[Journal of Electrochemistry](https://jelectrochem.xmu.edu.cn/journal)

[Volume 28](https://jelectrochem.xmu.edu.cn/journal/vol28) Issue 7 [Special Issue on Electronic](https://jelectrochem.xmu.edu.cn/journal/vol28/iss7) [Electroplating \(](https://jelectrochem.xmu.edu.cn/journal/vol28/iss7)Ⅱ)

2022-07-28

Investigation of Through-Hole Copper Electroplating with Methyl Orange as A Special Leveler

Jia-Ying Xu

Shou-Xu Wang

Yuan-Zhang Su

Yong-Jie Du

Guo-Dong Qi

Wei He

Guo-Yun Zhou

See next page for additional authors

Recommended Citation

Jia-Ying Xu, Shou-Xu Wang, Yuan-Zhang Su, Yong-Jie Du, Guo-Dong Qi, Wei He, Guo-Yun Zhou, Wei-Hua Zhang, Yao Tang, Yu-Yao Luo, Yuan-Ming Chen. Investigation of Through-Hole Copper Electroplating with Methyl Orange as A Special Leveler[J]. Journal of Electrochemistry, 2022, 28(7): 2213003. DOI: 10.13208/j.electrochem.2213003 Available at:<https://jelectrochem.xmu.edu.cn/journal/vol28/iss7/8>

This Article is brought to you for free and open access by Journal of Electrochemistry. It has been accepted for inclusion in Journal of Electrochemistry by an authorized editor of Journal of Electrochemistry.

Investigation of Through-Hole Copper Electroplating with Methyl Orange as A Special Leveler

Authors

Jia-Ying Xu, Shou-Xu Wang, Yuan-Zhang Su, Yong-Jie Du, Guo-Dong Qi, Wei He, Guo-Yun Zhou, Wei-Hua Zhang, Yao Tang, Yu-Yao Luo, and Yuan-Ming Chen

Corresponding Author(s)

Yuan-Ming Chen(ymchen@uestc.edu.cn)

$\begin{array}{lll} &\text{\rm \# } & \text{\rm \# } \\ &\text{\rm \# } & \text{\rm \# } & \text{\rm \# } \\ \end{array}$ **E** *(K* $\overset{\#}{\to}$ *1. Electrochem.* 2022, 28(7), 2213003 (1 of 8)

DOI: 10.13208/j.electrochem.2213003 Http://electrochem.xmu.edu.cn
 ON Of Through-Hole Copper Electroplating with
 Methyl Orange as A Special Leveler
 $\begin{array}{c} \text{\#} \quad \mathcal{H} \quad \rightrightarrows \\ \text{\#} \quad L \quad \rightrightarrows \\ \text{\#} \quad L \quad \rightrightarrows \\ \text{DOI: } 10.13208/j.electrochem. 2213003 \qquad \qquad \text{Htp://electrochem} \\ \text{\#} \quad \text{DOL: } 10.13208/j.electrochem. 2213003 \qquad \qquad \text{Htp://electrochem} \\ \text{\#} \quad \text{Wetly/electrochem} \end{array}$ $\begin{array}{ll} &\text{E.} & \# & \# \\ \text{L.} & \# & \# & \# \\ \text{DOL: 10.13208/j.electrochem.2213003} & \text{Htp://electrochem.xml.eduen} \end{array}$

DOI: 10.13208/j.electrochem.2213003
 OI: 10.13208/j.electrochem.2213003

 OI: Through-Hole Copper Electroplating with Methyl Or (1 of 8)

003 Http://electrochem.xmu.edu.cn
 r Electroplating with
 al Leveler

, Yong-Jie Du³, Guo-Dong Qi⁴,

Yu-Yao Luo², Yuan-Ming Chen^{1,2*}

Science and Technology of China,

High-density Electronics Co., L Http://electrochem.xmu.edu.cn
 lating with

, Guo-Dong Qi⁴,

Yuan-Ming Chen^{1,2*}
 hnology of China,
 cetronies Co., Ltd and
 Guangdong. China: $\frac{d}{dt} \mathcal{L} \overset{\text{def}}{=} \frac{1}{2} \mathcal{L} \mathcal{L} \overset{\text{def}}{=} \frac{1}{2} \mathcal{L} \mathcal{L} \mathcal{L} \overset{\text{def}}{=} \frac{1}{2} \mathcal{L} \mathcal{L} \mathcal{L} \mathcal{L} \overset{\text{def}}{=} \frac{1}{2} \mathcal{L} \$ $# \mathcal{L} \not\cong$
 L Electrochem. 2022, 28(7), 2213003 (1 of 8)

DOI: 10.13208∱.electrochem.2213003
 Extigation of Through-Hole Copper Electroplating with
 Methyl Orange as A Special Leveler

Final Xu¹, Shou-Xu Wa $\begin{array}{ll} & \text{#} & \text{#} \\ \text{L} & \text{H} & \text{H} \\ \text{L} & \text{L} & \text{L} \\ \$ *AC* $\frac{d^2}{2}$
 $(28(7), 2213003 (1 of 8))$
 B_0 B_1 B_2 B_3 B_4 B_5 B_6 B_7 B_6 B_7 B_8 B_8 $\frac{3(1 \text{ of } 8)}{3003}$ Http://electrochem.xmu.edu.cn
 er Electroplating with
 ial Leveler
 $\frac{1}{3}$, Yong-Jie Du³, Guo-Dong Qi⁴,
 $\frac{1}{3}$, Yu-Yao Luo², Yuan-Ming Chen^{1,2*}
 c Science and Technology of China Http://electrochem.xmu.edu.cn

plating with

r

u³, Guo-Dong Qi⁴,

chnology of China,

lectronics Co., Ltd and

Guangdong, China;

Guangdong, China; (1. School of **Materials and Energy, University of Electronic Science and Technology of China,**

1. School of **Through-Hole Copper Electroplating with**
 Investigation of Through-Hole Copper Electroplating with
 Invest E. $\mathcal{H} \overset{\text{g}}{\rightarrow}$

L. Electrochem. 2022, 28(7), 2213003 (1 of 8)

DOI: 10.13208/j.electrochem.2213003
 Investigation of Through-Hole Copper Electroplating with
 Methyl Orange as A Special Leveler

Jia-Ying Xu', $\frac{1}{2}$ *R. Electrochem.* 2022, 28(7), 2213003 (1 of 8)

DOE 10.132085-electrochem.2213003
 Electroplating with
 Electroplating with
 Electroplating Co.

Jia-Ying Xu¹, Shou-Xu Wang^{1,} Yunar-Zhang Su¹, Yong-Ji $\frac{1}{2}$ *Ehectrochom.* 2022, 28(7), 2213003 (1 of 8)
DOI: 10.132085 electrochem.2213003
DOI: 10.132085 electrochem.2213003
Impe://electrochem.xmu.edu.cn
Directing Xu¹, Show-Yu Wang^{1,} Yuan-Zhang Su¹, Yong-Jic Du² $\frac{d}{dx}$ *B* $\frac{d}{dx}$ *B* $\frac{d}{dx}$ *B B LEtectrochem. 2022, 28(7), 2213003 (1 of 8)*
DOI: 10.13208/j.electrochem.2213003 Http://electrochem.xmu.edu.cn
 Investigation of Through-Hole Copper Electroplating with

Me $\begin{array}{lll} &\text{\#} & \text{\#} & \text{\#} \\ \text{\#} & \text{\#} & \text{\#} \\ \text{\#} & \text{\#} & \text{\#} \\ \text{DOI: 10.13208/j.electrochem.2213003} & & & \text{\#ftp://electrochem.xml.edu.cn} \\ \end{array}$

4. GCI Science & Technology (Zhuhai) Co., Ltd, Zhuhai 319175, Guangdong, China)

Stract: Methyl Orange (MO) with two kinds of functional groups can act as both an accelerator and an inhibitor, which has

in used as a spec **Abstract:** Methyl Orange (MO) with two kinds of functional groups can act as both an accelerator and an inhibitor, which has
been used as a special leveler to simplify the electrophaling additive system in the through-lo **Abstract:** Methyl Orange (MO) with two kinds of functional groups can act as both an accelerator and unihalistic, which has
been used as a special leveler to simplify the electroplating additive system in the through-bol **Abstract:** Methyl Orange (MO) with wo kinds of functional groups can act as both an accelerator and an inhibitor, which has
been used lievel to simplify the electrophating additive system in the through-hole (TH) copper becaused as a special levelor to simplify the electroplating additive system in the through-hole (TH) copper electroplating experientals. In that word, the role of MO in The deteroplating is characterized by molecular dyna ments. In this work, the role of MO in TH electroplating is characterized by molecular dynamics simulations and quantum chemical
calculations. It is suggested that MO can spontaneously thaten the copper surface and be wel calculations. It is suggested that M0 can spontaneously flaten the copper surface and be well adsorbed on the cathodog surface and the sole per surface and per surface and per surface and the solely and cyclic voluments (toon, *Learna 31911)*, otangwong, Chrina;

Co., *Ltd, Zhuhai 519050*, *Guangdong, China*;
 td, Zhuhai 519175, *Guangdong, China*)

sups can act as both an accelerator and an inhibitor, which has

system in the through-h of most accelerators accelerates copper deposition
the acceleration and the content of H most and H models and H models and H models are act as both an accelerator and an inhibitor, which has system in the through Example of the matter of the matter and an inhibitor, which has
system in the through-hole (TH) copper electroplating experi-
ized by molecular dynamics simulations and quantum chemical
copper surface and be well adsorbed by scan act as both an accelerator and an inhibitor, which has
system in the through-hole (TH) copper electroplating experi-
ized by molecular dynamics simulations and quantum chemical
copper surface and be well adsorbed oups can act as both an accelerator and an inhibitor, which has
system in the through-hole (TH) copper electroplating experi-
ized by molecular dynamics simulations and quantum chemical
copper surface and be well adsorbed system in the through-hole (TH) copper electroplating experi-
ized by molecular dynamics simulations and quantum chemical
copper surface and be well adsorbed on the cathode surface,
hemical behavior of MO was evaluated by ized by molecular dynamics simulations and quantum chemical
copper surface and be well adsorbed on the cathode surface,
hemical behavior of MO was evaluated by galvanostatic mea-
rardly affects the potential due to its du $\frac{1}{2}$ *K* $\frac{1}{2}$
*L Electrochem. 2022. 28(7), 2213003 (1 of 8)
DOI: 10.132085 electrochem.2213003
DOI: 10.132085 electrochem.2213003
Existing 2011
Existing Arison of Through-Hole Copper Electroplating with
Ti* Abstract: Methyl Orange as A Special Leveler

Investigation of Through-Hole Copper Electroplating with

Methyl Orange as A Special Leveler

Jia-Ying Xu', Shou-Xu Wang^{1, 2}, Yuan-Zhang Su', Yong-Jie Du', Guo-Dong Qi⁴,
 Article **IDENTIFY ACTION CONSUMPLE COPPERT EXECT CONSUMPLE IN A CONSUMPLE IN A SURFACT MORE IN A SURFACT METAL SURFACT IN A SURFACT METAL SURFACT METAL SURFACT METAL CONSULTABLY AND A CONSULTABLY AND CALL** \sim **(***I***, Study Investigation of Through-Hole Copper Electroplating with**
 Methyl Orange as A Special Leveler

Jia-Ying Xu', Shou-Xu Wang^{1,2}, Yuan-Zhang Su', Yong-Jie Du', Guo-Dong Qi⁴,

Wei He^{1,2}, Guo-Yun Zhou¹, Wei-Hua Zhang **Investigation of Through-Hole Copper Electroplating with**
Methyl Orange as A Special Leveler

Jia-Ying Xu', Shou-Xu Wang^{1,2}, Yuan-Zhang Su', Yong-Jie Du', Guo-Dong Qi',

Wei He¹², Guo-Yun Zhou', Wei-Hua Zhang', Ya **internal Cu2+ Cu2+ Cu2+ Cu2+ Cu2+**

Jia-Ying Xu¹, Shou-Xu Wang^{1,2}, Yuan-Zhang Su¹, Yong-Jie Du², Yuao-Tong Qi⁴,

(*i*. School of Materials and Energy, University of Electronic Science and Technology of Cuina,
 Is a-Ying Xu¹, Shou-Xu Wang^{1, 2}, Yuan-Zhang Su¹, Yong-Jie Du³, Guo-Dong Qi⁴,
Wei He^{1,2}, Guo-Yun Zhou¹, Wei-Hua Zhang², Yao Tang², Yu-Yao Luo³, Yuan-Ming Chen^{1,26}
(1. School of Materials and Energy, U Jia-Ving Xu¹, Shou-Xu Wang¹², Yuan-Zhang Su¹, Yong-Jic Du², Guo-Dong Qi⁴,
Wei He¹³, Guo-Yua Zhou², Wei-Hua Zhang², Yua Tang-Tua-Ving 2-7 Vu² Yao Lua⁵, Yuan-Ming Chent.²
(1. School of Materials and En Wei $He^{1,2}$, Guo-Yun Zhou¹, Wei-Hua Zhang², Yao Tang², Yu-Yao Luo², Yuan-Mir

(1. School of Materials and Energy, University of Electronic Science and Technology of Chengalu 611731, Sichuan, China; 2. Zhuhai Foun (1. School of Materials and Energy, University of Electronic Science and Technology of China,

Chengdu 611731, Sichuan, China; 2. Zhuhai Founder Sci-Tech High-density Electronics Co., Ltd and

Zhuhai Founder Sci-Tech Mult

which inhibit the copper electrodesposition on the canted Electrodenial behavior of MO was evaluated by galvanestatic mean-
surements (GM) and cyclic volumentery (CV) to contime that MO hardly affects the potential due to surements (GM) and cycle volumes the colume in the Maria MO metric of the platinia due to is due it methods of epolential
ting and polarizing effects from the molecular structure of sulfaints independent groups to achieve my any isomation and the control methods are through through and the control methods are control methods are through through through the spectration and must have been through-hole additive. Throw power value of TII with Learning solution basis with the additive system and only the system and only the system and the development of
electrophaing additive system.
 Key words: cooper electroplating through-hole; additive; methyl orange
 Ke 1 Introduction
 Introduction
 Electroplating copper technology greatly affects of most accelerators accelerates copper deposition at

the development of electronic interconnection of mul-

the center in the TH^E. A Examplaining additive system.
 City words: conper electroplating: through-hole; additive; methyl orange
 1 Introduction

the development of electronic interconnection of mul-

the center in the TH^E. According to exi **ords:** copper electroplating: through-hole; additive; methyl orange

rophating copper rechnology greatly affects

of most accelerators accelerates copper eleposition at

topment of clectronic interconnection of mul-

to

1 Introduction the synergistic of chloride ions, sulfonic acid group pper surface and be well adsorbed on the cathode surface,
nical behavior of MO was evaluated by galvanostatic mea-
ly affects the potential due to its duel functions of depolariz-
propy and other groups to achieve the int hemical behavior of MO was evaluated by galvanostatic mea-
rardly affects the potential due to its duel functions of depolariz-
ind group and other groups to achieve the internal Cu² reduction
with the aspect ratio of 1 andly affects the potential due to its duel functions of depolarizad
d group and other groups to achieve the internal Cu²⁺ reduction
with the aspect ratio of 10:1 could reach 92.34% from the base
study of MO could provid a group and other groups to a
eneve the internal Cu^r reduction
with the aspect ratio of 10:1 could reach 92.34% from the base
study of MO could provide new ideas for the development of
yl orange
for a state of chloride whil the spect take of 10.1 collar catal 22.34% noni the sase
study of MO could provide new ideas for the development of
pl orange
of most accelerators accelerates copper deposition at
the center in the TH^[2]. According

 $\qquad \qquad \oplus \{\&\cong (J. \:Electrochem.) \: 2022, 28(7), 2213003 \: (2 \text{ of } 8)$ new leveling agent TS-L to increase throw power stant agitation in order to ensure the good mass trans-

(TP) with the increase in the concentration of TS-L.
 $# \ell \# \langle J. \text{ Electronic} \rangle$

Here is the increase throw power

tant agitation in order to ensure the good mass trans-

(TP) with the increase in the concentration of TS-L.

When 50 mg·L⁻¹ TS-L, 10 mg·L⁻¹ brightener and 600 $#E\# (J. Electron.) 2022, 28(7), 2213003 (2 of 8)$ new leveling agent TS-L to increase throw power stant agitation in order to ens

(TP) with the increase in the concentration of TS-L. fer.

When 50 mg⋅L⁻¹ TS-L, 10 mg⋅L⁻¹ brighte $# \&L \ncong (J. \tElectrochem.) 2022, 28(7), 2213003 (2 of 8)$

gent TS-L to increase throw power stant agitation in order to ensure the good mas

ncrease in the concentration of TS-L. fer.

⁻¹ TS-L, 10 mg⋅L⁻¹ brightener and 600 Ba $mg \cdot L^{-1}$ inhibitor were added to the plating solution. $\frac{d}{dt}E^2(T, Electrochem.) 2022, 28(7), 2213003 (2 of 8)$

Eveling agent TS-L to increase throw power stant agitation in order to ensure the good mass trans-

with the increase in the concentration of TS-L.

50 mg·L⁻¹ TS-L, 10 mg· $\pm k\frac{2\pi}{2}(I. Electronchem.) 2022, 28(7), 2213003 (2 of 8)$

The property are the increase throw power start agitation in order to ensure the good mass trans-

(TP) with the increase in the concentration of TS-L.

When 50 mg · L^{.+} TS **the aspect ratio (AR) of 6.4:1.** Zheng et al.^[4] Subsequent ratio (CP) and domestion of 175-1. The concentration of TS-1. For the increase in the concentration of TS-1. For the aspect ratio (AR) or μ is the concentr **E** *(E.**) Electrochem.) 2022, 28(7), 2213003 (2 of 8)

new leveling agent TS-L to increase throw power stant agitation in order to ensure the good mass trans-

(TP) with the increase in the concentration of TS-L. fer.
 Example 10 mg = E¹ Electrochem.) 2022, 28(7), 2213003 (2 of 8)
 EXAMPLE 10 mercase in the concentration of TS-L.
 CP) with the increase in the concentration of TS-L.
 CP when 50 mg ⋅L⁻¹ TS-L, 10 mg ⋅L⁻¹ bri mew leveling agent TS-L to increase throw power

for the metallon in order to ensure the good mass trans-

(TP) with the increase in the concentration of TS-L. fer.

When 50 mg·L⁺ TS-L, 10 mg·L⁺ brightener and 600 Bas **EVALUATE 19.4:** If E is the more standard more to ensure the good mass transfer (TP) with the increase in the concentration of TS-L. for.

When 5.0 mg-1.³ is T₁.0 mg-1.³ is T₁.0 mg-1.³ is T₁.4 mg-1.³ is T **EXAMPLE 11**
 EXAMPLE 10 EXAMPLE 10 COLOGIT 10 EXAMPLE 10 COLOGIT 10 EXAMPLE 10 COLOGIT 10 EXAMPLE 10 COLOGIT 10 EXAMPLE 10 EATE ALTERT CONDIGES (*Electrochem*, 2022, 28(7), 2213003 (2 of 8)

The localizing agent TS-L to increase throw power stant agitation in order to ensure the good mass trans-

(TP) with the increase in the concentration **10. (ALC**) **Example 10. (ALC**) **Example 10. (AS**) **C C C C C C C C C C C C C C C C C C C C C C C C C C C C C EVALUAT EXAMPLE 100** (EVALUAT 10000 (2.2, 28(7), 2213003 (2. of 8)

THE REVALUAT THE REVALUAT THE STRUCT UP WITH THE STRUCT UP WITH THE STRUCT UP WITH THE STRUCT WAT THE STRUCT UP TO THE STRUCT THAT THE STRUCT UP THAT TH $\frac{16}{27}(L*Eecrocheen*) 2022, 28(7), 2213003 (2 of 8)$
new leveling agent TS-L to increase throw power stant agitation in order to ensure the good mass trans-
(TP) with the increase in the concentration of TS-L. fer.
When 50 new leveling agent TS-L to increase throw μ star, and agitation in order to ensure the good mass trans-
(TP) with the increase in the concentration of TS-L
When 50 mg-L⁺ TS-L, 10 mg-L⁺ brightener and 600
Basic bath new leveling agent TS-L to increase throw power

(TP) with the increase in the concentration of TS-L. Fr.

(The vincences in the concentration of TS-L. Increase in the concentration of TS-L. Increase in the concentration (TP) with the increase in the concentration of TS-L.

From 5-1⁷ TS-1, 10 mg -1³ inghtchure rand 600

mg -1² in initiative were added to the plating solution,

240 g-1² H₂SO, and 60 mg -1² (C. Fulylene oxide

T When 50 mg·L⁺ TS-L, 10 mg·L⁺ brightener and 600 Basic bath was composed of 75 g·L⁺ CoSO₄· 5H₂O, mg·L⁺ C. Ethylcone oxide to the plating solution (~ 140) and 60 mg·L⁺ C. Ethylcone oxide
TP value reached 87 mg - L⁺ inhibitor were added to the plating solution,

TP value reached 87% in the condition of TH with and propylene exited block copolymers (EoPO) were

the aspect ratio (AR) of 6.4:1. Zheng et al.ⁱ⁴ synthesized an TP value reached 87% in the condition of TH with

and propylene oxide block copolymers (F.O/PO) were

the aspect ratio (AR) of 6.4:1. Zheng et al.¹⁸ synthe-

used as the inhibitor, while Mo was employed for the

sized a the aspect ratio (AR) of 6.4:1. Zheng et al.¹⁴ synthe-

sized a new leveling agent VIBDGE. When the con-

sead at the inhibitor, while MO was employed for the

centration of VIBDGE was 10 mg -L⁻¹, the TP in ass additi sized a new leveling agent VIBDGE. When the con-

special leveler. 200 mg·L⁺¹ EO/PO and 6 mg·L⁻¹ MO

centation of VIBDGE was 10 mg·L⁺¹, the TP in a sadditives were added into basic bash for the typs-

creased to 90. centration of VIBDGE was 10 mg -L⁺, the TP in-

certased to 90.0% for the TH with the aspect ratio of

fuentic experiment. The thickness of the elect

6.4:1. In addition, some new levelers have become ed copper in TH wa ased to 90.0% for the TH with the aspect ratio of

itelative argeriment. The thickness of the electroplat-

i. In addition, some new levelers have become in CHV was vaulated from the cross-sec-

and to improve the quality 6.4:1. In addition, some new levelers have been

ed copper in TH was evaluated from the cross-sec-

found to improve the quality of TH interconnection³¹ tional pitters using a medallographie mirroscope

Wang et al.¹⁹ found to improve the quality of TH interconnection^[6]. tional pictures using a metallographic microscope
Wang et al.¹⁸ proved through a series of experiments

(ASIDA-JAZ3RT, Zhengye Technology). TP value

that Safamin Wang et al.¹³ proved through a series of experiments

(ASIDA-JX23RT, Zhengye Technology). TP value

that saframing T(ST) could not play a levelly include was used to characterize the thickness uniformity of

JGB atthoug that Safranine T (ST) could not play a leveling role like

or SIGB at those smiles tructure of ST vas similar to that $\frac{1}{2}$ of B at the plaining in the relation of Disc

or JGB in the attention of ST vas similar to th JGB although the structure of ST was similar to that

of JGB. Li ct al.¹⁸ proposed a subversive view that

of JGB would be adsorbed on copere through its $N=N$

of R would be adsorbed on copere through its $N=N$

bond aft of JGB. Li et al.¹⁸ proposed a subversive view that

179 = $\frac{2 \times (\delta_z + \delta_t)}{\delta_t + \delta_t + \delta_t + \delta_t} \times 100\%$ (1)

1608 would be adsorbed on copper through its $\lambda = \lambda$, $\delta_t = \delta_t$, $\delta_t =$ JGB would be adsorbed on copper through its -N=N-

bond after studying the adsorption process of JGB where δ_a , δ_b , and δ_b are the plating thickness

during corpor deposition using the methods of mass surface of T

during copper deposition using the methods of mass
surface of TH, δ_s and δ_t are the
spectrometry and nuclear magnetic resonance. Tao et the center of TH in Figure 1.

al.¹⁷¹ obtained an optimal plating solution co

2 Experimental

fer. $\frac{\text{H} \& \frac{2}{3} (J. \text{ *Electrochem.*}) 2022, 28(7), 2213003 (2 of 8)}{\text{crease throw power}} \qquad \text{start agitation in order to ensure the good mass trans-
ncentration of TS-L.} \qquad \text{fer.}$

Fer.

Fer. The prophetic and 600 Basic bath was composed of 75 g⋅L⁻¹ CuSO₄⋅5H₂O, the plating solution 240

 $#E\#(J. Electrochem.)$
 $#E\#(J. Electrochem.)$
 $H = 2022$, $28(7)$, 2213003 (2 of 8)

 $H = 2022$, $28(7)$, 2213003 (2 of 8)

 $H = 2022$, $H = 2022$, $H = 2022$

 $H = 2022$, $H = 2022$

 $H = 2022$
 $H = 2022$
 $H = 2022$
 $H = 2022$
 (*J. Electrochem.*) 2022, 28(7), 2213003 (2 of 8)

throw power stant agitation in order to ensure the good mass trans-

tion of TS-L. fer.

tener and 600 Basic bath was composed of 75 g· L⁻¹ CuSO₄·5H₂O,

ting soluti 2, 28(7), 2213003 (2 of 8)
stant agitation in order to ensure the good mass trans-
fer.
Basic bath was composed of 75 $g \cdot L^{-1}$ CuSO₄ \cdot 5H₂O,
240 $g \cdot L^{-1}$ H₂SO₄ and 60 mg $\cdot L^{-1}$ Cl. Ethylene oxide
and propylene $(8(7), 2213003 \ (2 \text{ of } 8))$

ant agitation in order to ensure the good mass trans-
 \therefore

Basic bath was composed of 75 g $\cdot L^{-1}$ CuSO₄ \cdot 5H₂O,
 $0 \ g \cdot L^{-1}$ H₂SO₄ and 60 mg $\cdot L^{-1}$ Cl⁻. Ethylene oxide

d propyl Basic bath was composed of 75 $g \cdot L^{-1}$ CuSO₄ \cdot 5H₂O, 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·SH₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl⁻. Ethylene oxide

and propylene 213003 (2 of 8)

213003 (2 of 8)

1 H₂SO₄ or to ensure the good mass trans-

bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl⁻. Ethylene oxide

ylene oxide block copolymers (EO/PO) 240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl. Ethylene oxide good mass trans-

L⁻¹ CuSO₄ · 5H₂O,

. Ethylene oxide

rs (EO/PO) were

employed for the

nd 6 mg · L⁻¹ MO

bath for the sys-2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl'. Ethylene oxide

and propylene ox 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl. Ethylene oxide

and propylene oxi 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl: Ethylene oxide

and propylene oxi ensure the good mass trans-
ed of 75 g·L⁻¹ CuSO₄·5H₂O,
mg·L⁻¹ Cl⁻. Ethylene oxide
c copolymers (EO/PO) were
e MO was employed for the
⁻¹ EO/PO and 6 mg·L⁻¹ MO
into basic bath for the sys-
hickness of the ele \mathcal{L}^1 MO 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl⁻ Cl: Ethylene oxide

and propyle 2, 28(7), 2213003 (2 of 8)
stant agitation in order to ensure the good mass trans-
fer.
Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,
240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl⁻ Cl: Ethylene oxide
and propylene ox 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁺ CuSO₄·SH₂O,

240 g·L⁺ H₂SO₄ and 60 mg·L⁺ Cl: Ethylene oxide

and propylene oxide 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁺ CuSO₄·SH₂O,

240 g·L⁺ H₂SO₄ and 60 mg·L⁺ Cl: Ethylene oxide

and propylene oxide 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ CI. Ethylene oxide

and propylene oxi 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl⁻ Cl- Ethylene oxide

and propyle 2, 28(7), 2213003 (2 of 8)

stant agitation in order to ensure the good mass trans-

fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl. Ethylene oxide

and propylene oxi L⁻¹ H₂SO₄ and 60 mg · L⁻¹ Cl. Ethylene oxide
pylene oxide block copolymers (EO/PO) were
the inhibitor, while MO was employed for the
leveler. 200 mg · L⁻¹ EO/PO and 6 mg · L⁻¹ MO
itives were added into basic b b, 2213003 (2 of 8)

agitation in order to ensure the good mass trans-

sic bath was composed of 75 g·L⁻¹ CuSO₄·SH₂O,

·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl⁻. Ethylene oxide

ropylene oxide block copolymers (EO/PO) in order to ensure the good mass trans-
vas composed of 75 g·L¹ CuSO₄·5H₂O,
O₄ and 60 mg·L¹ Cl¹. Ethylene oxide
oxide block copolymers (EO/PO) were
ibitor, while MO was employed for the
200 mg·L¹ EO/PO and 6 fer.

Basic bath was composed of 75 g·L⁻¹ CuSO₄·5H₂O,

240 g·L⁻¹ H₂SO₄ and 60 mg·L⁻¹ Cl: Ethylene oxide

and propylene oxide block copolymers (EO/PO) were

used as the inhibitor, while MO was employed for th composed of 75 g·L⁻¹ CuSO₄·5H₂O,
and 60 mg·L⁻¹ Cl. Ethylene oxide
ide block copolymers (EO/PO) were
tor, while MO was employed for the
90 mg·L⁻¹ EO/PO and 6 mg·L⁻¹ MO
added into basic bath for the sys-
thickne Basic bath was composed of 75 g·L⁺ CuSO₄·SH₂O,
240 g·L⁺ H₂SO₄ and 60 mg·L⁺ Cl: Ethylene oxide
and propylene oxide block copolymers (EO/PO) were
used as the inhibitor, while MO was employed for the
special le 240 g \cdot L⁻¹ H₂SO₄ and 60 mg \cdot L⁻¹ CI: Ethylene oxide
and propylene oxide block copolymers (EO/PO) were
used as the inhibitor, while MO was employed for the
special leveler. 200 mg \cdot L⁻¹ EO/PO and 6 mg ed as the inhibitor, while MO was employed for the
ccial leveler. 200 mg·L⁻¹ EO/PO and 6 mg·L⁻¹ MO
additives were added into basic bath for the sys-
natic experiment. The thickness of the electroplat-
copper in TH was special leveler. 200 mg·L⁻¹ EO/PO and 6 mg·L⁻¹ MO
as additives were added into basic bath for the sys-
tematic experiment. The thickness of the electroplat-
ed copper in TH was evaluated from the cross-sec-
tional pic as additives were added into basic bath for the sys-
tematic experiment. The thickness of the electroplat-
ed copper in TH was evaluated from the cross-sec-
tional pictures using a metallographic microscope
(ASIDA-JX23RT, tematic experiment. The thickness of the electroplat-
ed copper in TH was evaluated from the cross-sec-
tional pictures using a metallographic microscope
(ASIDA-JX23RT, Zhengye Technology). TP value
was used to characteri

$$
TP = \frac{2 \times (\delta_{\rm e} + \delta_{\rm f})}{\delta_{\rm a} + \delta_{\rm b} + \delta_{\rm c} + \delta_{\rm d}} \times 100\%
$$
 (1)

where δ_a , δ_b , δ_c and δ_d are the plating thicknesses

Test

ed copper in TH was evaluated from the cross-sec-
tional pictures using a metallographic microscope
(ASIDA-JX23RT, Zhengye Technology). TP value
was used to characterize the thickness uniformity of
the plating in the TH, mal pictures using a metallographic microscope

SIDA-JX23RT, Zhengye Technology). *TP* value

s used to characterize the thickness uniformity of

plating in the TH, as defined in Equation (1) as:
 $= \frac{2 \times (\delta_e + \delta_t)}{\delta_a + \delta_e +$ (ASIDA-JX23RT, Zhengye Technology). TP value
was used to characterize the thickness uniformity of
the plating in the TH, as defined in Equation (1) as:
 $TP = \frac{2 \times (\delta_z + \delta_r)}{\delta_a + \delta_b + \delta_c + \delta_a} \times 100\%$ (1)
where δ_a , δ_b , $\$ was used to characterize the thickness uniformity of
the plating in the TH, as defined in Equation (1) as:
 $TP = \frac{2 \times (\delta_c + \delta_t)}{\delta_t + \delta_c + \delta_d} \times 100\%$ (1)
where δ_a , δ_b , δ_c and δ_a are the plating thicknesses at the
 the plating in the TH, as defined in Equation (1) as:
 $TP = \frac{2 \times (\delta_z + \delta_t)}{\delta_a + \delta_b + \delta_c + \delta_a} \times 100\%$ (1)

where δ_a , δ_b , δ_c and δ_d are the plating thicknesses at the

surface of TH, δ_s and δ_t are the plating

 $\frac{d}{dx}$ = $\frac{d$ $\exists \ell \ell \neq (L \ \text{Electrochem.}) 2022, 28(7), 2213003 (3 \text{ of } 8)$

calculation are chosen as COMPASS II for force field

and canonical ensemble. After completing the above

optimization, the Forcite module is used to perform

molecula $\pm \frac{1}{2}$ (*L Electrochem.*) 2022, 28(7), 2213003 (3 of 8)

calculation are chosen as COMPASS II for force field

Galvanostatic potential transient measurements (GM)

and canonical ensemble. After completing the above **EVALUATE 1988** If $E^2(L \t{Eetrochem})$ 2022, 28(7), 2213003 (3 of 8)

calculation are chosen as COMPASS II for force field

and canonical ensemble. After completing the above

were completed using Pt-RDE at rotation speeds of
 $\frac{f_0(E\#(J, Electrichem.) 2022, 28(7), 2213003 (3 of 8))}{\frac{1}{2}}$ calculation are chosen as COMPASS II for force field

and canonical ensemble. After completing the above were completed using Pt-RDE at rotation speeds of

optimization **EXAMPLE 1.** External the addition are chosen as COMPASS II for force field Galvanostatic potential transient measurements (GM) and canonical ensemble. After completing the above were completed using Pt-RDE at rotation sp **Example 19** Fig. 11 Fig. 11 Fig. 11 Fig. 12 **EVALUATION THE CONSERVIG CONDUCE (Electrochemical 2022, 28(7), 2213003 (3 of 8)**
 Evaluation are chosen as COMPASS II for force field Galvanostatic potential transient measurements (GM)

d canonical casemble. After com **Example 19.1**
 Example 19.1
 **Example to the frontier molecular control of the frontier molecular control of the frontier molecular control of the frontier molecular or-

and canonical ensemble. After completing the ab Example 19.1**
 Example 19.1 $E^2(L)$ Electrochem.) 2022, 28(7), 2213003 (3 of 8)

and canonical ensemble. After completing the above

ore completed using Pt-RDE at rotation speeds of

optimization, the Forcite module is

the $\frac{1}{2}$ the *S* $\frac{1}{2}$ the *S* $\frac{1}{2}$ the *ChP* is obtained by the completing the above completed using Pt-RDE at rotation speeds of and canonical ensemble. After completing the above were completed using Pt-R **EVALUATION THE CONSERVANCE (EXECUTE THE FROM AND CONDUCT ACTED AND THE CONDUCTED (SUPLAR ON THE FROM AND CONDUCTED THE CONDUCTED THE CONDUCTED AND CONDUCTED AND CONDUCTED AND CONDUCTED (SUPLAR ON THE CONDUCTED AND CONDUC Example 19.** Example 19. The formulation are chosen as COMPASS II for force field Galvanostatic potential transient measurements (GM) and canonical ensemble. After complete molecular dynamics is the complete molecular dy **EXALLE 19** THE EVALUAT CONDEVALUAT THE STANDALLE CONDEVALUAT THE REVALUAT THE REVALUAT CONDEX AND INTERFER THE AND THE CONDEVALUAT THE CONDEVALUAT THE CONDEVALUAT THE CONDEVALUAT THE CONDEVIATION THE FORE THANDALLE CONDE $\frac{16}{2}$ ($\frac{12}{2}$ ($\frac{12}{2}$ Electroshem, 2022, 28(7), 2213003 (3 of 8)

and canonical cnsemble. After completing the above

were completed using Pt-RDE at rotation speeds of

optimization, the Forcite module is use calculation are chosen as COMPASS II for force field

calculation are chosen as COMPASS II for force field

calculation be above the completing the above

and canonical ensemble. After completing the above

or completed u .

$$
\Delta E = E_{\text{LUMO}} - E_{\text{HOMO}} \tag{2}
$$

(28(7), 2213003 (3 of 8)
Galvanostatic potential transient measurements (GM)
were completed using Pt-RDE at rotation speeds of
1000 r·min⁻¹ and 100 r·min⁻¹.
The contact angle was measured by the contact an-
gle tester $(28(7), 2213003 \text{ (3 of 8)}$
Galvanostatic potential transient measurements (GM)
were completed using Pt-RDE at rotation speeds of
1000 r·min⁻¹ and 100 r·min⁻¹.
The contact angle was measured by the contact an-
gle teste 电化学(*J. Electrochem.*) 2022, 28(7), 2213003 (3 of 8)

PASS II for force field Galvanostatic potential transient measurements (GM)

completing the above were completed using Pt-RDE at rotation speeds of

le is used to

 $28(7)$, 2213003 (3 of 8)

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r·min⁻¹ and 100 r·min⁻¹.

The contact angle was measured by the contact an-

gle $(3(7), 2213003 \text{ (3 of 8)}$

alvanostatic potential transient measurements (GM)

recompleted using Pt-RDE at rotation speeds of
 $00 \text{ r} \cdot \text{min}^{-1}$ and $100 \text{ r} \cdot \text{min}^{-1}$.

The contact angle was measured by the contact an $(28(7), 2213003 \text{ (3 of 8)}$
Galvanostatic potential transient measurements (GM)
were completed using Pt-RDE at rotation speeds of
 $1000 \text{ r} \cdot \text{min}^{-1}$ and $100 \text{ r} \cdot \text{min}^{-1}$.
The contact angle was measured by the contact $(28(7), 2213003 \text{ (3 of 8)}$

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of
 $1000 \text{ r} \cdot \text{min}^{-1}$ and $100 \text{ r} \cdot \text{min}^{-1}$.

The contact angle was measured by the con $28(7)$, $2213003(3 \text{ of } 8)$

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of
 $1000 \text{ r} \cdot \text{min}^{-1}$ and $100 \text{ r} \cdot \text{min}^{-1}$.

The contact angle was measured by the (28(7), 2213003 (3 of 8)

(Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r·min⁻¹ and 100 r·min⁻¹.

The contact angle was measured by the contact angle

th (28(7), 2213003 (3 of 8)

(Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r·min⁻¹ and 100 r·min⁻¹.

The contact angle was measured by the contact angle

te . 28(7), 2213003 (3 of 8)

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r-min⁻¹ and 100 r-min⁻¹.

The contact angle was measured by the contact an-

gle te 28(7), 2213003 (3 of 8)

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r-min⁻¹ and 100 r-min⁻¹.

The contact angle was measured by the contact an-

the qu (7), 2213003 (3 of 8)

lvanostatic potential transient measurements (GM)

re completed using Pt-RDE at rotation speeds of

00 r·min⁻¹ and 100 r·min⁻¹.

The contact angle was measured by the contact an-

tester (JY Pha 28(7), 2213003 (3 of 8)

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r·min⁻¹ and 100 r·min⁻¹.

The contact angle was measured by the contact an-

gle te

EO/PO. When only EO/PO was added, the plating d canonical ensemble. After completing the above

twere completed using Pt-RDF: at rotation speeds of

direction, the Foreite modale is used to perform and 100 r-min¹ and 100 r-min¹.

directionar dynamics simulation f optimization, the Forcite module is used to perform

andecellar dynamics simulation for 200 ps with time

The contact angle was measured by the contact
step of 1 fs at 25 °C. In this way, the adsorption enc-

gle tester (molecular dynamics simulation for 200 ps with time
step of I. fs at 25 oC. In this way, the adsorption ener-
step of the solariton ener-
gray and the binding energy of the additive on the cop-
the quantitative liquid drop step of 1 fs at 25 °C. In this way, the adsorption ener-

gay ad the binding nergy of the additive on the cop-

gre surfice can be calculated.

gay ad the binding method in deplets on the coperarinec,

or surfice can be c gy and the binding energy of the additive on the cop-

be quantitative liquid droplets on the copper surface,

comparation and the hydrophilic and hydrophobic properties of

Outantum chemical calculations are performed by per surface can be calculated.

(and the hydropholic and hydropholic properties of

Quadut mechanical calculations are performed by

DMal3 module to illustrate the frontier molecular or-

contest angle⁵⁹.

bital energie Quantum chemical calculations are performed by

the copper surface are reflected by

DMol3 module to illustrate the frontier molecular or-

bital energies and energy gap of MO. The molecular or-

structure optimization of calculations are performed by

the copper surface are reflected by the size of the

strate the frontier molecular or-

contact angle¹⁹.
 3. Results and Discussion

of MO in Sobtained by DFT
 3. Results of the TH elec DMol3 module to illustrate the frontier molecular or-

contact angle⁹⁷.

Structure optimization of MO is obtained by DFT

structure optimization of MO is obtained by DFT

and **The Electroplating**

method. The frontier m bital energies and energy gap of MO. The molecular **3 Results and Discussion**
structure optimization of MO is obtained by DFT **3.1 Function of MO in TH Electroplating**
structure optimization of MO is obtained by DFT **Exam** structure optimization of MO is obtained by DFT 3.1 Function of MO in TH Electroplating
method. The formic molecular consisted of energy of the highest occupied melecular consists of the TH electroplating for 10:1 TH
cons $\frac{28(7)}{2213003}$ (3 of 8)

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r·min⁻¹ and 100 r·min⁻¹.

The contact angle was measured by the contact an-

g $(28(7), 2213003 \text{ (3 of 8)}$

Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of
 $1000 \text{ r} \cdot \text{min}^{-1}$ and $100 \text{ r} \cdot \text{min}^{-1}$.

The contact angle was measured by the con Galvanostatic potential transient measurements (GM)

were completed using Pt-RDE at rotation speeds of

1000 r·min⁻¹ and 100 r·min⁻¹.

The contact angle was measured by the contact an-

gle tester (JY Pha, Zhengye Tec Galvanostatic potential transient measurements (GM)
were completed using Pt-RDE at rotation speeds of
1000 r·min⁻¹ and 100 r·min⁻¹.
The contact angle was measured by the contact an-
gle tester (JY Pha, Zhengye Technol were completed using Pt-RDE at rotation speeds of 1000 r-min⁻¹ and 100 r-min⁻¹.
The contact angle was measured by the contact an-
gle tester (JY Pha, Zhengye Technology) to analyze
the quantitative liquid droplets on 1000 r min⁻¹ and 100 r min⁻¹.

The contact angle was measured by the contact angle tester (JY Pha, Zhengye Technology) to analyze

the quantitative liquid droplets on the copper surface,

and the hydrophilic and hydro The contact angle was measured by the contact angle tester (JY Pha, Zhengye Technology) to analyze the quantitative liquid droplets on the copper surface, and the hydrophilic and hydrophobic properties of the copper surfa gle tester (JY Pha, Zhengye Technology) to analyze
the quantitative liquid droplets on the copper surface,
and the hydrophilic and hydrophobic properties of
the copper surface are reflected by the size of the
contact angl the quantitative liquid droplets on the copper surface,
and the hydrophilic and hydrophobic properties of
the copper surface are reflected by the size of the
contact angle^[6].
3.1 Function of MO in TH Electroplating
T to 92.34% using the bath containing 200 mg \cdot L⁻¹ EO/ and the hydrophilic and hydrophobic properties of
the copper surface are reflected by the size of the
contact angle^[9].
3. Results and Discussion
3.1 Function of MO in TH Electroplating
The results of the TH electro hilic and hydrophobic properties of
ace are reflected by the size of the
nnd Discussion
of MO in TH Electroplating
f the TH electroplating for 10:1 TH
electroplating baths are shown in
P with AR of 10:1 was only 56.59%
 the copper surface are reflected by the size of the
contact angle^[9].
3. Results and Discussion
3.1 Function of MO in TH Electroplating
The results of the TH electroplating for 10:1 TH
using different electroplating contact angle^[9].
 3. Results and Discussion
 3.1 Function of MO in TH Electroplating

The results of the TH electroplating for 10:1 TH

using different electroplating baths are shown in

Figure 2. The TP with AR of **3 Results and Discussion**
 3.1 Function of MO in TH Electroplating

The results of the TH electroplating for 10:1 TH

using different electroplating baths are shown in

Figure 2. The TP with AR of 10:1 was only 56.59%
 3.1 Function of MO in TH Electroplating

The results of the TH electroplating for 10:1 TH

using different electroplating baths are shown in

Figure 2. The TP with AR of 10:1 was only 56.59%

using the basic electroplatin

VIBDGE^[4].

 $#E\#(J. Electron) 2022, 28(7), 2213003 (4 of 8)$

EO/PO and MO is larger.
 EO/PO and MO is larg $\text{H}(k\#(J. Electrochem.) 2022, 28(7), 2213003 (4 of 8))$
 EO/PO and MO is larger.
 3.2 The Role of MO in TH Electroplating
 3.2 The Role of MO in TH Electroplating

Figure 3 shows the molecular structure of MO. Re-

garding the \pm *f**Exectrochem.*) 2022, 28(7), 2213003 (4 of 8)
 EXECTABLE 1022 The Role of MO in TH Electroplating wettability of the base plating solution without any

Figure 3 shows the molecular structure of MO. Re-
 EXE EO/PO and MO is larger.
 EO/PO and MO is larger. The **Role of MO** in **TH Electroplating** wettability of the base plating solution without any Figure 3 shows the molecular structure of MO. Recording the adsorption of M the $\#k \neq (I. \text{Electrochem.}) 2022, 28(7), 2213003 (4 of 8)$

EO/PO and MO is larger. measured as shown in Figure 4. Among them, the

3.2 The Role of MO in TH Electroplating wettability of the base plating solution without any

Figu ble bond and the sulfonic acid group just like JGB **EO/PO and MO is larger.**
 Also additives on the some parallity of the base plating solution without any

Figur **EO/PO** and MO is larger.
 Boond MO in **TH Electroplating**
 EO/PO and MO is larger.
 Roond MO in **TH Electroplating**
 EO/PO and MO i $\#R\#CL\$ *Electrochem.*) 2022, 28(7), 2213003 (4 of 8)
 The Role of MO in TH Electroplating wettability of the base plating solution without any

Figure 3 shows the molecular structure of MO. Re-

diditives on the cop ± 0.7 PO and MO is larger.
 EO/PO and MO is larger. measured as shown in Figure 4. Among them, the Sate ingle of **MO in TH Electroplating** wettability of the base plating solution without any Figure 3 shows the molec **EOPO** and MO is larger.
 EOPO and MO is larger. The **Role of MO in TH Electroplating** we measured as shown in Figure 4. Among them, the Figure 3 shows the molecular structure of MO. Re-
 EQUE ACT MO in TH Electroplati EXPO and MO is larger.
 EXPO and MO is larger. The adsorption energy of $\frac{1}{2}$ and $\frac{1$ $\frac{dE}{dt}$ (*EE* (*Electrochem*,) 2022, 28(7), 2213003 (4 of 8)
 EO/PO and MO is larger.
 ELECTRO INTERECTOP (ISON) $\frac{dE}{dt}$ ($\frac{dE}{dt}$ ($\frac{dE}{dt}$ ($\frac{dE}{dt}$) (**EO/PO** and MO is larger.
 EV and **CO in TH Electroplating** solutives on the copper surface, we
additives on the $4E\neq (LJ, J, J, J, 2213003 (4 of 8)$
 co.) The Role of MO in TH Electroplating wettability of the base plating solution without any

Figure 3 shows the molecular structure of MO. Re-

additives on the copper surface was 2). The Dand MO is larger.

and MO is larger.
 Eight De TH Electroplating contact as shown in Figure 4. Among them, the

Figure 3 shows the molecular structure of MO. Re-

additives on the coeper surface was the worst t 3.2 The Role of MO in TH Electroplating wattability of the base plating solution without any Figure 3 shows the molecular structure of MO. Re- additives on the copper surface was the worst to reach the context of the cont Figure 3 shows the molecular structure of MO. Re-

additives on the copper surface was the worst to

garding the adsorption of MO on the copper surface, reach the contact angle of 67.4° because the copper

it is likely to garding the adsorption of MO on the copper surface,

it is likely to be criated to the nitrogen-nitrogen dou-

surface for an integral of the nitrogen integral of the contact angle of the contact

ble bond and the sulform it is likely to be related to the nitrogen-nitrogen dou-
surface did not contain hydroxyl groups, and the plat-
bot and the sulform did investigate include the surface on corper through $N=1$
that would be adsorbed on cor 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)

measured as shown in Figure 4. Among them, the

wettability of the base plating solution without any

additives on the copper surface was the worst to

reach the contact angle of 67.4° because 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the 2, 28(7), 2213003 (4 of 8)
measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the **Example 1999**
 Example to obsequence
 Example to the base plating solution without any

ditives on the copper surface was the worst to

to the contact angle of 67.4° because the copper

rface did not contain hydroxyl measured as shown in Figure 4. Among them, the
wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the copper
surface did not cont wettability of the base plating solution without any
additives on the copper surface was the worst to
reach the contact angle of 67.4° because the copper
surface did not contain hydroxyl groups, and the plat-
ing solution additives on the copper surface was the worst to
reach the contact angle of 67.4° because the copper
surface did not contain hydroxyl groups, and the plat-
ing solution without additives had poor wettability on
the pure co reach the contact angle of 67.4° because the copper
surface did not contain hydroxyl groups, and the plat-
ing solution without additives had poor wettability on
the pure copper surface^[13]. The wettability of the bath
 surface did not contain hydroxyl groups, and the plating solution without additives had poor wettability on the pure copper surface^[13]. The wettability of the bath containing only EO/PO was better with the contact angl $\frac{d\Phi}{dt} = \frac{d\Phi}{dt}$
 $\frac{d\Phi}{dt} = \frac{d\Phi}{dt}$
 $\frac{d\Phi}{dt} = \frac{d\Phi}{dt}$
 Electroplating wetability of the base plating solution without any

structure of MO. Re-
 Alternatives on the copper surface was the worst to

t

Example 1980
 CEPT EXECUTE CONSTRANS C iFONO
 Example 1980
 Exa EXECUTE:
 Exerces The calculation results of HOMO and LUMO for MO molecule (color on line)

(HOMO and LUMO) of reacting species. The clec-
 -5.548 eV, respectively. It indicates that the clectron

tron donating abil **Cy of the molecule to accept the molecule to accept to accept electrons** of E_{LDA} and the molecule to accept electrons (solar accepts). The distribution for a specifical state of the molecule (color on this)
are ass **Example 19**
 Example 3 The calculation results of HOMO and LUMO for MO molecule (color on line)

(HOMO and LUMO) of reacting species. The clee-
 $\frac{4.5268 \text{ eV}}{5}$, respectively. It indicents that the cleeror

term d **Example 19** Example 10 LUMO and LUMO for MO molecule (color on line)
 Example 3 Example 1100MO and LUMO for MO molecule (color on line)

(HOMO and LUMO) of reacting species. The elec-

5.548 eV, respectively. It indica **Example 19**
 Example 19
 Example 19
 Example 19
 Example 19
 Example 100MO and **LUMO** for racting species. The elec-
 Example 100MO and **LUMO** for racting considers. The elec-
 Example 100MO has the highest **Eigence 5** The calculation results of HOMO and LUMO for MO molecule (color on line)

(HOMO and LUMO) of reacting species. The elec-
 -5.548 eV, respectively. It indicates that the electron

troon donating ability and c (HOMO and LUMO) of reacting species. The elec-

and the metal surface (clos of anti-

and the decreasing subility and electron accepting ability

donating abilities of JGB and MO are similar. On the

are associated with t OMO and LUMO) of reacting species. The elec-

and molonating ability and electron

and molonating ability and electron

and molonating ability and electron

are associated with the energy of HOMO and LUMO.

coher hand, M

(a) basic bath; (b) basic bath + EO/PO; (c) basic bath + MO; (d)

LUMO

LUMO

ev

ev

ev

expressively. It indicates that the electron

domating abilities of JGB and MO are similar. On the

of MO are similar. On the

of M (a) basic bath; (b) basic bath + EO/PO; (c) basic bath + MO; (d)

LUMO
 $\frac{1}{2}$
 $\frac{1}{2}$
 $\frac{1}{2}$
 $\frac{1}{2}$

ev $\frac{1}{2}$
 $\frac{1}{2}$
 $\frac{1}{2}$

ev $\frac{1}{2}$
 $\frac{1}{2}$

ev $\frac{1}{2}$
 $\frac{1}{2}$
 $\frac{1}{2}$

ev (a) basic bath; (b) basic bath + EO/PO; (c) basic bath + MO; (d)

LUMO

COMEXAL TRIMITED AND TRIMITED AND TRIMITED AND CONTROLLED AND CONTROLLED AND CONTROLLED AND CONTROLLED TO the contraction on the cathode. Through the (a) oasie bain; (b) basie bain + EOPO; (e) basie bain + FNO; (d)

LUMO

events of the calculation, the calculation

developed to the calculation, the calculation

domating abilities of JGB and MO are similar. On the

onte LUMO
 EVALUMO

EVALUMO

EVALUMO

EVALUMO

EVALUMO

SAVA FORE SERVALUATE AND ARREST AND A THE EXERCISE AND A SUMPLE ADDITION the characteristic and inhibit the copper electrodeposition

on the cathode. Through the calcul **EXERCT 1999**
Structure between MO and MO are similar. On the
other hand, MO could be well adsorbed on the cath-
other hand, MO could be well adsorbed on the cath-
ode surface and inhibit the copper electrodeposition
on t **EVALUATE:**
 Example 18 Proper Set profit and the CV curves the cluster of the color on line)

S48 eV, respectively. It indicates that the electron

nating abilities of JGB and MO are similar. On the

near hand, MO could be well ads ev

beveloped the color on line)

place and the ends of JGB and MO are similar. On the

other hand, MO could be well adsorbed on the cath-

other hand, MO could be well adsorbed on the cath-

other hand, MO could be well eV

view $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 &$ eV
 \bullet
 \bullet

 \vec{P}

ecule (color on line)

-5.548 eV, respectively. It indicates that the electron

donating abilities of JGB and MO are similar. On the

other hand, MO could be well adsorbed on the cath-

ode surface and inhibit th ecule (color on line)
-5.548 eV, respectively. It indicates that the electron
donating abilities of JGB and MO are similar. On the
other hand, MO could be well adsorbed on the cath-
ode surface and inhibit the copper elec -5.548 eV, respectively. It indicates that the electron
donating abilities of JGB and MO are similar. On the
other hand, MO could be well adsorbed on the cath-
ode surface and inhibit the copper electrodeposition
on the c -5.548 eV, respectively. It indicates that the electron
donating abilities of JGB and MO are similar. On the
other hand, MO could be well adsorbed on the cath-
ode surface and inhibit the copper electrodeposition
on the c

The GM results at the rotation speeds of 1000

The *Biskique 2.*

The above the curves between -0.40 V to -0.32 V for Figure

transfer to copper surface; (2) Under the synergy of

MO and EO/PO the deposition rate is reduc The GM results at the curves between -0.40 V to -0.32 V for Figure

nsfer to copper surface; (2) Under the synergy of

O and EO/PO the deposition rate is reduced, and

copper layer becomes uniform. Due to a synergis-
 Example 20 reader the curves between -0.40 V to -0.32 V for Figure
transfer to copper surface; (2) Under the synergy of
MO and EO/PO the deposition rate is reduced, and
the copper layer becomes uniform. Due to a synergi The *n*⁵*N*₂₄₄₄*g*²⁰⁰⁷

The *n*⁵*N*₂₄₄₄*g*²⁰⁰⁷

The angle of the curves between -0.40 V to -0.32 V for Figure

transfer to copper surface; (2) Under the synergy of

MO and EO/PO the deposition rate is reduced, For the curves between -0.40 V to -0.32 V for Figure

corporer surface; (2) Under the synergy of

CO/PO the deposition rate is reduced, and

layer becomes uniform. Due to a synergis-

etween MO and EO/PO to promote the de

decrease of copper deposition. This could be ex-

plained as follows: (1) the group l# of MO could each the copper layer becomes uniform. Due to a synegris-

electrons while the group 2# of MO hinders Cu²⁺ to

electrons plained as follows: (1) the group 1# of MO could eatch

the Cu² to promote the relations of the characterise MO and EO/PO to promote the de-

electrons while the group 2# of MO hinders Cu² to position rate on the surf the Cu^{s-} to promote the reduction after obtaining
electrons while the group 2# of MO hinders Cu²⁻ to position rate on the surface, the thickness of coper-
plating on the surface, the thickness of coper-
plating on t The basic bath, the cathodic solution of ED/PO could strongly inhering the cathodic potential was sharply of MO and EO/PO the deposition rate is reduced, and the copper layer becomes uniform. Due to a synergistic effect b and view of the curves between -0.40 V to -0.32 V for Figure

transfer to copper surface; (2) Under the synergy of

MO and EO/PO the deposition rate is reduced, and

the copper layer becomes uniform. Due to a synergis-

t arged view of the curves between -0.40 V to -0.32 V for Figure

transfer to copper surface; (2) Under the synergy of

MO and EO/PO the deposition rate is reduced, and

the copper layer becomes uniform. Due to a synergis-
 Example 12
 Example 12 The adsorption rate is reduced, and the copper layer becomes uniform. Due to a synergistic effect between MO and EO/PO to promote the deposition rate on the surface, the thickness of copper plat transfer to copper surface; (2) Under the synergy of
MO and EO/PO the deposition rate is reduced, and
the copper layer becomes uniform. Due to a synergis-
tic effect between MO and EO/PO to promote the de-
position rate o transfer to copper surface; (2) Under the synergy of
MO and EO/PO the deposition rate is reduced, and
the copper layer becomes uniform. Due to a synergis-
tic effect between MO and EO/PO to promote the de-
position rate o transfer to copper surface; (2) Under the synergy of
MO and EO/PO the deposition rate is reduced, and
the copper layer becomes uniform. Due to a synergis-
tic effect between MO and EO/PO to promote the de-
position rate o MO and EO/PO the deposition rate is reduced, and
the copper layer becomes uniform. Due to a synergis-
tic effect between MO and EO/PO to promote the de-
position rate on the surface, the thickness of copper
plating on the the copper layer becomes uniform. Due to a synergistic effect between MO and EO/PO to promote the deposition rate on the surface, the thickness of copper plating on the surface is reduced from about 15 μ m to about 14 tic effect between MO and EO/PO to promote the de-
position rate on the surface, the thickness of copper
plating on the surface is reduced from about 15 μ m
to about 14 μ m in Figure 2.
The GM results at the rotation

 $\#E\#(J. Electron) 2022, 28(7), 2213003 (7 of 8)$
a gentle change in potential because MO was formed ment of TH copper electroplating with only two addi-
by simultaneous competition between the group 1# in
MO for the Cu²⁺ transfer $#E# (J. Electron) 2022, 28(7), 2213003 (7 of 8)$

a gentle change in potential because MO was formed

by simultaneous competition between the group 1# in

MO for the Cu²⁺ reduction acceleration and the group 1# in

MO for the Cu² $#E \cong (L \t{Electrochem.}) 2022, 28(7), 2213003 (7 of 8)$

a gentle change in potential because MO was formed

the Cu²⁺ reduction between the group 1# in

MO for the Cu²⁺ reduction acceleration and the group
 $\frac{1}{2}$ in MO for **E** *i Electrochem.*) 2022, 28(7), 2213003 (7 of 8)
 a gentle change in potential because MO was formed ment of TH copper electroplating with only two addi-

by simultaneous competition between the group 1# in tives. $\pm \frac{\text{d} \frac{1}{4} \$ $\frac{\text{#}\{\mathcal{E}\neq^{\omega}(I, \text{Electrochem.})\ 2022, 28(7), 2213003\ (7 of 8)}{\text{a gentle change in potential because MO was formed} \quad \text{ment of TH copper electrophating with only two addi-
by simultaneous competition between the group 1# in
MO for the Cu²⁺ reduction acceleration and the group\n\nAcknowledgements:
2# in MO for the Cu²⁺ transfer inhibition to the earth\n\nThe authors gratefully acknowledge the support of
ode. In addition, the GM results in the conditions of
1000 r·min³ and 100 r·min¹ presented respective
potentials of -0.763 V and -0$ $\pm k \mathcal{F}(J. Electron) 2022, 28(7), 2213003 (7 of 8)$

a gentle change in potential because MO was formed ment of TH copper electroplating with only two addi-

by simultaneous competition between the group 1# in tives.

MO for the Cu $\pm (E\mathcal{P}(L \nvert L) - 222, 28(7), 2213003 (7 \text{ of } 8))$
a gentle change in potential because MO was formed ment of TH copper electroplating with only two addi-
by simultaneous competition between the group 1# in tives.
MO for th **the first Example 10** and the subset of State of TH coper electroplating with only two addi-
by simultaneous competition between the group 1^g in tives.
MO for the Cu² reduction acceleration and the group **Acknowledge** $\frac{d_1}{d_2} \frac{d_2}{d_2} \frac{d_3}{d_3} \frac{d_4}{d_4} \frac{d_5}{d_4} \frac{d_5}{d_5} \frac{d_6}{d_6} \frac{d_7}{d_7} \frac{d_7}{d_7} \frac{d_7}{d_7} \frac{d_8}{d_7} \frac{d_7}{d_7} \frac{d_8}{d_7} \frac{d_7}{d_7} \frac{d_8}{d_7} \frac{d_9}{d_7} \frac{d_9}{d_7} \frac{d_9}{d_7} \frac{d_9}{d_7} \frac{d_9}{d_7}$ $\frac{1}{2}$ (*Exertowhem.*) 2022, 28(7), 2213003 (7 of 8)

a gentle change in potential because MO was formed ment of TH copper electroplating with only two addi-

by simultaneous competition between the group 1# in tives **EVALUATION THE TENT CONDOM CONTINUATION** (For the change in potential because MO was formed ment of TH copper electroplating with only two addi-
by simultaneous competition between the group 1^H in tives.
MO for the Cu the $\mathcal{H}_2\mathcal{H}(L \times M_0)$ and $\mathcal{H}_2\mathcal{H}(L \times M_0)$ and $\mathcal{H}_2\mathcal{H}(L \times M_0)$ and \mathcal{H}_3 comparison the surface of the surfac **EXALMEE 19** THE THE METHEM (D. 2021, 28(7), 2213003 (7 of 8)

is gentle change in potential because MO was formed ment of TH copper electroplating with only two addi-

by simultaneous competition acceleration and the gro th($E^{up}(L \& Ebernochem, 2022, 28(7), 2213003 (7 of F)$

tions of EO/Po and ment of TH copper electroplating with only two addi-

by simultaneous competition between the group 1# in

MO for the Cu²⁺ reduction acceleration and the a gentle change in potential cosaw MO was formed method capture in the cu² transfer but good capture in the cu² real method capture in the cu² real method for the Cu²⁺ reduction acceleration and the group **Acknowl** a gentle change in potential because MO was formed

by simultaneous competition between the group

MS for the Cu²⁺ reansfer inhibition to the group

MS for the Cu²⁺ reansfer inhibition to the cath

2*n* in M for the C by simultaneous competition hetween the group 1# in tives.

MO for the Cu² reduction acceleration and the group

2# in MO for the Cu² reduction and the group

2# in MO for the Cu² remarkr inhibition to the cath-

Th MO for the Cu²⁺ reduction acceleration and the group

24: The Co¹¹ transfer inhibition to the calib-

24: in MO for the Co¹¹ transfer inhibition to the collinear state.

1000 r - min⁻¹ and 100 r - min⁻¹ presente 2# in MO for the Cu²⁺ transfer inhibition to the cath-

The authors gratefully acknowledge the support of

close. In addition, the GM results in the conditions of Change National Natural Sienee Foundation of China (No.
 ode. In addition, the GM results in the conditions of National Natural Science Foundation of China (No.

1000 r · · · min' and 100 r · · min' levested respective by protocolly harowed to prove the surface of SurV because 1000 r - min⁻¹ and 100 r - min⁻¹ presented respective (1974020). The work is also supported by Innovation
potentials of -0.763 V and -0.771 V, causing a potential composition difference of S mV because of fast mass tr potentials of -0.763 V and -0.771 V, causing a poten-

tial difference of 8 mV because of fast mass transfer

FWC), and the project of Zhuhai

project of binder the absorptions of EO/PO and MO on cop-

zhuhai City (No. ZH inder the absorptions of FO/PO and MO on cop-

Eucha City (No. ZH01084702180040HIL)

condition of 1000 r-min⁺ resulted in a little faster

²² reduction. In this way, a thick copper plating of

²³ reduction. In this per surface. Higher potential of the plating solution in

the condition of 1000 r-min' resulted in a little faster

Cu² reduction. In this way, a finick coper plating of

Li1 Wang C, Zhang J Q, Yang P X, Zhang B Q, An M the condition of 1000 r-min³ resulted in a little faster **References:**

Cu² reduction. In this way, a thick copper plating of [1] wang c₂ Zhang J Q, Yang P X, Zhang B Q, An M Z

cabout 14.0 µm in this way, a thick c Cu²⁺ reduction. In this way, a thick copper plating of [1] Wang C, Zhang 1 Q, Yang P X, Zhang B Q, An M Z,

of TH with insteams was formed at the surface innovelable copperelectioplating using nitrichicalism

of TH with about 14.0 µm in thickness was formed at the surface through-hole congredient
paing using ninearczofium for which fast mass transfer and unstalled usor
paint to simulate that the MO molecule could make both inhibition and of TH with first mass transfer and unstable absorption and MO. On the other hand, gently and color first man, gently $160(3)$; Disselbation spontaneously and the surface of the advertame of Cu² behaviors of January 160(

4 Conclusions

tions of EO/PO and MO. On the other hand, gently

lead(3). Discuss transfer but good capture of Cu²⁺ from MO and the sole continuous metallical could make both inhibit Iow mass transfer but good capture of Cu²⁺ from MO

cold make both inhibition and acceleration of Cu³⁺

cold make both inhibition and acceleration of Cu³⁺

cold make both inhibition and acceleration with competitive could make both inhibition and acceleration of Cu²⁺
contains various voral and unough-note or proper plains of about 13.5 µm in thick-
ing to the conper plainting of about 13.5 µm in thick-
note of TH. Above result at th reduction with competitive interaction, thereby, lead-

in thick-

in the coupler plaint of an extraction of the state of the coupler plaint of a subsection and the surface of TH. Above result on copper leveling agent TSing to the corper plating of about 13.5 μ m in thick-

meass mission compared to [3] μ mg x C, Peng DM, Chen ZX, Cheng J. Freet of results of Michael Corps (μ mg DM, Chen ZX, Cheng J. Freet of reverse inside the the ness inside TH but close to the thickness compared to

that at the surface of TH. Above result on copper

deposition rate matched well with that displayed in

deposition rate matched well with that displayed in

depositio that at the surface of TH. Above result on copper

deposition and inhibit complementation of cooperation of competer

deposition rate matched well with that displayed in a molecular competency of the complementation and t deposition rate matched well with that displayed in $\frac{1}{4}$ renoptating &Finishing, 2016, 3501) \times 56-559.

[4] **Zone Luissions** (a) $\tan \frac{1}{4}$ renew interesting the more electrochemical performance and
 44 Conclusio Figure 2c.

41 Zheng L. Investigation on electrochemical performance and

44 Conclusions

46 Conclusions (and NO in the TH copper

4 electrochemicsion for experiments to replace the accelerator

4 electrochemicsion for ex **4 Conclusions**
 Example the Solution Control (MO was used as a special leveler in the TH copper

electroplating acperiments to replace the accelerator

solution could contribute to that the electroplating additive syst MO was used as a special leveler in the TH copper

electrophating or china, 2020.

electrophating orderinor-

and leveler so that the clectrophating additive system

and leveler so that the Coefenlating additive system

c electroplating experiments to replace the accelerator $S = 1$ (s) S and leveler so that the electroplating additive system

y marces in electroplating of though-bale copper intercon-

coculd be simplified. Results from indicalend apparam-

its simulations showed that the MO molecule could

(28(7), 2213003 (7 of 8)

ment of TH copper electroplating with only two addi-

tives.
 Acknowledgements:

The authors gratefully acknowledge the support of

National Natural Science Foundation of China (No. tives. 电化学(*J. Electrochem.*) 2022, 28(7), 2213003 (7 of 8)
ause MO was formed ment of TH copper electroplating with only two addi-
tween the group 1# in tives.
eration and the group **Acknowledgements:**
the authors gratefully a

Acknowledgements:

 $\frac{3(7)}{213003}$ (7 of 8)

ent of TH copper electroplating with only two addi-

es.
 Exhowledgements:

The authors gratefully acknowledge the support of

titional Natural Science Foundation of China (No.

974020). The 28(7), 2213003 (7 of 8)

ment of TH copper electroplating with only two addi-

tives.
 Acknowledgements:

The authors gratefully acknowledge the support of

National Natural Science Foundation of China (No.

61974020). T $28(7)$, 2213003 (7 of 8)
ment of TH copper electroplating with only two addi-
tives.
Acknowledgements:
The authors gratefully acknowledge the support of
National Natural Science Foundation of China (No.
61974020). Th $(28(7), 2213003 (7 \text{ of } 8)$
ment of TH copper electroplating with only two addi-
tives.
Acknowledgements:
The authors gratefully acknowledge the support of
National Natural Science Foundation of China (No.
61974020). The $(28(7), 2213003 (7 \text{ of } 8))$

ment of TH copper electroplating with only two addi-

tives.
 Acknowledgements:

The authors gratefully acknowledge the support of

National Natural Science Foundation of China (No.

61974020 $(28(7), 2213003 (7 \text{ of } 8))$

ment of TH copper electroplating with only two addi-

tives.
 Acknowledgements:

The authors gratefully acknowledge the support of

National Natural Science Foundation of China (No.

61974020 $28(7)$, 2213003 (7 of 8)
ment of TH copper electroplating with only two addi-
tives.
Acknowledgements:
The authors gratefully acknowledge the support of
National Natural Science Foundation of China (No.
61974020). The 7), 2213003 (7 of 8)

at of TH copper electroplating with only two addi-

s.
 cnowledgements:

The authors gratefully acknowledge the support of

fional Natural Science Foundation of China (No.

74020). The work is also 7), 2213003 (7 of 8)

the of TH copper electroplating with only two addiss.

s.
 choride as a leveler constant constant of Chandal Soc.

The authors gratefully acknowledge the support of

fional Natural Science Foundatio 7), 2213003 (7 of 8)

the of TH copper electroplating with only two addi-

s.
 EXECUTE: The authors gratefully acknowledge the support of

ional Natural Science Foundation of China (No.

74020). The work is also supporte (28(7), 2213003 (7 of 8)

ment of TH copper electroplating with only two addi-

tives.
 Acknowledgements:

The authors gratefully acknowledge the support of

National Natural Science Foundation of China (No.

61974020). the of TH copper electroplating with only two addiss.

S.

S.
 S.

The authors gratefully acknowledge the support of

fonal Natural Science Foundation of China (No.

74020). The work is also supported by Innovation

m Pr s.

S.

S.

S.

chot in copper electrophating with only two addi-

S.

The authors gratefully acknowledge the support of

China (No.

74020). The work is also supported by Innovation

m Project of Zhuhai City (No. ZH040519 s.
 chowledgements:

the authors gratefully acknowledge the support of

fonal Natural Science Foundation of China (No.

74020). The work is also supported by Innovation

m Project of Zhuhai City (No. ZH0405190005

C), an **chowledgements:**

The authors gratefully acknowledge the support of

fional Natural Science Foundation of China (No.

74020). The work is also supported by Innovation

m Project of Zhuhai City (No. ZH0405190005

C), and The authors gratefully acknowledge the support of
National Natural Science Foundation of China (No.
61974020). The work is also supported by Innovation
Team Project of Zhuhai City (No. ZH0405190005
PWC), and the project of ional Natural Science Foundation of China (No.
74020). The work is also supported by Innovation
m Project of Zhuhai City (No. ZH0405190005
C), and the project of Sci & Tech planning of
thai City (No. ZH01084702180040HJL)

References:

-
- 74020). The work is also supported by Innovation
m Project of Zhuhai City (No. ZH0405190005
C), and the project of Sci & Tech planning of
thai City (No. ZH01084702180040HJL)
ferences:
Wang C, Zhang J Q, Yang P X, Zhang B Team Project of Zhuhai City (No. ZH0405190005

PWC), and the project of Sci & Tech planning of

Zhuhai City (No. ZH01084702180040HJL)
 References:

[1] Wang C, Zhang J Q, Yang P X, Zhang B Q, An M Z.

Through-hole copper C), and the project of Sci & Tech planning of

thai City (No. ZH01084702180040HJL)
 ferences:

Wang C, Zhang J Q, Yang P X, Zhang B Q, An M Z.

Through-hole copper electroplating using nitrotetrazolium

blue chloride as hai City (No. ZH01084702180040HJL)
 ferences:

Wang C, Zhang J Q, Yang P X, Zhang B Q, An M Z.

Through-hole copper electroplating using nitrotetrazolium

blue chloride as a leveler[J]. J. Electrochem. Soc., 2013,

160(3 **ferences:**

Wang C, Zhang J Q, Yang P X, Zhang B Q, An M Z.

Through-hole copper electroplating using nitrotetrazolium

blue chloride as a leveler[J]. J. Electrochem. Soc., 2013,

160(3): D85-D88.

Wang C, Zhang J Q, Yang **References:**

[1] Wang C, Zhang J Q, Yang P X, Zhang B Q, An M Z.

Through-hole copper electroplating using nitrotetrazolium

blue chloride as a leveler[J]. J. Electrochem. Soc., 2013,

160(3): D85-D88.

[2] Wang C, Zhang **EFFERICES:**

Wang C, Zhang J Q, Yang P X, Zhang B Q, An M Z.

Through-hole copper electroplating using nitrotetrazolium

blue chloride as a leveler[J]. J. Electrochem. Soc., 2013,

160(3): D85-D88.

Wang C, Zhang J Q, Yan Wang C, Zhang J Q, Yang P X, Zhang B Q, An M Z.
Through-hole copper electroplating using nitrotetrazolium
blue chloride as a leveler[J]. J. Electrochem. Soc., 2013,
160(3): D85-D88.
Wang C, Zhang J Q, Yang P X, An M Z. Ele Inrough-note copper electroplating using introtetrazolum

blue chloride as a leveler[J]. J. Electrochem. Soc., 2013,

160(3): D85-D88.

[2] Wang C, Zhang J Q, Yang P X, An M Z. Electrochemical

behaviors of Janus Green B i blue chlorde as a leveler[J]. J. Electrochem. Soc., 2013,
160(3): D85-D88.
Wang C, Zhang J Q, Yang P X, An M Z. Electrochemical
behaviors of Janus Green B in through-hole copper elec-
behaviors of Janus Green B in through-160(3): D85-D88.

Wang C, Zhang J Q, Yang P X, An M Z. Electrochemical

behaviors of Janus Green B in through-hole copper elec-

behaviors of Janus Green B in through-hole copper elec-

troplating: An insight by experiment [2] Wang C, Zhang J Q, Yang P X, An M Z. Electrochemical
behaviors of Janus Green B in through-hole copper elec-
trophating: An insight by experiment and density function-
al theory calculation using Safranine T as a comp
-
- behaviors of Janus Green B in through-hole copper electroplating: An insight by experiment and density function-
al theory calculation using Safranine T as a comparison[J].
Electrochim. Acta, 2013, 92: 356-364.
Ding X C, P troplating: An insight by experiment and density function-
al theory calculation using Safranine T as a comparison[J].
Electrophim. Acta, 2013, 92: 356-364.
Ding X C, Peng D M, Chen Z X, Cheng J. Effect of novel
leveling a
-
-
- 124-131.
- Electrochim. Acta, 2013, 92: 356-364.

[3] Ding X C, Peng D M, Chen Z X, Cheng J. Effect of novel

leveling agent TS-L on electrodeposition of copper[J]. Electroleplating &Finishing. 2016, 35(11): 556-559.

[4] Zheng L. In Ding X C, Peng D M, Chen Z X, Cheng J. Effect of novel
eleveling agent TS-L on electrodeposition of copper[J]. Elec-
etroplating&Finishing, 2016, 35(11): 556-559.
Zheng L. Investigation on electrochemical performance and
t eveling agent 1S-L on electrodeposition of copper[J]. Electroplating &Finishing, 2016, 35(11): 556-559.

Zheng L. Investigation on electrochemical performance and tuning property of the organic-additive-system for copper
 ctroplating & Funishing, 2016, 35(11): 356-559.

Zheng L. Investigation on electrochemical performance and

tuming property of the organic-additive-system for copper

electrodeposition [D]. Chengda: University of Electroni Zheng L. Investigation on electrochemical performance and
tuning property of the organic-additive-system for copper
electrodeposition [D]. Chengdu: University of Electronic
Science and Technology of China, 2020.
Zhang Y H, tion property of the organic-additive-system for copper
electrodeposition [D]. Chengdi: University of Electronic
Science and Technology of China, 2020.
[5] Zhang Y H, An M Z, Yang P X, Zhang J Q. Recent ad-
vances in elect electrodeposition [D]. Chengati: University of Electronic

Science and Technology of China, 2020.

Zhang Y H, An N Z, Yang P X, Zhang J Q. Recent ad-

vances in electroplating of hough-hole copper intercon-

nection[J]. El Science and 1echnology of China, 2020.

Zhang Y H, An M Z, Yang P X, Zhang J Q. Recent ad-vances

vances in electroplating of though-hole copper intercon-

nection[J]. Electrocatalysis, 2021, 12(6): 619-627.

Li Y B, Wang Zhang Y H, An M Z, Yang P X, Zhang J Q. Recent advances in electroplating of though-hole copper intercon-
nectoroll]. Electrocatalysis, 2021, 12(6): 619-627.
Li Y B, Wang W, Li Y L. Adsorption behavior and related
mechanis
-
- $# \{\nmid \text{if } (J. Electrochem.)\ 2022, 28(7), 2213003 (8 of 8)$ [10] Chen B A, Wang A Y, Wu S Y, Wang L M. Polyquaterni-

um-2: A New levelling agent for copper electroplating

from acidic sulphate bath[J]. Electrochemistry, 2016, 84 22(6 then B A, Wang A Y, Wu S Y, Wang L M. Polyquaterni

um-2: A New levelling agent for copper electroplating

ting ability of plating electrolyte on Cu seed layer for

um-2: A New levelling agent for copper electroplating

f
- (6): 414-419. (10) Chen B A, Wang A Y, Wu S Y, Wang L M. Polyquaterni

(10) Chen B A, Wang A Y, Wu S Y, Wang L M. Polyquaterni

um-2: A New levelling agent for copper electroplating

from acide sulphate bath[J]. Electrochemistry, 2016
-
-

(7), 2213003 (8 of 8)
ting ability of plating electrolyte on Cu seed layer for
electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,
22(6): 2315-2320.
Wang C. Study on molecular simulation and mechanism
of the addit 电化学(*J. Electrochem.*) 2022, 28(7), 2213003 (8 of 8)

Vang L M. Polyquaterniting ability of plating electrolyte on Cu seed layer for
or copper electroplating
electropheted copper film[J]. J. Vac. Sci. Technol. A, 2004,

- the de the method of printed circuit board [J]. J. Vac. Sci. Technol. A, 2004,

Then B A, Wang A Y, Wu S Y, Wang L M. Polyquaterni-

ting ability of plating electrolyte on Cu seed layer for

tum-2: A New levelling agent f $\textbf{E}(E\#(J, Electrochem.) 2022, 28(7), 2213003 (8 of 8) \text{Then B A, Wang A Y, Wu S Y, Wang L M. Polyquaterni- \text{diag ability of plating electrolyte on Cu seed layer for the same level. A, 2004, 2004, 2004. \text{from acide sublate bath [J]. Electrochemistry, 2016, 84 \text{from acide sublate bath [J]. Electrochemistry, 2016, 84 \text{from acide subrate bath [J]. Electrochemistry, 2016, 84 \text{from a_ide subrate bath [J]. Electrochemistry, 2016, 84 \text{from a_ide subrate bath [$ (7), 2213003 (8 of 8)

ting ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

Wang C. Study on molecular simulation and mechanism

of the (2213003 (8 of 8)

2213003 (8 of 8)

22(6): 2315-2320.

22(6): 2315-2320.

22(6): 2315-2320.

22(6): 2315-2320.

22(6): 2315-2320.

22 of the additives used for through-hole copper electroplat-

2013. Harbin: Harbin Instit 2, 28(7), 2213003 (8 of 8)

ing ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

[14] Wang C. Study on molecular simulation and mechanis 7), 2213003 (8 of 8)

ting ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

Wang C. Study on molecular simulation and mechanism

of the a 7), 2213003 (8 of 8)

ting ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

Wang C. Study on molecular simulation and mechanism

of the a 2013.
- per film[J]. J. Vac. Sci. Technol. A, 2004,

),

m molecular simulation and mechanism

sed for through-hole copper electroplat-

Harbin: Harbin Institute of Technology,

Y, Zhou G Y, Wang X H, Song J H, He

ng W H, Sun R, **in interference in the interference in the interference of principle intervalsed connection of principle intervalsed connection of principle intervalsed connection of principle intervalsed connection of principle interva** trochem., 2021, 27(3): 257-268.

Electrochem.) 2022, 28(7), 2213003 (8 of 8)

Chen B A, Wang A Y, Wu S Y, Wang L M. Polyquaterni-

ting ability of plating electrolyte on Cu see

tim-2: A New levelling agent for copper ele **EVALUATION THE SEARCH AND SET UP:** THE SEARCH SCHONG SCEND MAND THE SEARCH AND UPLATION OF PHOTOMOTICAL SCENDING THAT UPLATION (1) UPLATION CONTROLL THAT Fig. 16 Electrophone (Electrophone of prime simple science of the interconnection micro-holes of pri-

Electrophatic science of the intercolonus of the intercolonus of the intercolonus (6). 414-419.

From accelectroplatin the *R* Wang A Y, Was Y, Wang I. M. Polyquaternic ing ability of plating electrolyte on Cu seed layer for un-2: A New levelling agent for copper electrophating

un-2: A New levelling agent for copper electrophating

from (*L Bietrochem*,) 2022, 28(7), 2213003 (8 of 8)

Science B A, Wang A Y, Wu S Y, Wang L M. Polyquaternii

sing ability of plating electrolyte on Cu seed layer for

tum-2: A New levelling agent for copper electrophating
 E(E² (*L* Electrocherm.) 2022, 28(7), 2213003 (8 of 8)

[10] Chen B A, Wing X, Wing SY, Wang LM. Polynutarii ing ubiting decirations of Cu seed layer for

um-2: A New levelling agent for copper electroplating

from 2, 28(7), 2213003 (8 of 8)

ting ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

[14] Wang C. Study on molecular simulation and mechanis 7), 2213003 (8 of 8)

ting ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

Wang C. Study on molecular simulation and mechanism

of the a 7), 2213003 (8 of 8)

ting ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

Wang C. Study on molecular simulation and mechanism

of the a 7), 2213003 (8 of 8)
ting ability of plating electrolyte on Cu seed layer for
electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,
22(6): 2315-2320.
Wang C. Study on molecular simulation and mechanism
of the additi 7), 2213003 (8 of 8)

ting ability of plating electrolyte on Cu seed layer for

electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,

22(6): 2315-2320.

Wang C. Study on molecular simulation and mechanism

of the 7), 2213003 (8 of 8)
ting ability of plating electrolyte on Cu seed layer for
electroplated copper film[J]. J. Vac. Sci. Technol. A, 2004,
22(6): 2315-2320.
Wang C. Study on molecular simulation and mechanism
of the addit

特殊整平剂甲基橙在通孔电镀铜的应用

徐佳莹¹,王守绪^{1,2},苏元章¹,杜永杰³,齐国栋⁴, figure M. Molyquaterni-

copper electroplating

celetroplating electroplating electroplating electroplating electroplating
 Y M, He W, Su X H,
 Y M, He W, Su X H,

or the additives used for through-hole copper electr \overline{a} , \overline{a} , veling agent for copper electroplating

acts bath[J]. Electrochemistry, 2016, 84

22(6): 2315-2320.

(14) Wang C. Study on molecular simulation and mech

citon of prince discussions (14) Wang C. Study on molecular simula 徐佳莹¹,王守绪^{1,2},苏元章¹,杜永杰³,齐国栋⁴,
何 为^{1,2},周国云¹,张伟华²,唐 耀²,罗毓瑶²,陈苑明^{1,2*}
(1.电子科技大学材料与能源学院,四川成都611731;2.珠海方正科技高密电子有限公司& (1. 电子科技大学材料与能源学院,四川 成都 611731; 2. 珠海方正科技高密电子有限公司 &
珠海方正科技多层电路板有限公司,广东 珠海 519175; 3. 珠海市能动科技光学产业有限公司,
广东 珠海 510669 A | 珠海本塞科廿左四公司 广东 珠海 519175; ペチの神コ能露手阮,四川 放都 611/51; 2. 珠海ガ五神技高岳屯J有限公司 &
多层电路板有限公司,广东 珠海 519175; 3. 珠海市能动科技光学产业有限公司,
广东 珠海 519050; 4. 珠海杰赛科技有限公司,广东 珠海 519175)

摘要: 甲基橙具有两种基团, 可以同时起到加速和抑制作用, 可作为特殊的整平剂应用与通孔电镀铜实验中。通 过分子动力学模拟和量子化学计算来表征甲基橙在通孔电镀铜中的作用,结果表明甲基橙可以很好地吸附在阴 极表面并抑制铜的电沉积。 通过恒电流测试和循环伏安测试结果显示,甲基橙由于同时具有磺酸基的去极化和 其分子结构部分的极化作用,形成协同分子内对铜加速还原和阻碍传质的竞争效应,所以几乎不影响电位。在板 厚孔径为 10:1 的通孔电镀铜实验中, 仅以甲基橙和环氧乙烷和环氧丙烷嵌段共聚物作为添加剂, TP 值可达到 92.34%

关键词: 电镀铜; 通孔; 添加剂; 甲基橙