.

Our results showed that by the interdeduction of the ingle the stability of the Our results showed that by the introduction of the ing the electrodeposition.

cholordic ions from chloanter eaid, the stability of the 2.3 **Coating Characterizations**

egold sulfite bath was improved, meanwhile, the clechloride ions from chloauric acid, the stability of the **2.3 Coating Characterizations**
gold sulfite bath was improved, meanwhile, the elec-
treeduction of gold ions was promoted and the eco-
The coating thicheness was me gold sulfite bath was improved, meanwhile, the clee-

The coating thickness was measured vie

troreduction of gold ions was promoted and the coat-

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sulfite was suppres grain was fine. In our another previous work, we
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nothic acid (HEDP) at the solid variet soliton in \bullet 2.4 Electrochemical Measurements

phonic acid (HEDP) at the solid variet soliton in \bullet 2.4 Electrochemical ofton phonic acid (HEDP) at the solidwater solution in-

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erefore and particular conditions and the devel-

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sulfite immediately. Finally, the addictive was added
and the pH was adjusted to 9.0.
2.2 Galvanostatic Electrodeposition
Gold electrodeposition was performed in the gold
sulfite bath on a watt n 电化学(*J. Electrochem.*) 2022, 28(7), 2213005 (2 of 8)

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28(7), 2213005 (2 of 8)

sulfite immediately. Finally, the addictive was added

and the pH was adjusted to 9.0.
 2.2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

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2.2 Galvanostatic Electrodeposition

3.2 Galvanostatic Electrodeposition

3.2 Galvanostatic Electrodeposition

5.2 Galvanostatic Electrodeposition

5.2 Galvanostatic Electrodeposition

5.2 Galva S(7), 2213005 (2 of 8)

fite immediately. Finally, the addictive was added

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 2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

fite bath on a watt nickel 9. 28(7), 2213005 (2 of 8)

sulfite immediately. Finally, the addictive was added

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 2.2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

sulfite bath on 28(7), 2213005 (2 of 8)
sulfite immediately. Finally, the addictive was added
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Gold electrodeposition was performed in the gold

sulfite bath on a 28(7), 2213005 (2 of 8)

sulfite immediately. Finally, the addictive was added

and the pH was adjusted to 9.0.
 2.2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

sulfite bath on a w $(28(7), 2213005 (2 \text{ of } 8))$

sulfite immediately. Finally, the addictive was added

and the pH was adjusted to 9.0.
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composition**

Gold electrode

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2.2 Compression of the parameterization of the parameterization of the parameterization

2.2 Galvanostatic Electrodeposition

4.2 Calvanostatic Electrodeposition

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If the immediately. Finally, the addictive was added

d the pH was adjusted to 9.0.
 2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

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and the pH was adjusted to 9.0.
2.2 Galvanostatic Electrodeposition
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sulfite bath on a watt n $\frac{1}{28(7)}$, $\frac{2213005(2 \text{ of } 8)}{222}$

sulfite immediately. Finally, the addictive was added

and the pH was adjusted to 9.0.
 2.2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

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sulfite immediately. Finally, the addictive was added

and the pH was adjusted to 9.0.
 2.2 Galvanostatic Electrodeposition

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and the pH was adjusted to 9.0.
2.2 Galvanostatic Electrodeposition
Gold electrodeposition was performed in the gold
sulfite bath on a watt **EXECUTE:** Example 1.1 Finally, the addictive was added

and the pH was adjusted to 9.0.
 2.2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

sulfite bath on a watt nickel pre-plated c lfite immediately. Finally, the addictive was added
d the pH was adjusted to 9.0.
2 Galvanostatic Electrodeposition
Gold electrodeposition was performed in the gold
lfite bath on a watt nickel pre-plated copper sheet
45

terface ⁽³⁸). Researches on the mechanism of the devel-
open is surrenties and chronoamperometric mea-
open gold plating process are of great importance in surrenties were carried out on an Autoloh PGSTAT30
open grad pr oped gold plating process are of great importance in surements were carried out on an Autolab PGST.

theory and practics. In this paper, we further intro-

theoretic and overload ecl. A gold electrode cell. A gold electro and the pH was adjusted to 9.0.
 2.2 Galvanostatic Electrodeposition

Gold electrodeposition was performed in the gold

sulfite bath on a watt nickel pre-plated copper sheet

at 45 °C, pH 9.0 and current densities of 0 2.2 **Galvanostatic Electrodeposition**

Gold electrodeposition was performed in the gold

sulfite bath on a watt nickel pre-plated copper sheet

at 45 °C, pH 9.0 and current densities of $0.1 \sim 1.1$

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sulfite bath on a watt nickel pre-plated copper sheet
at 45 °C, pH 9.0 and current densities of $0.1 \sim 1.1$
A -dm². A platinum plated titanium mesh was served
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A·dm². A platinum plated titanium mesh was served
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ing t h on a watt nickel pre-plated copper sheet
pH 9.0 and current densities of $0.1 \sim 1.1$
platinum plated titanium mesh was served
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ctrodeposition.
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there at 45 °C, pH 9.0 and current densities of $0.1 \sim 1.1$

A \cdot dm². A platinum plated titanium mesh was served

as the anode and the solution was stirred slightly dur-

ing the electrodeposition.
 2.3 Coating Characteriz A \cdot dm². A platinum plated titanium mesh was served
as the anode and the solution was stirred slightly dur-
ing the electrodeposition.
2.3 Coating Characterizations
The coating thickness was measured via a XAN-
DPP as the anode and the solution was stirred slightly during the electrodeposition.

2.3 Coating Characterizations

The coating thickness was measured via a XAN-

DPP X-ray fluorescence spectrometer (Fischer, Germany). The s ing the electrodeposition.

2.3 **Coating Characterizations**

The coating thickness was measured via a XAN-

DPP X-ray fluorescence spectrometer (Fischer, Germany). The surface morphology of the gold coating

was recorded 2.3 **Coating Characterizations**
The coating thickness was measured via a XAN-
DPP X-ray fluorescence spectrometer (Fischer, Ger-
many). The surface morphology of the gold coating
was recorded by a scanning electron micros The coating thickness was measured via a XAN-

DPP X-ray fluorescence spectrometer (Fischer, Germany). The surface morphology of the gold coating

was recorded by a scanning electron microscope (HI-

TACHI S-4800, Japan). DPP X-ray fluorescence spectrometer (Fischer, Germany). The surface morphology of the gold coating
was recorded by a scanning electron microscope (HI-
TACHI S-4800, Japan).
2.4 Electrochemical Measurements
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was recorded by a scanning electron microscope (HI-
TACHI S-4800, Japan).
2.4 Electrochemical Measurements
Cyclic voltammetric and chronoamperometric mea-
surements were is recorded by a scanning electron microscope (HI-CHI S-4800, Japan).
 4 Electrochemical Measurements

Cyclic voltammetric and chronoamperometric mea-

rements were carried out on an Autolab PGSTAT30

tentiostat in a th TACHI S-4800, Japan).
 2.4 Electrochemical Measurements

Cyclic voltammetric and chronoamperometric mea-

surements were carried out on an Autolab PGSTAT30

potentiostat in a three-electrode cell. A gold electrode

with 2.4 Electrochemical Measurements

Cyclic voltammetric and chronoamperometric mea-

surements were carried out on an Autolab PGSTAT30

potentiostat in a three-electrode cell. A gold electrode

with 3 mm diameter, a platinu Cyclic voltammetric and chronoamperometric mea-
surements were carried out on an Autolab PGSTAT30
potentiostat in a three-electrode cell. A gold electrode
with 3 mm diameter, a platinum foil and a Hg/HgO
(1 mol ·L¹ KOH) surements were carried out on an Autolab PGSTAT30
potentiostat in a three-electrode cell. A gold electrode
with 3 mm diameter, a platinum foil and a Hg/HgO
(1 mol \cdot L⁻¹ KOH) electrode were employed as the
working ele lab PGSTAT30

A gold electrode

and a Hg/HgO

mployed as the

e and reference

ele ctrochemical

polished by alu-

of 0.3 mm and

nically rinsed in

ain problems to

To investigate

ility, we varied

saic gold sulfite
 $\$

ory and practice. In this paper, we further intro-

potentiostat in a three-electrode cell. A gold electrode

ce a novel cyntaine ceid was directly employed as the

units ameliance and Higrargo

cesess, chloautric ecid wa \cdot ¹ mol \cdot L⁻¹, addictive 0.01 mL \cdot L⁻¹). Figure 1 shows the duce a novel cyanide-free gold sulfite process. In the with 3 mm diameter, a platinum foil and
process, cholourie acid was directly employed as the acid working electrode, contrelected content
(HEDP) acted as the stabiliz old sulfite process. In the with 3 mm diameter, a platinum foil and a Hg/HgO
directly employed as the directly employed as the directived end reference deferred end probable and referred end referred end referred end refe process, chloauric acid was directly employed as the

main salt, and hydroxyethylidene diphosphonic acid

(HEDP) acted as the stabilizer and coating grain re-

(HEDP) acted as the stabilizer and coating grain re-

electro I was directly employed as the (1 mol \cdot L⁻¹ KOH) electrode were employed as the vorbig electrode, conter electrode, conter electrode and reference stabilizer and conting grain re-
electrode, respectively. Before each main salt, and hydroxyethylidene diphosphonic acid working electrode, counter electrode and reference

dHEDP ated as the stabilizer and coating grain re- electrode, respectively. Before each electrodentical

finer. Based (HEDP) acted as the stabilizer and coating grain re-

electrode, respectively. Before each electrochemical

finer. Based on the process, the bult stability, the measurement, the gold electrode as posibled by a

imorpholog finer. Based on the process, the bath stability, the measurement, the gold electrode was polished by alu-
morphology of gold coating and the mechanism of min supersion with the diameters of 0.3 mm and
gold clectrodepositi morphology of gold coating and the mechanism of

and asyspension with the diameters of 0.3 mm and

gold electrodeposition were studied in detail. 0.05 mm separately, and then ultrasonically rinsed in
 2. I Regents and So gold electrodeposition were studied in detail.

20.05 mm separately, and then ultrasonically rinsed in

2.1 **Experimental Section**

2.1 **Experimental Section**

2.1 **Regents and Solutions**

3 **Results and Discussion**

HAuC **2 Experimental Section**
 2. Expension and Solutions
 2. The expension and Solutions
 3. Results and Solutions
 3. Results Stability

by Sinopharm Chemical Reagent Co. Ltd. (China). Ity-

Poor bath stability is on ostat in a three-electrode cell. A gold electrode
mm diameter, a platinum foil and a Hg/HgO
 \cdot L⁻¹ KOH) electrode were employed as the
g electrode, counter electrode and reference
de, respectively. Before each electroc e cell. A gold electrode
um foil and a Hg/HgO
were employed as the
lectrode and reference
e each electrochemical
de was polished by alu-
meters of 0.3 mm and
ultrasonically rinsed in
SiON
f the main problems to
process. with 3 mm diameter, a platinum foil and a Hg/HgO

(1 mol \cdot L⁻¹ KOH) electrode were employed as the

working electrode, counter electrode and reference

electrode, respectively. Before each electrochemical

measuremen (1 mol \cdot L⁻¹ KOH) electrode were employed as the
working electrode, counter electrode and reference
electrode, respectively. Before each electrochemical
measurement, the gold electrode was polished by alu-
mina suspe Examployed as the

code and reference

check the ectrochemical

vas polished by alu-

ers of 0.3 mm and

assonically rinsed in
 nn
 nn working electrode, counter electrode and reference
electrode, respectively. Before each ele ctrochemical
measurement, the gold electrode was polished by alu-
mina suspension with the diameters of 0.3 mm and
0.05 mm separa electrode, respectively. Before each electrochemical
measurement, the gold electrode was polished by alu-
mina suspension with the diameters of 0.3 mm and
0.05 mm separately, and then ultrasonically rinsed in
thanol and u measurement, the gold electrode was polished by alu-
mina suspension with the diameters of 0.3 mm and
0.05 mm separately, and then ultrasonically rinsed in
thanol and ultrapure water.
3 Results and Discussion
3.1 Bath mina suspension with the diameters of 0.3 mm and
0.05 mm separately, and then ultrasonically rinsed in
ethanol and ultrapure water.
3 **Results and Discussion**
3.1 **Bath Stability**
Poor bath stability is one of the main pr 0.05 mm separately, and then ultrasonically rinsed in ethanol and ultrapure water.
 3 Results and Discussion
 3.1 Bath Stability

Poor bath stability is one of the main problems to

be solved for the gold sulfite proc ethanol and ultrapure water.
 3 Results and Discussion
 3.1 Bath Stability

Poor bath stability is one of the main problems to

be solved for the gold sulfite process. To investigate

the effect of HEDP on the bath st ever, the gold sulfite solutions with $0.025 \text{ mol} \cdot L^{-1}$ and

 $# \&\nexists (J. \t{Electrochem.}) 2022, 28(7), 2213005 (3 of 8)$
0.050 mol⋅L⁻¹ HEDP remained colorless and transparent (Figure 1b and Figure 1c). Obviously, the stability
of gold sulfite solution is significantly improved by
HEDP, which the ℓ^2 (*L* Electrochem.) 2022, 28(7), 2213005 (3 of 8)

0.050 mol·L⁻¹ HEDP remained colorless and transpar-

ent (Figure 1b and Figure 1c). Obviously, the stability

of gold sulfite solution is significantly improv the $\{k\}^{\omega}(I. \nElectrochem.)$ 2022, 28(7), 2213005 (3 of 8)

0.050 mol·L⁺¹ HEDP remained colorless and transpar-

ent (Figure 1b and Figure 1c). Obviously, the stability

of gold sulfite solution is significantly improved by
 $\frac{4E}{E^2(L \: \text{Electrochem.})}$ 2022, 28(7), 2213005 (3 of 8)

0.050 mol·L¹ HEDP remained colorless and transpar-

ent (Figure 1b and Figure 1c). Obviously, the stability

of gold sulfite solution is significantly improved by
 three reasons: (I) Gold sulfite could be wrapped with

according to the reasons: (I) Gold sulfite could be wrapped with

three reasons: (I) Gold sulfite could be wrapped with

HEDP, which may be attributed to the followi $\frac{d}{dt}\left\{\frac{\partial^2 f}{\partial t} \left(\frac{\partial^2 f}{\partial t} \right) - \frac{\partial^2 f}{\partial t} \left(\frac{\partial^2 f}{\partial t} \right) \right\}$
 $\frac{d}{dt}\left\{\frac{\partial^2 f}{\partial t} \left(\frac{\partial f}{\partial t} \right) - \frac{\partial^2 f}{\partial t} \left(\frac{\partial f}{\partial t} \right) \right\}}{dt}$

on ent (Figure 1b and Figure 1c). Obviously, the stability

of gol the \mathbb{R}^n (*L Electrochem.*) 2022, 28(7), 2213005 (3 of 8)

0.050 mol·L⁻¹ HEDP remained colorless and transpar-

ent (Figure 1b and Figure 1c). Obviously, the stability

of gold sulfite solution is significantly **E** *(E) Electrochem.*) 2022, 28(7), 2213005 (3 of 8)

emained colorless and transpar-

ure 1c). Obviously, the stability

on is significantly improved by

ea attributed to the following

als suffite could be wrapped w **EVALUATION**
 EVALUATION EXECUTE THE MORE CONSTRANS (A) $\frac{1}{2}$ (a) (b) (c)
 EVALUATION EVALUATION EXECUTE CONSTRANS (a) (b)
 EVALUATION EVALUATION EVALUATION EVALUATION EVALUATION
 EVALUATION EV the $\mathcal{R}(L, R)$ etch (and the space of the small coordinate with gold suffice simple and the space of the studies of $\mathcal{R}(L, R)$ and $\frac{E}{E^2}$ (*L Blectrochem*,) 2022, 28(7), 2213005 (3 of 8)

0.050 mol - L¹ HEDP remained colorless and transpar-

ent (Figure 1b and Figure 1e). Obviously, the stability

of gold sulfite solution is significently i **HEDP** considered and transpartion of SQ² to the end state of the pH in solution happens of the pH in solution has a state of the pH in solution has significantly in proved by HEDP, which may be attributed to the follo **EXECUTE THE CONSTRANT CONDUCT**
 EXECUTE THE CONDUCT CONDUCT
 EXECUTE THE CONDUCT CONDUCT
 EXECUTE THE CONDUCT CONDUCT
 EXECUTE THE CONDUCT
 EXECUTE THE CONDUCT
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 EXECUTE THE CONDUCT
 EX 2^2 to SO_4^2 and disproportionation of Au⁺, a decrease of the (a) $\frac{4(2\frac{3\pi}{4}L \text{ K}l) \text{ E}(\text{Ff}(\text{m} \cdot \text{m}))}{4\pi \text{ K}(\text{Ff}(\text{m} \cdot \text{m}))}$
 $\frac{4(2\frac{3\pi}{4}L \text{ K}l) \text{ E}(\text{Ff}(\text{m} \cdot \text{m}))}{4\pi \text{ K}(\text{F}(\text{m} \cdot \text{m}))}$ (a) $\frac{4(2\frac{3\pi}{4}L \text{ K}^2)}{4\pi \text{ K}(\text{m} \cdot \text{m})}$
 $\frac{4(2\$ **E** *(Figure 1 Eigenochem, 2022, 28(7), 2213005 (3 of 8)*

(3) 0.050 mol·L⁴ HEDP remained colorless and transpar-

ent (Figure 1 b and Figure 1c). Obviously, the stability

(b)

(c)

(d)

HEDP, which may be attributed $3SO_3^2 + H_2O \rightarrow Au(SO_3)_2^3 + SO_4^2 + 2H^2$). By keep- \pm /*E* + HEDP remained colorless and transpar-

²igure 1b and Figure 1c). Obviously, the stability

and sulfite solution is significantly improved by

P, which may be attributed to the following

reasons: (I) Gold s th(*k*\\the *K*) the stability

in the difference of the ball in the galacteries of the ball in the properties of the ball in the stability

3. Solved to the following

in the could be wrapped with

in and thus its spont $2(2.2 + 1)$
 $2(2.2 + 2)$
 ing the go- (1) Electrochem.) 2022, 28(7), 2213005 (3 of 8)

ing the grant of triguer 1b and Figure 1e). Obviously, the stability

of gold sulfite solution is significantly improved by

HEDP, which may be attributed to 0.050 mol \cdot L¹ HEDP remained colorless and transpart-

ent (Figure 1 b and Figure 1 e). Obviously, the stability

of gold sulfite solution is significantly improved by

HEDP, which may be attributed to the following
 0.050 mol -L² HEDP remained colorless and transpar-

onf (Egarc 1b and Figure 1c). Obviously, the stability

of gold stailine solution is significantly improved by

HEDP, which may be attributed to the following

HEDP b ent (Figure 1b and Figure 1c). Obviously, the stability

of gold suffite solution is significantly improved by

HEDP, which may be attributed to the following

HEDP by hydrogen bonds and thus its spontaneous

(f) Gold sul of gold sulfite solution is significantly improved by

HEDP, which may be attributed to the following

HEDP by hydrogen bonds and thus its spontaneous

decomposition to SO_i² and Au was hindered^{ial}. (II)

II has been HEDP, which may be attributed to the following

HEDP, which coupled side warped with

HEDP by hydrogen bonds and thus its spontaneous

decomposition to SO₃⁵ and Au⁺ was hindered^[23]. (II)

It has been reported tha three reasons: (1) Gold sulfite could be wrapped with

HEDP by hydrogen bonds and thus its spondance of equal of the dispression of Au-

decomposition to SO_r² and Au⁻ was himdered¹³¹. (11)

thus been reported that HEDP by hydrogen bonds and thus its spontaneous

decomposition to SO₂² and Au' was hindered¹⁵⁰¹. (II)

H has been reported that the molecules with N, P or O

Hence 1 Appearances of the gold sulfite baths after

atom decomposition to SO_i² and Au 'was hindered²³¹. (II)

It has hoce reproted that the molecules with N, P or O
 Eigne 1 Appearances of the gold sulfite baths after keeping

atoms could coordinate with gold ions²²¹.

be wrapped with

its spontaneous

interded^[21], (II)

inderecel^[21], (II)

with N, P or O

Figure 1 Appearances of the gold sulfite baths after keeping

³⁷²¹, Therefore, a

for 4 months: (a) without HEDP; (b) HEDP 0 as been reported that the molecules with N, P or O

Higher 1 Appearances of the gold staffite baths after keeping

ms could coordinate with gold ions²². Therefore, a

discreption in the more contained in the more contai atoms could coordinate with gold ions²⁰. Therefore, a

were months (a) wholon HEDP; (b) HEDP 0.03 mol- $L^+($; (e)

WEDP and Au', (III) During the oxidation of SO₂^{*} to

HEDP and Au', (III) During the oxidation of SO₂ weak coordination interaction may exist between

EDF 0.000 mor-L: (coordination (SO₁² to HEDF) and Au², a decrease of the

min and 20 min in the gold sulfite bath without HEDP

pH in solution happened (3Au² \rightarrow 2 -1 , addictive 0.1 mL窑^L -1) were prepared in a constant current density of 5 matrix (a) without HEDP states above the gold sulfite baths after keeping for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L⁺; (c) HEDP 0.050 mol·L⁺. (color on line) min and 20 min in the gold s (a) (b) (c)

(a) (b) (c)

(c)
 Figure 1 Appearances of the gold sulfite baths after keeping

for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L¹; (c)

HEDP 0.050 mol·L¹. (color on line)

min and 20 min in the gold (a) (b) (c)

It can be seen that the gold suffite baths after keeping

for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L⁺; (c)

HEDP 0.050 mol·L⁻¹. (color on line)

min and 20 min in the gold sulfite bath without H (a) (b) (c)

Figure 1 Appearances of the gold sulfite baths after keeping

for 4 months: (a) without HEDP; (b) HEDP 0.025 mol - L¹; (c)

HEDP 0.050 mol - L⁻¹. (color on line)

min and 20 min in the gold sulfite bath w Figure 1 Appearances of the gold sulfite baths after keeping
for 4 months: (a) without HEDP; (b) HEDP 0.025 mol - L¹; (c)
HEDP 0.050 mol - L¹. (color on line)
min and 20 min in the gold sulfite bath without HEDP
(HAuC **Figure 1** Appearances of the gold sulfite baths after keeping for 4 months: (a) without HEDP; (b) HEDP 0.025 mol - L¹; (c) HEDP 0.050 mol - L¹: (color on line) min and 20 min in the gold sulfite bath without HEDP (HA **Figure 1** Appearances of the gold sulfite baths after keeping
for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L¹; (c)
HEDP 0.050 mol·L¹: (color on line)
min and 20 min in the gold sulfite bath without HEDP
(HAuCl **Figure 1** Appearances of the gold sulfite baths after keeping
for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L¹; (c)
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min and 20 min in the gold sulfite bath without HEDP
(HAuCl **Figure 1** Appearances of the gold sulfite baths after keeping
for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L¹; (c)
HEDP 0.050 mol·L¹. (color on line)
min and 20 min in the gold sulfite bath without HEDP
(HAuCl **Figure 1** Appearances of the gold sulfite baths after keeping
for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L¹; (c)
HEDP 0.050 mol·L¹: (color on line)
min and 20 min in the gold sulfite bath without HEDP
(HAuCl for 4 months: (a) without HEDP; (b) HEDP 0.025 mol·L⁻; (c)
HEDP 0.050 mol·L⁻¹: (color on line)
min and 20 min in the gold sulfite bath without HEDP
(HAuCl₄ -4H₂O 0.01 mol·L⁻¹; Na₂SO₃ 0.24 mol·L⁻¹;
dadictiv FIEDP 0.050 mol·L'. (coor on line)
min and 20 min in the gold sulfite bath without HEDP
(HAuCl₄ ·4H₂O 0.01 mol·L⁻¹, Na₂SO₃ 0.24 mol·L⁻¹,
addictive 0.1 mL·L⁻¹) were prepared in a constant
current density of 5

 $\# \# \# (L \text{ Electrochem.}) 2022, 28(7), 2213005 (4 of 8)$
gier and more reddish-brown. As deposition for 20 with a thickness of 1 μ m was obtained. Therefore, it
min, the thickness of gold coating was 0.7 μ m, the may conclude tha $\frac{dE}{dt}(L \text{ }Electrochem.)$ 2022, 28(7), 2213005 (4 of 8)

gier and more reddish-brown. As deposition for 20 with a thickness of 1 μ m was obtained. Therefore, it

min, the thickness of gold coating was 0.7 μ m, the

length $\frac{d}{dt}\left\{\frac{d\mu}{d\mu}\right\}$ (*Electrochem.*) 2022, 28(7), 2213005 (4 of 8)
gier and more reddish-brown. As deposition for 20 with a thickness of 1 µm was obtained. Therefore, it
min, the thickness of gold coating was 0.7 µm $\frac{dE}{dt}\mathcal{E}^{\#}(J. Electrochem.) 2022, 28(7), 2213005 (4 of 8)$
gier and more reddish-brown. As deposition for 20 with a thickness of 1 μ m was obtained. Therefore, it
min, the thickness of gold coating was 0.7 μ m, the may concl $\frac{4}{5}$ 4. *Hectrochem.*) 2022, 28(7), 2213005 (4 of 8)

gier and more reddish-brown. As deposition for 20 with a thickness of 1 μ m was obtained. Therefore, it

min, the thickness of gold coating was 0.7 μ m, the m $\pm \frac{\text{if}_{x} \pm \text{if}_{x} \pm$ \pm *d*: *Hectrochem.*) 2022, 28(7), 2213005 (4 of 8)
gier and more reddish-brown. As deposition for 20 with a thickness of 1 μ m was obtained. Therefore, it
min, the thickness of gold coating was 0.7 μ m, the may co **Example 18** The increased production, that is, with the increased gradually, and thus the increase of contentration, the mass of the increase of pold coating was 0.7 pm, the may conclude that HEDP can significantly impro $\text{#t} \cong (1, \text{Electrochem.}) \times 2022, 28(7), 2213005 (4 \text{ of } 8)$

gier and more reddish-brown. As deposition for 20 with a thickness of 1 µm was obtained. Therefore, it

min, the thickness of gold coating was 0.7 µm, the may concl **increased gradually, and thus, the gold coating space of** $\frac{1}{2}$ and thus, the current density on an integral on the increased graduating was 0.7 μ m, the may conclude that HEDP can significantly improve the gradual $\text{#}E\#(J. Electron) \text{ } 2022, 28(7), 2213005 \text{ (4 of 8)}\text{ [g]} \text{ [g]} \text{ [g]} \text{ [h]} \text{ [h]}$ **EVALUATION 1989**
 **EVALUATION CONTEX (Exceedation Solution Section 1992, 28(7), 2213005 (4 of 8)

The morphology and appearance of the more controlled to the more properties of pulled conting was 0.7** μ **m, the may conc HEPP** (*LEtertochen.*) 2022, 28(7), 2213005 (4 of 8)
gier and more reddish-brown. As deposition for 20 with a thickness of 1 μ m was obtained. Therefore, it
min, the thickness of gold cosing was $57 \mu m$, the may conclu **EVALUATIVELA EXALUATIVELA (EXALUATIVELA** 46. $\frac{1}{2}$ molecular more reddish-brown. As deposition for 20 with a thickness of 1 μm was obtained. Therefore,

min, the thickness of gold coating was 0.7 μm, the may conclude that HEDP can significantly implength o

mol \cdot L⁻¹, HEDP 0.05 mol \cdot L⁻¹, addictive 0.1 mL \cdot L⁻¹)

 $(28(7), 2213005 (4 of 8))$
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transfo $(28(7), 2213005)$ (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were tra $(28(7), 2213005)$ (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were tra $(28(7), 2213005)$ (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were tra $\frac{1}{28(7)}$, 2213005 (4 of 8)

with a thickness of 1 μ m was obtained. Therefore, it

may conclude that HEDP can significantly improve

the quality of gold coating. As HEDP was introduced

to the bath, the gold grains $28(7)$, $2213005(4 \text{ of } 8)$
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were t pearance. (7) , 2213005 (4 of 8)

th a thickness of 1 μ m was obtained. Therefore, it

y conclude that HEDP can significantly improve

quality of gold coating. As HEDP was introduced

the bath, the gold grains were transformed f $(28(7), 2213005 (4 \text{ of } 8))$
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were tra 28(7), 2213005 (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transf $\frac{\text{d} \mathcal{H}}{\text{d} \mathcal{H}}$ (*J. Electrochem.*) 2022, 28(7), 2213005 (4 of 8)
As deposition for 20 with a thickness of 1 μm was obtained. Therefore, it
ing was 0.7 μm, the may conclude that HEDP can significantly improve

 $\frac{1}{2}$ (*L Electrochem.*) 2022, 28(7), 2213005 (4 of 8)

eposition for 20 with a thickness of 1 μ m was obtained. Therefore, it

vas 0.7 μ m, the may conclude that HEDP can significantly improve

400 nm (Figure th ¹¹2.16² molecular to the alternation of the alternation of the size of the size of the mickens of gold coating was 0.7 μ m, the may conclude that HEDP can significant the thickness of gold coating was 0.7 μ m, the ¹⁶1*CF* (*L bleetnothem,*) 2022, 28(*i*), 2213003 (4 of 8)

In. As deposition for 20 with a thickness of 1 μ m was obtained. Therefore, it

coating was 0.7 μ m, the may conclude that HEDP can significantly improve
 increasing of current density, the grain size increased
gradually and resulted in a pyramidal morphology. gier and more reddish-brown. As deposition for 20 with a thickness of 1 µm was obtained. Therefore, it
min, the thickness of gold coating was 0.7 µm, the may conclude that HEDP can significantly improve
length of the rodin, the thickness of gold coating was 0.7 μ m, the may conclude that HEDP can significantly improve
length of the rod-like grains reached 400 nm (Figure the quality of gold coating. As HEDP was introduced
2.9, and the c length of the rod-like grains reached 400 nm (Figure the quality of gold coating. As HEDP was introduced
2e), and the coating showed a deep foggy and red-
to the bath, the gold grains were transformed from
the coating sho 2e), and the coating showed a deep foggy and red-

us the buth, the gold grains were transformed from

dish-brown appearance (the lower right corner of Fig-

the buth, the gold grains were transformed from

dish-brown app dish-brown appearance (the lower right comer of Figure 31 min and smiller the grains were caused to the median response to the seal of Figure 3.1). The results in Figure 2 reveal a key problem decreased, resulting in a go ure 20). The results in Figure 2 reveal a key problem decreased, resulting in a golden bright coating ap-
during gold electrodeposition with a low gold ion pearance.
the morphology and the appearance of the gold
time and during gold electrodeposition with a low gold ion
concentration, that is, with the increases of deposition
concentration, that is, with the increases of deposition
of the morphology and the appearance of the gold
increase concentration, that is, with the increases of deposition

"The morphology and the appearance of the gold

time and coating thickness, the size of coating grains

increased gradually, and thus, the gold coating thred coati time and coating thickness, the size of coating grains

coatings for the deposition of 10 min with various

increased gradually, and thus, the gold coating turned

correct densities in the sulfite-HEDP bath are shown

fro increased gradually, and thus, the gold coating turned

current densities in the suffice-HEDP bath are shown

from golden bright to foggy and reddish-brown.

Figure 3, the morphology of the eigenvs the morphology of the d from golden bright to foggy and reddish-brown.

in Figure 4. It is clear that the morphology of the

Figure 3 shows the morphology and appearance of

Figure 3 shows the morphology and appearance of

the current density wa 28(7), 2213005 (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transf 28(7), 2213005 (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transf 2. 28(7), 2213005 (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were tra 28(7), 2213005 (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transf , 28(7), 2213005 (4 of 8)
with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were tran with a thickness of 1 μ m was obtained. Therefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transformed from
rod-like to p with a thickness of 1 µm was obtained. I herefore, it
may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transformed from
rod-like to pyr may conclude that HEDP can significantly improve
the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transformed from
rod-like to pyramidal, whose growing rate was much
decreased, resulti the quality of gold coating. As HEDP was introduced
to the bath, the gold grains were transformed from
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decreased, resulting in a golden bright coating ap-
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current densities in the sulfite-HEDP bath are shown
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The morphology and the appearance of the gold

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current densities in the sulfite-HEDP bath are shown
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current densities in the sulfite-HEDP bath are shown
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Figure 4 Morphologies of the gold coating from the sulfite-HEDP bath under various current densities: (a) 0.1 (6) 0.5 Λ -dm²; (a) 0.7 Λ -dm²; (e) 0.9 Λ -dm²; (f) 1.1 Λ -dm²; (g) photograph showing The electrochemical behaviors of Au(I) in the sul-

for shows the cycle voltammetric curve

fite-HEDP bath on a gold electrode and a nickel elec-

troreduction with and without HED

trode were studied in detail. Figure 5

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 (a) Figure 4 Morphologies of the gold coating from the sulfite-HFDP hathunder various current densities: (a) 0.1 A -dm³; (b) 0.3 A -dm³;

(c) 0.5 A -dm²; (d) 0.7 A -dm²; (d) 0.9 A -dm²; (f) 1.1 A -dm²; (g) photogr **Figure 4** Morphologies of the gold coatings from the sulfits-HHDP bath under various current densities (a) 0.1 A -dm²; (b) 0.3 A -dm²; (c) 0.7 A -dm²; (e) 0.8 A -dm²; (e) 0.8 A -dm²; (e) 0.8 A -dm²; (e) 0.8 A Figure 4 Morphologies of the gold coatings from the sulfite-HEDP bath under various current densities (a) 0.1 A \cdot dm²; (b) 0.3 A \cdot dm²; (c) 0.5 A \cdot dm²; (c) 0.9 A \cdot dm²; (f) 1.1 A \cdot dm²; (g) photograph $mA \cdot dm^2$. For the bath with 0.05 mol $\cdot L^1$ HEDP sulfite bath (Figure 6 Curve 2), the onset potential re-Figure 4 Morphologies of the gold coatings from the sadilic-HEDP balt ander various current densities: (a) 0.1 A -dm²; (b) 0.3 A -dm²; (c) 0.5 A -dm²; (d) 0.7 A -dm²; (c) 0.9 A -dm²; (c) 0.9 A -dm²; (c) 0.9 A **Figure 4** Morphologies of the gold contings from the sulfite-HEDP but under various current densities (a) 0.1 A \cdot dm²; (b) 0.3 A -dm²; (c) 0.5 A -dm²; (e) 0.9 A -dm²; (e) 1.9 A -dm²; (e) 1.1 A -dm²; (e) thr (e) 0.5 A - dm⁻; (a) 0.7 A - dm⁻; (e) 0.9 A - dm⁻; (g) that - dm⁻; (g) photograph showing the appenance of gold coatings. (color on including)

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 3.3 Electrochemical Analysis duction is also observed on a nickel electrode. Figure

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If the electroreduct **3.3 Electrochemical Analysis** duction is also observed on a nickel electrode. Figure
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tarization cur de were studied in detail. Figure 5 shows the po-

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6 shows the cycle voltammetric curves of Au(I) elec-
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el duction is also observed on a nickel electrode. Figure
6 shows the cycle voltammetric curves of Au(I) elec-
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6 shows the cycle voltammetric curves of Au(I) elec-
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6 shows the cycle voltammetric curves of Au(I) electroreduction with and without HEDP on the nickel
electrode. The curves were scanned negatively from
-0.1 V to -1.1 6 shows the cycle voltammetric curves of Au(I) electroreduction with and without HEDP on the nickel electrode. The curves were scanned negatively from -0.1 V to -1.1 V, then positively to -0.1 V at a scan rate of 10 mV ·s troreduction with and without HEDP on the nickel
electrode. The curves were scanned negatively from
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rate of 10 mV·s⁻¹. As shown in Figure 6 Curve 1 for
the bath with ectrode. The curves were scanned negatively from
1 V to -1.1 V, then positively to -0.1 V at a scan
ce of 10 mV·s⁻¹. As shown in Figure 6 Curve 1 for
bath without HEDP, gold sulfite ions started be-
g reduced at -0.65 V

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gold sulfite ion, but cannot explain the brightening

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and refining effects of HEDP on the gold** the dissociated and reduced Au(I) species were trans-

indicate that HEDP accelerates the electroreduction of

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and refining effects of HEDP on the gold coating.** ance. Notably, no current loop appeared in Figure 6, indicate that HEDP accelerates the electrorchach 2022, 28(7), 2213005 (6 of 8)

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press gold sulfite ion, but cannot explain the brightening

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presses the dimerization of sulfite to metabisalifite by

th and refining effects of HEDP on the gold coating. In

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our previous work^[30], we confirmed that HEDP sup-

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studying the interfaction of sulfite. Therefore,

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Studying its interfaction could will be a Therefore,

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(SOO)³, Au(SOO))², Au(SOO))², Au(SOO)²), Au(SOO)²), Au(SOO)²), Au(SOO)²) to a single complex (Au

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single gold complex and a weaker hydrogen evolu-

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single gold complex and a weaker hydrogen evolu-

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time reaction lead to fine grains and a bright a single gold complex and a weaker hydrogen evolu-
suffite ions on a gold electrode at a sean rate of 10 mV-s⁻¹ with-
tion raction lead to fine grains and a bright appear-
out IEDP (Curve 1) and with 0.05 mol -L⁺ HEDP (tion reaction lead to fine grains and a bright appear-

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Notably, no current loop appeared in Figure 6, in-

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 Notably, no current loop appeared in Figure 6, in-

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or a nickel electrode did not undergo a nucleation

stage⁷⁹¹. The chronoampenometric curves for the elec-

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sulfite ions on a gold electrode at a scan rate of $10 \text{ mV} \cdot \text{s}^{-1}$ with-

 $\frac{d}{dt}\left(\frac{d}{dt}\right)$ Electrochem.) 2022, 28(7), 2213005 (7 of 8)
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mizing the bath components and deposition condi-
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rectly along the crystal plane of the substrate. Revisit-
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in Figure 2 and Figure 3, we can deduce that since
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mizzing the bath components and deposition condi-
ing the SEM images of the grain growing processes ions to promote gold nucleation, it is expected to ob-
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rectly along the crystal plane of the substrate. Revisit-

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in Figure 2 and Figure 3, we can deduce that size we can $\pm \frac{1}{2}$ along the crystal plane of the substrate. Revisit-

rectly along the crystal plane of the substrate. Revisit-

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The authors are all thankful for the fin stage, the grain size increased gradually with the in-

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terease of deposition time, and it was difficult to de-

(Figure 2). For the sulfite-HEDP bath (Figure 3), t reased gradually with the in-

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et-HEDP bath (Figure 3), the The authors are all thankful for the financial sup-

ite-HEDP bath (Figure 3), the The authors are crease of deposition time, and it was difficult to de-

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(Figure 2). For the sulfite-HEDP bath (Figure 3), the

(Figure 2). For the sulfite-HEDP bath (Figure 3), the

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5 Conclusions

mol·L¹ HAuCl₄, 0.24 mol·L¹ Na₂SO₃, 0.05 mol·L¹ posit a thick gold coating with fine and dense grains

(Figure 2). For the sufficient H-HEDP hast (Figure 3), the analysis are all thankful for the financial sup-

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por (Figure 2). For the sulfite-HEDP bath (Figure 3), the

growing rate of grians was slowed. However, it is in

evitable that the grian size will be increased by the

evitable that the grian size will be increased by the

co growing rate of grians was slowed. However, it is in-

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extension of deposition time eventhough with HEDP.

Therefore, optimizing the bath components and de-

Externet espoi and No. evitable that the grian size will be increased by the

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Therefore, optimizing the bath components and de-

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The relationship between microstructure and the herman

the key factors for obtaining bright gold coatings with

the Therefore, optimizing the bath components and de-
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The signition conditions to promote the gold nucleation is [1] have K, Susaki N, Susakim T, Watambe T, Nakata T.

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the region for the thremation from the thermatical the key factors for obtaining bright gold coatings with

The relationship between microstructure and the thermal

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 5. Conclusions

A cyanide-free gold plating process using chloroa-

Trans. 2006, 47 fine and dense grians.
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this paper. The bath composition cons A cyanide-free gold plating process using ehloroa.

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mol-L¹ HaaCl₄, 0.24 mol-L¹ Na_aSO_D, 0.05 mol-L this paper. The bath composition consisted of 0.01

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IFFDP and 0.01 mol -L¹ Aadictive. With the intro-

IFFDP and 0.01 mol -L¹ Ad mol -L⁺ HAuCl_a, 0.24 mol -L⁺ Na₃SO₂, 0.05 mol -L⁺

21) Okimak V, Hoshima M, Smen recent topics in gold plating

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The grains of the gold coating obtained from the bath

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with the incr mificantly and the coating grains became refined. anide gold plating for electronics application(J). Gold Hull,

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introduced to the bath, the gold grains were

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in Figure 2 and Figure 3, we can d $\# \& \# \& (J. Electronchem.)$ 2022, 28(7), 2213005 (7 of 8)

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mizing the bath components and deposition condi-
tions to promote gold nucleation, it is expected to ob-
tain bright gold coatings with fine and dense grains.
This work is helpful to provide $(2.28(7), 2213005(7 \text{ of } 8))$
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tions to promote gold nucleation, it is expected to ob-
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tions to promote gold nucleation, it is expected to ob-
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tions to promote gold nucleation, it is expected to ob-
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tain bright gold coatings with fine and dense grains.

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亚硫酸盐无氰电沉积金新工艺及机制

杨家强,金 磊,李威青,王赵云,杨防祖*,詹东平*,田中群
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摘要: 直接以氯金酸作为主盐、羟基乙叉二膦酸(HEDP)作为镀液稳定剂和镀层细化剂、结合添加剂,组成亚硫 酸盐无氰镀金新工艺;研究镀液稳定性、镀层形态及金电沉积机制。结果表明,HEDP 可明显提升镀液稳定性; 不含 HEDP 的亚硫酸盐镀金液中, 镀层呈棒状晶粒并随沉积时间延长而逐渐生长, 导致镀层外观随镀层厚度增 加由金黄色转变为红棕色。镀液含有 HEDP 时, 金晶粒形态由棒状转变为棱锥状, 且棱锥状晶粒随沉积时间延 长生长速率较小, 镀层厚度为 1 μm 时仍呈现金外观。电化学实验表明金电沉积不经历成核过程。 关键词: 无氰镀金: 亚硫酸金: 羟基乙叉二膦酸: 电沉积: 金镀层