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# Effect of Corrosion Inhibitors on Copper Etching to Form Thick Copper Line of PCB in Acidic Etching Solution

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## Effect of Corrosion Inhibitors on Copper Etching to Form Thick Copper Line of PCB in Acidic Etching Solution

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# Effect of Corrosion Inhibitors on Copper Etching to Form Thick Copper Line of PCB in Acidic Etching Solution <sup>(d)</sup>  $\#$ <br> *K Kectrochem.* 2022, 28(7), 2213007 (1 of 10)<br>
DOI: 10.13208/j.electrochem.2213007<br> **Corrosion Inhibitors on Copper Etching to Form**<br> **Copper Line of PCB in Acidic Etching Solution**<br>
Xiao-Li Wang<sup>1</sup>, Wei He  $\begin{array}{lll} &\text{\#} & \text{\#} & \\\text{\#} & \text{\#} & \text{\#} \\ \text{DoI: } 10.13208/j.electrochem. 2213007 \text{ (I of 10)} & & & \text{Htp://electrochem.xml.edu.cn} \\[2mm] &\text{DoI: } 10.13208/j.electrochem. 2213007 & & & \text{Htp://electrochem.xml.edu.cn} \\[2mm] &\text{\bf{sion}} & \text{\bf Inhibitors on Copper Etching to Form} \\[2mm] &\text{\bf r} & \text{\bf Line of PCB in Acidic Etching Solution} \\[2mm] &\text{Wei He$ **Example 18 (Altra 2022, 28(7), 2213007 (1 of 10)**<br>
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y, Yuan-Zhang Su<sup>1</sup>,<br>
ang<sup>2</sup>, Yuan-Ming Chen<sup>1\*</sup><br> *d Technology of China*,<br>
2., Ltd, Zhuhai 519175,<br>
510735. Guangdong. China) , Chong Wang1 e<br> *L* Electrochem. 2022, 28(7), 2213007 (1 of 10)<br>
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, Yuan-Ming Chen<sup>1\*</sup><br> *chnology of China*,<br> *d, Zhuhai 519175*,<br>
35, *Guangdong, China*) **1.** *Bestrochem, 2022, 28(7), 2213007* (1 of 10)<br>
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Thick Copper Line of PCB in Acidic Etching Solution<br>
Xiao-Li Wang<sup>1</sup>, W**  $\frac{1}{2}$   $[Article] \begin{tabular}{c} {\footnotesize \begin{tabular}{l} \hline & $\#\$ \end{tabular} \end{tabular} \begin{tabular}{l} \hline & $\#\$ \end{tabular} \end{tabular} \begin{tabular}{c} \hline & $D113208/j.electrochem.2213007 (1 of 10) \end{tabular} \end{tabular} \begin{tabular}{c} \hline \hline & {\footnotesize \begin{tabular}{l} \hline \textbf{Article} & \textbf{D113208/j.electrochem.2213007} \end{tabular} \end{tabular} \begin{tabular}{c} \hline & \textbf{Htp://electrochem.xml.edu.cn$ も 化 学<br> *J. Electrochem.* 2022, 28(7), 2213007 (1 of 10)<br>
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Chengla 611731, Sichuan, China; 2. Zhuhai ACCESS Semiconductor Co., 11d, Zhuhai 519175,<br>
Grangalong, China; 3. Delton Technolo Chengdu 611731, Siehum, China; 2. Zhuhai ACCESS Semiconductor Co., 11d, Zhuhai 519175,<br>
Guangdong, China; 3. Delton Technology (Guangchou) Co., Ltd, Guangchou 510735, Guangdong, China)<br>
<br> **Abstract:** The chemical compound Grangdong, China; 3. Delton Technology (Grangghou) Co., Ltd, Grangchou 510735, Grangdong, China)<br> **Abstract:** The chemical compounds of 2-mercaptobenzothizable (2-MBT), benzothizable (BTA) and phenoxyethanol (MSDS)<br>
as co **Abstract:** The chemical compounds of 2-mercaptohenzothiazole (2-MBT), benzotriazole (BTA) and phenoxycthanol (MSDS)<br>as corrosion inhibitors were used to inhibit the copper exching to form the thick copper line of PCB in **Abstract:** The chemical compounds of 2-mercaptoherroothiazole (2-MBT), benrotatizede (BTA) and phenoxyednanol (MSDS) as corrosion inhibitons were used to inhibit the copper etching to form the thick copper line of PCB in **Abstract:** The chemical compounds of 2-merosplobenzothizzole (2-MBT), benzotizzale (BTA) and phenoxyethand (MSDS)<br>as corresion inhibitors were used to inhibit the copper elching to form the thick copper line of PCB in th so consistent inholtens were lead to inhibit the copper challenge low mate this copper line of CB in the acide etching solution.<br>The inholtion states was characterized with constent apple measurement, electrochemical test Lei Feng<sup>2</sup>, Gao Huang<sup>2</sup>, Yuan-Ming Chen<sup>1\*</sup><br>Electronic Science and Technology of China,<br>ESS Semiconductor Co., Ltd, Zhuhai 519175,<br>Co., Ltd, Guangzhou 510735, Guangdong, China)<br><br> $(2-MBT)$ , benzotriazole (BTA) and phenoxye *Electronic Science and Technology of China,*<br> *ESS Semiconductor Co., Ltd, Zhuhai 519175,*<br> *Co., Ltd, Guangzhou 510735, Guangdong, China)*<br>  $e$  (2-MBT), benzotriazole (BTA) and phenoxyethanol (MSDS)<br> **m** the thick copp ESS Semiconductor Co., Ltd, Zhuhai 519175,<br>
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20., Ltd, Guangzhou 510735, Gua  $\begin{tabular}{ll} \textbf{#2} & \textbf{#2} & \textbf{#2} \\ \hline \textbf{[Article]} & \textbf{DOI: 10.132087} & \textbf{Step 10.132087} & \textbf{[Htp://electrochem.xml.cot1.com} \\ \hline \end{tabular} \label{tab:2} \begin{tabular}{ll} \textbf{[After C} & \textbf{[Def: 10.132087} & \textbf{[Def: 10.132087} & \textbf{[Htp://electrochem.xml.cot1.com} \\ \hline \end{tabular} \end{tabular} \begin{tabular}{ll} \textbf{[HepC:$ *Electrochem 2022, 28(7), 2213007* (1 of 10)<br>
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Xiao-Li Wang!, Wei He!, Xian-Ming Chen<sup>2</sup>, Hong Zeng<sup>2</sup>, Yuan-Zhang Su<sup>1</sup>,<br>
Chong Wang!, Gao-Shen** *Si He!***, S** THICK COPPET LINE OF TCD III ACture Externing SOILILOID<br>
Xiao-Li Wang<sup>1</sup>, Wei He<sup>1</sup>, Xian-Ming Chen<sup>2</sup>, Hong Zeng<sup>2</sup>, Yuan-Zhang Su<sup>1</sup>,<br>
(*I. School of Materials and Energy, University of Fleteration; discretiones and Cel* 

(7): 2213007. lines<sup>[2]</sup>.

**I Introduction**<br> **Printed circuit board (PCB) tends to produce high heterocyclic atoms (N, P, S, O) have multiple active<br>
precision and high-density interconnection to match adsorption sites, making them easily adsorbed roduction**<br>
to derive the and high-density intercorpetic to match<br>
adsorption sites, making them easily adsorbed on<br>
lopment of electronic products miniaturiza.<br>
metal surfaces to form protective films and to inhibit<br>
th **1** Introduction based heterocyclic compounds containing  $\pi$  bonds or The inithition states and changele measurement, electrochemical stat and each theore calculation, while the state theore is a may be compet surface was sudicel by seaming electron microscope. The absorption mechanism (cor Euromon memphelogy of expert surface was studied by samming electron merosocon. The adeorphon mechanism of corroson in-<br>shistics on corper surface is malyzed by molecular dynamics and quantum chemistry calculations. The ntohos on cooper surface is snapyer of molecular optimum cannot connect and quality considered to the surface of the single inhibitor. The etch fi .<br>
Sime the state of S9 from the ething solution with 2-MBT and MSDS for goal agreement of PCB manufacture.<br> **Synchetics** corrosion inhibitor, synceptic function, thick copper line; eidic etching solution<br> **Introduction**<br> **Example 11**<br> **Example 11**<br> **Example 11**<br> **Example 11**<br> **Example 12**<br> **Example 12 11. Introduction**<br> **11. Introduction**<br> **21. Direct** directive bard (PCB) tends to produce high hererocyclic atoms (N, P, S, O) have multiple active<br>
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Co., Ltd, Guangzhou 510735, Guangdong, China)<br>
The example in the films correct (BTA) and phenoxyethanol (MSDS)<br>
The the films correct mericoscope. The adsorption mechanism o e (2-MBT), benzotriazole (BTA) and phenoxyethanol (MSDS)<br>cm the thick copper line of PCB in the acidic etching solution.<br>ectrom increascope. The adsorption mechanism of corrosion in-<br>quantum chemity calculations. The resu e (2-MBT), benzotriazole (BTA) and phenoxyethanol (MSDS)<br>fm the thick copper line of PCB in the acidic etching solution.<br>ent, electrochemical test and etch factor calculation, while the<br>etcom microscope. The adsorption me e (2-MBT), benzotriazole (BTA) and phenoxyethanol (MSDS)<br>mm the thick copper line of PCB in the acidic etching solution.<br>nent, electrochemical test and etch factor calculation, while the<br>etcron microscope. The adsorption m the thick copper line of PCB in the acidic etching solution.<br>
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equantum chemistry calculat nent, electrochemical test and etch factor calculation, while the<br>etcron microscope. The adsorption mechanism of corrosion in-<br>equantum chemistry calculations. The results indicated that the<br>eici adsorption on the copper terton microscope. The adsorption mechanism of corrosion in-<br>quantum chemistry calculations. The results indicated that the<br>etch factor of the chiper surface in parallel, while their ad-<br>etch factor of the thick copper li quantum chemistry calculations. The results indicated that the<br>eir adsoption on the copper surface in parallel, while their ad-<br>etch factor of the thick opper line with about 33  $\mu$ m in thick-<br>DS for good agreement of PC reir assorption on the copper suriace in paraliet, while their according to the thick copper line with about 33 μm in thick-<br>cost factor of the thick copper line with about 33 μm in thick-<br>DS for good agreement of PCB ma can active of the times copper interval acondomic speaking of the set of the same of PCB manufacture.<br>
Then, acidic etching solution<br>
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heterocyclic atoms (N, P, S, O) be an giotal economic or the maintainal expression in the straight of the strongle divided heterocyclic atoms (N, P, S, O) have multiple active adsorption sites, making them easily adsorbed on metal surfaces to form prote based heterocyclic compounds containing  $\pi$  bonds or heterocyclic atoms (N, P, S, O) have multiple active adsorption sites, making them easily adsorbed on metal surfaces to form protective films and to inhibit corrosion. . Freceived: 2022-03-04, Revised: 2022-04-14. \* Corresponding author, Tel: (86)18980602785 Li-mail: ymchen@uestc.edu.cn<br>Received: 2022-04-04, Revised: 2022-04-14. \* Corresponding author, Tel: (86)1898062278 E-mail: year-to-

 $\# \ell \# (J. \ \text{Electrochem.}) 2022, 28(7), 2213007 (2 \text{ of } 10)$ <br>Chen et al.<sup>[6]</sup> found out that the etch factor of fine line hibit lone pair electrons to contribute to binding emp-<br>for IC substrates was only 3.7 from semi-additive ty  $\pm \frac{16}{5}$  (*L Electrochem.*) 2022, 28(7), 2213007 (2 of 10)<br>Chen et al.<sup>[6]</sup> found out that the etch factor of fine line hibit lone pair electrons to contribute to binding emp-<br>for IC substrates was only 3.7 from sem  $\pm \frac{k^2}{2}$  *LEectrochem.*) 2022, 28(7), 2213007 (2 of 10)<br>Chen et al.<sup>[6]</sup> found out that the etch factor of fine line hibit lone pair electrons to contribute to binding emp-<br>for IC substrates was only 3.7 from semi-add  $\frac{dE}{dt}$  (*LEterinochem.*) 2022, 28(7), 2213007 (2 of 10)<br>
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Chen et al.<sup>66</sup> found out that the etch factor of fine line hibit lone pair electrons to contribute to binding emp-<br>
for IC substrates was only 3.7 fr **integrity of the signal transmission** integrity of the set allow the signal divisor of the signal transmission in this signal transmission in the signal process. Zhong et al.<sup>pa</sup> added corrosion inhibitors into your serv  $\mathbb{R}E^{\omega}(L \text{ } Electmchem.)$  2022, 28(7), 2213007 (2 of 10)<br>
Chen et al.<sup>181</sup> found out that the etch factor of fine line hibit lone pair electrons to contribute to binding emp-<br>
for IC substrates was only 3.7 from semi-addit **Example 19**<br> **Example 19**  $\text{E/}\mathcal{E}/L$  Electrochem.) 2022, 28(7), 2213007 (2 of 10)<br>Chen et al.<sup>90</sup> found out that the etch factor of fine line bibit lone pair electrons to contribute to binding emp-<br>for IC substrates was only 3.7 from semi-addi **EXALUAT:** The three purine may are the purine of the three purine deltained and the correspondence and  $\Delta t$  a the et al.<sup>16</sup> found out that the etch factor of fine line<br>the etch folioty (2-a f 10)<br>Chen et al.<sup>16</sup> found out that the etch factor of fine line<br>by of copper surface rails, while the benzene ring<br>process. Zhong et al.<sup>1</sup> the corrosion in the corrosion of the corrosion of corrosion of contribute to binding empty for the corrosion of the corrosion of contribute to binding empty for the comparation of contribute to the comparation of contrib **EXALE EXACTE (EXACTE 200**), 2213007 (2 of 10)<br> **EXACTE 2000** (Condition of the results showed that the celebration of memi-additive<br>
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ty of copper surface rails, while th  $\oplus$  ( $\oplus$   $\oplus$  ( $\oplus$   $\oplus$  ( $\oplus$   $\$ the  $2^x(t, Keemchem)$  and  $2^{x(t, Keemchem)}$  = 222.28(7), 2213007 (2 of 10)  
\nChen et al.<sup>68</sup> found out that the echo factor of fine line  
\nfor IC substrates was only 3.7 from semi-additive  
\nby Copper surface ratios, while the benzene ring  
\nprocess. Zhong et al.<sup>10</sup> added corrosion inhibitors into  
\nconceous. Zhong et al.<sup>10</sup> added corrosion inhibitors into  
\ncoed to work as resist media on the metal surface.  
\nthe common acide cething solution to increase the Tnerefner, the organic compounds including BTA,  
\nthe factor to more than 4.0. However, in order toChen et al.<sup>86</sup> found out that the etch factor of fine lime<br>
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for IC substrates was only 3.7 from semi-additive<br>
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could work as resist media on the metal surface.<br>
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tech filetor the common acidic etching solution to increase the<br>
relations of the compounds including BTA,<br>
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improve the signal etch factor to more than 4.0. However, in order to 2-MBT and MSDS could be suitable to be selected as<br>improve the signal transmission integrity of thick corrosion inhibitors to study the inhibition perfor-<br>improve the sig improve the signal transmission integrity of thick corrosion inhibitors to study the inhibition perfor-<br>covered to add corrosion inhibition should be dis-<br>manecs of coper in PCB acide ching solution.<br>covered to add into copper lines, good corrosion inhibitors should be dis-<br>nances of cooper in PCB acidic etching solution.<br>Corrected to add into the etching solution for the in-<br>in-this study, 2-MBT, BTA and MSDS as corro-<br>erease of etch fa covered to add into the etching solution for the in-<br>
for the infinition mechanism and sion inhibition serve added into the sacisto-<br>
eradsoption behavior of three purinc derivatives (guar-<br>
ultion to form thick copper lin crease of etch factor. The inhibition mechanism and<br>
asion inhibitors were added into the acidic eching so-<br>
adsorption behavior of three purinc derivatives (gua-<br>
lution to form thick copper line of PCB. Electro-<br>
time, adsorption behavior of three purine derivatives (gua-<br>nine, adenomic and hyposamhine) were investigated chemical testing, quantum chemical computation and<br>on the corrosion of copper in alkaline artificial seava-<br>molecular nine, adenine and hypoxanthine) were investigated chemical testing, quantum chemical computation and<br>on the corrosion of corpor in alkaline artificial seawa-<br>modecular dynamics calculation were used to investi-<br>ter<sup>m</sup>. Th on the corrosion of cooper in alkaline artificial seawa-<br>molecular dynamics calculation were used to investi-<br>ter<sup>74</sup>. The results showed that the three inhibitions all<br>delayed corrosion by indicating a protective film on ter<sup>80</sup>. The results showed that the three inhibitors all<br>gate the influence of above molecules on corrosion<br>delayed corrosion by indicating a protective film on inhibition behavior.<br>the copper surface as well as the thre delayed corrosion by indicating a protective film on inhibition behavior.<br>
the corper surface as well as the three inhibitions all  $\sigma$  **Experimental Section**<br>
obeyed the Langmuir adsorption model and belonged The base et the copper surface as well as the three inhibitors all **2 Experimental Section**<br>
obeyed the Langmuir adsorption model and belonged<br>
or anixed physicochormical adsorption. Additionally, equive chloride digivatine (CuCi: obeyed the Langmuir adsorption model and belonged<br>
The base etching solution consisted of 85 g·1.<sup>1</sup><br>
to a mixed physiochedremical adsorption. Additionally, curies chloride dihydrate (Cucl<sub>1</sub>-21(10, 0,1 mol -1.<sup>1</sup><br>
2-merc to a mixed physicochemical adsorption. Additionally, expric chloride dihydrate (CuCl<sub>2</sub>-21H<sub>2</sub>O), 0.1 mol  $\cdot L^4$ <br>
2-mercaptoberazolthazole (2-MBT) and brazoltiazoles hydrochloric acid (HCl) and 25 g<sup>-1</sup><sup>2</sup> ammonium<br>
(IST 2-mercaptobenzothiazole (2-MBT) and benzotriazole<br>
(BYLO) and 25 g·L<sup>1</sup> ammonium<br>
(GTA) are also excellent inhibitions for corpor corrosion inhibitions were added into the base<br>
sion because they both have included  $\pi$  b (IITA) are also excellent inhibitors for copper corro-<br>chloride (NH<sub>S</sub>Cl). 2-MBT, BTA and MSDS as selec-<br>sion because they both have included  $\pi$  bond, and N iver corrosion inhibitors were added into the base<br>atom could sion because they both have included  $\pi$  bond, and N<br>
ater corresion inhibitors were added into the base<br>
atom conditation with vacant orbitals on copper enching solution. The chemical structures of 2-MBT,<br>
surface to fo tion at 30 °C. The results showed that BTA exhibited MSDS. Above ctching solution formulations with<br>the best himbition effect the to the larger adsorption above corrosion inhibitors: were used in etching<br>energy, obtaining the best inhibition effect due to the larger adsorption<br>energy, obtaining the inhibition efficiencies of 99.52% periments and electrochemical tests.<br>In 3.5wt/% NaCl solution. Chiere et al. <sup>[16]</sup> reported The copper sampl

28(7), 2213007 (2 of 10)<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds includin  $28(7)$ ,  $2213007$  (2 of 10)<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds inc  $28(7)$ ,  $2213007$  (2 of 10)<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds inc  $28(7)$ ,  $2213007$  (2 of 10)<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds inc 28(7), 2213007 (2 of 10)<br>
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of copper surface rails, while the benzene ring<br>
uld work as resist media on the metal surface.<br>
erefore, the organic compounds including BTA,  $28(7)$ ,  $2213007$  ( $2 \text{ of } 10$ )<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds  $28(7)$ ,  $2213007$  (2 of 10)<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds inc  $28(7)$ ,  $2213007$  (2 of 10)<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds inc  $28(7)$ ,  $2213007$  (2 of 10)<br>hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds inc 28(7), 2213007 (2 of 10)<br>
hibit lone pair electrons to contribute to binding emp-<br>
ty of copper surface rails, while the benzene ring<br>
could work as resist media on the metal surface.<br>
Therefore, the organic compounds inc 28(7), 2213007 (2 of 10)<br>
hibit lone pair electrons to contribute to binding emp-<br>
hy of copper surface rails, while the benzene ring<br>
could work as resist media on the metal surface.<br>
Therefore, the organic compounds inc 28(7), 2213007 (2 of 10)<br>
hibit lone pair electrons to contribute to binding emp-<br>
hibit lone pair electrons to contribute to binding emp-<br>
ty of copper surface rails, while the benzene ring<br>
could work as resist media on by the pair electrons to contribute to binding emp-<br>of copper surface rails, while the benzene ring<br>ald work as resist media on the metal surface.<br>erefore, the organic compounds including BTA,<br>MBT and MSDS could be suitab 电化学(*J. Electrochem.*) 2022, 28(7), 2213007 (2 of 10)<br>etch factor of fine line hibit lone pair electrons to contribute to binding emp-<br>7 from semi-additive ty of copper surface rails, while the benzene ring<br>prosion inhib

hibit lone pair electrons to contribute to binding emp-<br>ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds including BTA,<br>2-MBT and MSDS co ty of copper surface rails, while the benzene ring<br>could work as resist media on the metal surface.<br>Therefore, the organic compounds including BTA,<br>2-MBT and MSDS could be suitable to be selected as<br>corrosion inhibitors t

-1 -1 hydrochloric acid (HCl) and  $25 \text{ g} \cdot L^{-1}$  ammonium could work as resist media on the metal surface.<br>
Therefore, the organic compounds including BTA,<br>
2-MBT and MSDS could be suitable to be selected as<br>
corrosion inhibitors to study the inhibition perfor-<br>
mances of copper Therefore, the organic compounds including BTA,<br>2-MBT and MSDS could be suitable to be selected as<br>corrosion inhibitors to study the inhibition perfor-<br>mances of copper in PCB acidic etching solution.<br>In this study, 2-MBT 2-MBT and MSDS could be suitable to be selected as<br>corrosion inhibitors to study the inhibition perfor-<br>mances of copper in PCB acidic etching solution.<br>In this study, 2-MBT, BTA and MSDS as corro-<br>sion inhibitors were ad corrosion inhibitors to study the inhibition perfor-<br>mances of copper in PCB acidic etching solution.<br>In this study, 2-MBT, BTA and MSDS as corro-<br>sion inhibitors were added into the acidic etching so-<br>lution to form thic mances of copper in PCB acidic etching solution.<br>
In this study, 2-MBT, BTA and MSDS as corro-<br>
sion inhibitors were added into the acidic etching so-<br>
lution to form thick copper line of PCB. Electro-<br>
chemical testing, In this study, 2-MBT, BTA and MSDS as corro-<br>sion inhibitors were added into the acidic etching so-<br>lution to form thick copper line of PCB. Electro-<br>chemical testing, quantum chemical computation and<br>molecular dynamics c sion inhibitors were added into the acidic etching so-<br>
lution to form thick copper line of PCB. Electro-<br>
chemical testing, quantum chemical computation and<br>
molecular dynamics calculation were used to investi-<br>
gate the lution to form thick copper line of PCB. Electro-<br>chemical testing, quantum chemical computation and<br>molecular dynamics calculation were used to investi-<br>gate the influence of above molecules on corrosion<br>inhibition behav chemical testing, quantum chemical computation and<br>molecular dynamics calculation were used to investi-<br>gate the influence of above molecules on corrosion<br>inhibition behavior.<br>**2 Experimental Section**<br>The base etching s molecular dynamics calculation were used to investigate the influence of above molecules on corrosion inhibition behavior.<br> **2 Experimental Section**<br>
The base etching solution consisted of 85 g·L<sup>-1</sup><br>
eupric chloride dihy e the influence of above molecules on corrosion<br>ibition behavior.<br> **Experimental Section**<br>
The base etching solution consisted of 85 g·L<sup>+</sup><br>
oric chloride dihydrate (CuCl<sub>2</sub>·2H<sub>2</sub>O), 0.1 mol·L<sup>+</sup><br>
drochloric acid (HCl) an inhibition behavior.<br> **2 Experimental Section**<br>
The base etching solution consisted of 85 g·L<sup>-1</sup><br>
cupric chloride dihydrate (CuCl<sub>2</sub>·2H<sub>2</sub>O), 0.1 mol·L<sup>-1</sup><br>
hydrochloric acid (HCl) and 25 g·L<sup>-1</sup> ammonium<br>
chloride (NH<sub>4</sub> **2 Experimental Section**<br>The base etching solution consisted of 85 g·L<sup>-1</sup><br>cupric chloride dihydrate (CuCl<sub>2</sub>·2H<sub>2</sub>O), 0.1 mol·L<sup>-1</sup><br>hydrochloric acid (HCl) and 25 g·L<sup>-1</sup> ammonium<br>chloride (NH<sub>4</sub>Cl). 2-MBT, BTA and MSDS The base etching solution consisted of 85 g  $\cdot$  L<sup>-1</sup><br>cupric chloride dihydrate (CuCl<sub>2</sub> - 2H<sub>2</sub>O), 0.1 mol  $\cdot$  L<sup>-1</sup><br>hydrochloric acid (HCl) and 25 g  $\cdot$  L<sup>-1</sup> ammonium<br>chloride (NH<sub>4</sub>Cl). 2-MBT, BTA and MSDS as selec cupric chloride dihydrate (CuCl<sub>2</sub> - 2H<sub>2</sub>O), 0.1 mol  $\cdot$  L<sup>-1</sup><br>hydrochloric acid (HCl) and 25 g  $\cdot$  L<sup>-1</sup> ammonium<br>chloride (NH<sub>4</sub>Cl). 2-MBT, BTA and MSDS as selec-<br>tive corrosion inhibitors were added into the base<br>et hydrochloric acid (HCl) and 25  $g \cdot L^{-1}$  ammonium<br>chloride (NH<sub>4</sub>Cl). 2-MBT, BTA and MSDS as selec-<br>tive corrosion inhibitors were added into the base<br>etching solution. The chemical structures of 2-MBT,<br>BTA and MSDS are s chloride (NH<sub>4</sub>Cl). 2-MBT, BTA and MSDS as selective corrosion inhibitors were added into the base<br>etching solution. The chemical structures of 2-MBT,<br>BTA and MSDS are shown in Figure 1. All drugs<br>were of analytical grade. tive corrosion inhibitors were added into the base<br>etching solution. The chemical structures of 2-MBT,<br>BTA and MSDS are shown in Figure 1. All drugs<br>were of analytical grade. The mixture of 2-MBT and<br>MSDS is represented by



<sup>th</sup>  $\mathbb{E}\{E\}^{\#}(J. \text{Electrochem.})$  2022, 28(7), 2213007 (3 of 10)<br>
<sup>o</sup>C, and the copper lines were obtained by stripping <sup>In</sup> order to research the structure and geometry of<br>
the etchant resist film, as shown in Figure 2. Ac  $\mathbb{E}(\mathbb{E} \neq \mathbb{C})$ . Electrochem.) 2022, 28(7), 2213007 (3 of 10)<br>
"C, and the copper lines were obtained by stripping In order to research the structure and geometry of<br>
the etchant resist film, as shown in Figure 2. **ing the 4-** (*L Electrochem.*) 2022, 28(7), 2213007 (3 of 10)<br> **i**C, and the copper lines were obtained by stripping In order to research the structure and geometry of<br>
the etchant resist film, as shown in Figure 2. A  $#E\#(J. Electrochem.) 2022, 28(7), 2213007 (3 of 10)$ <br>
"C, and the copper lines were obtained by stripping In order to research the structure and g<br>
the etchant resist film, as shown in Figure 2. Accord<br>
the inhibitor molecules to s  $g \cdot L^{-1}$ . -1

circuit potential to -0.85 V at a scan rate of  $0.005 \text{ V} \cdot \text{s}^{-1}$ . faces, as well as the adsorption configuration and be-

**Example 19**<br> **Example 19**<br> **Example 19**<br> **Example 19**<br> **Example 19**<br> **Example 19**<br> **ID** order to research the structure and geometry of<br>
the etchant resist film, as shown in Figure 2. Accord-<br>
the inhibitor molecules to  $\# \# \# (J. \text{Electrochem.}) 2022, 28(7), 2213007 (3 of 10)$ <br>
re obtained by stripping In order to research the structure and geometry of<br>
wn in Figure 2. Accord<br>
the inhibitor molecules to study the inhibition mech-<br>
orption rules and  $\frac{vectorchem}{2}$ ) 2022, 28(7), 2213007 (3 of 10)<br>
stripping In order to research the structure and geometry of<br>
Accordthe inhibitor molecules to study the inhibition mech-<br>
anism, the adsorption energies of acidic etching sotively, and the optimal concentration of MSDS was 1 **ELECT 1.** Electrochemical experiments were carried out in a used to build the initial model to restance the simulated by stripping In order to research the structure and geometry of etchant resist film, as shown in Figu **E** *Co*. and the copper lines were obtained by stripping In order to research the structure and geometry of the etchant resist film, as shown in Figure 2. Accord-<br>the inhibitor molecules to study the inhibiton meching to  $\pm$  the expectric metaster of the structure and geometry of<br>  $\pm$  the echant resist film, as shown in Figure 2. Accord-<br>
the inhibitor molecules to study the inhibitor mech-<br>
ing to 2-MBT and BTA adsorption rules and MSD the  $\mathcal{C}_{\mathcal{C}}$  and the copper lines were obtained by stripping  $\blacksquare$  in order to research the structure and geometry of<br>the cichant resist film, as shown in Figure 2. Accord the inhibitor molecules to study the inhib ing electrode, with a 2 cm2 # $\frac{4}{5}$  +  $\frac{$ the economic metallic the economic metallic tectrodes were contained by stripping and contact to research the structure and geometry of<br>the echant resist film, as shown in Figure 2. Accord-<br>the imhibition melculast to stu  $\frac{u}{2}k\frac{u^2}{2}L$  *Electrochema*, 2022, 28(7), 2213007 (3 of 10)<br>
C, and the copper lines were obtained by stripping ln order to research the structure and geometry of<br>
the cehant resist film, as shown in Figure 2. Acc **EVALUAT EXAMONDER** (EXAMONDERATE 19022, 28(7), 2213007 (3 of 10)<br>
The order to research the structure and geometry of<br>
the elehant resist film, as shown in Figure 2. Accord-<br>
the inhibitior molecules to study the inhibit C, and the copper lines were obtained yerthing in order to search the structure and geometry of<br>the etchant resist film, as shown in Figure 2. Accord the inhibitor melecules to study the inhibition mech-<br>ing to 2-MBT and TC, and the copper lines were obtained by stripping In order to research the structure and geometry of<br>the echain resist filin, as shown in Figure 2. Accord-<br>- the inhibitor molecules to study the inhibitor mediate<br>concen the ctchant resist film, as shown in Figure 2. Accord-<br>the inhibition molecules to study the inhibition mech-<br>ing to 2-MBT and BTA waterption neutral and MSDS<br>one anisotic enterpress of acidic etching so-<br>one entration is concentration test<sup>18)</sup>, the optimal concentrations of 2-<br>
Metri and BTA were simulated by<br>
MBT and BTA were S mg-L<sup>2</sup> and 16 mg-L<sup>2</sup>, respect- mode for Marienals Studio, then MSDS<br>
Herby, and the optimal concentration of MBT and BTA were 8 mg-1.<sup>1</sup> and 16 mg-1.<sup>1</sup>, respec-<br>the Forcite module of Materials Studio, then MSDS<br>ively, and the optimal concentration of MSDS was 1 was added into the etching solution to calculate the<br>g-1.<sup>1</sup>.<br>g-1.<sup></sup> tively, and the optimal concentration of MSDS was 1<br>
was added into the ctching solution to calculate the<br>  $g \cdot L^{-1}$ .<br>
Electrochemical coperiments were carried out in a corrosion inhibitors. And then Dmol3 module is<br>
conv L<sup>1</sup>. description energy of the synergistic action between<br>Electrochemical experiments were carried out in a correstion inhibitions. And then Dmol3 module is<br>eventional three-clectrode glass cell at 50 °C, using an used t Electrochemical experiments were carried out in a corrosion inhibitors. And then Dmol3 module is<br>conventional three-electrode glass cell at 50°C, using an used to build the initial model and optimize the<br>Autolah electroch conventional three-electrode glass cell at 50 °C, using an used to build the initial model and optimize the Autolab electrochemical workstation (PGSTAT302N, molecular configuration. The relationship between Switzerland Me Autolab electrochemical workstation (PGSTAT302N, molecular configuration. The relationship between<br>Switzerland Metrohn). Copper foil several as the work-<br>imbibition smolecule structures and their inhibition<br>mig electrode, Switzerland Metrohm). Copper foil served as the work-<br>inhibitors molecule structures and their inhibition<br>ing electrode, with a 2 cm<sup>2</sup> effective conted area. The performances is investigated through the Guassian<br>referenc ing electrode, with a 2 cm<sup>2</sup> effective contact area. The performances is investigated through the Caussian<br>reference and contact electrodes were a saturated mer-<br>software calculation to determine the energy value<br>curons (28(7), 2213007 (3 of 10)<br>
In order to research the structure and geometry of<br>
the inhibitor molecules to study the inhibition mech-<br>
anism, the adsorption energies of acidic etching so-<br>
lution inhibitors 2-MBT and BTA we  $(28(7), 2213007 \, (3 \text{ of } 10))$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA w  $(28(7), 2213007 \text{ (3 of 10)})$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were (28(7), 2213007 (3 of 10)<br>
In order to research the structure and geometry of<br>
the inhibitor molecules to study the inhibition mech-<br>
anism, the adsorption energies of acidic etching so-<br>
lution inhibitors 2-MBT and BTA we 28(7), 2213007 (3 of 10)<br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were si  $(28(7), 2213007 \cdot (3 \text{ of } 10))$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA w  $28(7)$ ,  $2213007(3 \text{ of } 10)$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors  $2$ -MBT and BTA  $(28(7), 2213007 \cdot (3 \text{ of } 10))$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA w  $(28(7), 2213007 \text{ (3 of } 10))$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA wer  $(28(7), 2213007 \text{ (3 of 10)})$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were  $28(7)$ ,  $2213007$  (3 of 10)<br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA we , 28(7), 2213007 (3 of 10)<br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were s accelemiation of the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were simulated by<br>the Forcite mod  $(28(7), 2213007 (3 \text{ of } 10))$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA wer  $(28(7), 2213007 \text{ (3 of 10)})$ <br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were  $\frac{28(t)}{1221300t}$  (3 of 10)<br>In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA w In order to research the structure and geometry of<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were simulated by<br>the Forcite m the inhibitor molecules to study the inhibition mech-<br>anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were simulated by<br>the Forcite module of Materials Studio, then MSDS<br>was added into anism, the adsorption energies of acidic etching so-<br>lution inhibitors 2-MBT and BTA were simulated by<br>the Forcite module of Materials Studio, then MSDS<br>was added into the etching solution to calculate the<br>adsorption ener lution inhibitors 2-MBT and BTA were simulated by<br>the Forcite module of Materials Studio, then MSDS<br>was added into the etching solution to calculate the<br>adsorption energy of the synergistic action between<br>corrosion inhibi the Forcite module of Materials Studio, then MSDS<br>was added into the etching solution to calculate the<br>adsorption energy of the synergistic action between<br>corrosion inhibitors. And then Dmol3 module is<br>used to build the i was added into the etching solution to calculate the<br>adsorption energy of the synergistic action between<br>corrosion inhibitors. And then Dmol3 module is<br>used to build the initial model and optimize the<br>molecular configurat adsorption energy of the synergistic action between<br>corrosion inhibitors. And then Dmol3 module is<br>used to build the initial model and optimize the<br>molecular configuration. The relationship between<br>inhibitors molecule str compared. used to build the initial model and optimize the<br>molecular configuration. The relationship between<br>inhibitors molecule structures and their inhibition<br>performances is investigated through the Gaussian<br>software calculation molecular configuration. The relationship between<br>inhibitors molecule structures and their inhibition<br>performances is investigated through the Gaussian<br>software calculation to determine the energy value<br>of the lowest unoc itors molecule structures and their inhibition<br>mances is investigated through the Gaussian<br>are calculation to determine the energy value<br>e lowest unoccupied molecular orbital ( $E_{\text{HOMO}}$ ),<br>ighest occupied molecular orbit rformances is investigated through the Gaussian<br>thware calculation to determine the energy value<br>the lowest unoccupied molecular orbital ( $E_{\text{HOMO}}$ ), and<br>energy gap ( $\Delta E$ ) between the two frontline or-<br>als. Cu(111) sur 电化学(*J. Electrochem.*) 2022, 28(7), 2213007 (3 of 10)<br>bbtained by stripping In order to research the structure and geometry of<br>in Figure 2. Accord-<br>the inhibitor molecules to study the inhibition mech-<br>anism, the adsorpti



 $\frac{d}{dx}$   $\frac{d}{dx}$  the above corrosion inhibitors have different inhibi-<br>the above corrosion inhibitors have different inhibi-<br>tion effects on copper sample in etching solution. Seen from Figure 5(b), in the absence of corrosion in-<br>With th  $\# \ell \neq (J. Electron.)$  2022, 28(7), 2213007 (4 of 10)<br>the above corrosion inhibitors have different inhibi-<br>fore corrosion was smooth and uniform. As can be<br>tion effects on copper sample in etching solution. seen from Figure 5(b)

$$
\text{Etch factor} = \frac{2h}{b-a} \tag{1}
$$

ufacturing.

 $\frac{dE}{dt}$  (*L Electrochem.*) 2022, 28(7), 2213007 (4 of 10)<br>the above corrosion inhibitors have different inhibi-<br>fore corrosion was smooth and uniform. As can be<br>tion efficiency of copper sample in etching solution.<br>W **EVALUAT FRAMEL 1999**<br> **EVALUAT FRAMEL TO THE MAXIMUS THEOTERT (FOR THE MAXIMUS THEOTHET (FOR THE MAXIMUS THEOTHET (FOR THE MAXIMUS THEOTHET MAYIMUS THEOTHET MAYIMUS THEOTHET MAYIMUS THEOTHET MAYIMUS THEOTHET MAYIMUS THEO**  $\pm \frac{\text{Re}\frac{2\pi}{4}(L \text{ *Electrochem*)} 2022, 28(7), 2213007 (4 of 10)}{\text{the above conversion inhibitory have different inhibi-} for the above corresponding in the definition of the problem. As can be seen from Figure 5(b), in the absence of the corresponding solution of the problem. The number of the other sample was severely to the efficiency of copper sample increased gradually, correlated and many corrosion tracks were observed, and reached the maximum value in 2-MBT + MSDS indicating that the corrosion of copper was relatively system. Eth factor was calculated from the section is given. When 2-MBT and BTA inhibitors were diagram in Figure 4 according to Equation (1). The number of creates a compared with that from blank solutions in the problem. The number of creates the other factor is the number of the problem. The number of$  $\pm \frac{1}{2}$   $\pm \frac$  $\frac{d_1}{dx} (L)~Electrochem.) 2022, 28(7), 2213007 (4 of 10)$ the above corrosion inhibitors have different inhibi-<br>
for corrosion was smooth and<br>
tion effects on copper sample in etching solution. Seen from Figure 5(b), in the all<br>
Wi clear fracture traces, but the number of cracks decreased as compared with that from blank solution. In  $\pm 0.24$  (*B* economic inhibitors have different inhibi-<br>the above corrosion inhibitors have different inhibi-<br>fore corrosion was smooth and uniform. As can be<br>tion effects on copper sample in etching solution. Seen from **EVALUATION EXECT UP:** The length of bottom copper sample in extingue of the symparities on copper sample in etching solution. Seen from Figure 5(b), in the absence of corrosion in-<br>tion effects on copper sample in etchi **EVALUATION 1989**<br> **EVALUATION 1999**<br> **EVALUATION EVALUAT Electrochem.**) 2022, 28(7), 2213007 (4 of 10)<br>
the above corrosion inhibitors have different inhibi-<br>
fore corrosion was smooth and uniform. As ean be<br>
tion effects on copper sample in etching solution.<br>
With the  $\frac{16}{2}$  (*k* $\frac{27}{2}$  *k leterochem.*) 2022, 28(7), 2213007 (4 of 10)<br>the above corrosion inhibitors have different inhibi-<br>fore corrosion was smooth and uniform. As ean be<br>tion effects on copper sample in etching s (a) the  $\pi/4$ , *the temperary*) 2022, 28(7), 2213007 (4 of 10)<br>the above corrosion inhibitors have different inhibi-<br>fore corrosion was smooth and uniform. As can be<br>tion effects on copper sample in ethning solution. See the above corrosion inhibitors have different inhibi-<br>the above corrosion inhibitors have different inhibi-<br>tion-corrosion was smooth and uniform. As can be<br>tion effects on copper sample in etching solution. He incores fr the above corrosion inhibitors have different inhibi-<br>fore corrosion was smooth and uniform. As ean be<br>tion effects on copper sample in etching solution. seen from Figure 5(b), in the absence of corrosion in-<br>with the dad tion effects on copper sample in etching solution. seen from Figure 5(b), in the absence of corrosion in-<br>With the addition of corrosion inhibitor, the inhibi-<br>
individendent effecting copper sample inverseded gradually, With the addition of corrosion inhibitor, the inhibia-<br>
tion efficiency of copper sample innerased gradually, corroded and many corrosion reacks were observed,<br>
and reached the maximum value in 2-MBT + MSDS indicating tha tion efficiency of copper sample increased gradually, corroded and many corrosion cracks were observed,<br>and reached the maximum value in 2-MBT + MSDS indicating that the corrosion of copper was relatively<br>system. Etch fac and reached the maximum value in 2-MBT + MSDS indicating that the corrosion of copper was relatively<br>system. Eich factor was calculated from the section<br>section in Figure 4 decording to Equation (1).<br>
Election factor =  $\$ system. Etch factor was calculated from the section<br>
eriagram in Figure 4 according to Fiquation (1). added separately, the surface of copper presented<br>
Etch fractor =  $\frac{\hbar}{b-a}$  (1) clear fracture traces, but the number End the store  $\frac{2h}{b-a}$  (1) clear fracture traces, but the number of cracks decreased as conpered with that from blank solution. In the store of its inclusion, the correstion pit became shallow, because of copper and *b* Levi ascou  $\frac{1}{b-a}$  (i) creased as compared with that from blank solution. In<br>where *h* is the the hickness of copper, *a* is the length of addition, the corresion pit became shallow, because<br>top copper and *b* is the l where *h* is the thickness of copper, *a* is the length of<br>
dedition, the corresion pit became shallow, because<br>
to proper and *b* is the length of bottom copper.<br>
A single corresion inhibitor like 2-MBT or BTA copper cor top copper and b is the length of bottom copper.<br>
A single corrosion inhibition ike 2-MBT or BTA copper crorrosion. Furthermore, alter adding 2-MBT<br>
A single corrosion including the case of copper corrosion. Furthermore,  $28(7)$ ,  $2213007$  (4 of 10)<br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion crack  $28(7)$ ,  $2213007(4 \text{ of } 10)$ <br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion crac  $28(7)$ ,  $2213007$  (4 of 10)<br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion crack  $28(7)$ ,  $2213007$  (4 of 10)<br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion crack  $28(7)$ ,  $2213007$  (4 of 10)<br>
fore corrosion was smooth and uniform. As can be<br>
seen from Figure 5(b), in the absence of corrosion in-<br>
hibitor, the surface of the copper sample was severely<br>
corroded and many corrosion c  $28(7)$ ,  $2213007(4 of 10)$ <br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion cracks w  $28(7)$ ,  $2213007$  (4 of 10)<br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion crack  $28(7)$ ,  $2213007$  (4 of 10)<br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion crack  $28(7)$ ,  $2213007$  (4 of 10)<br>
fore corrosion was smooth and uniform. As can be<br>
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fore corrosion was smooth and uniform. As can be<br>
seen from Figure 5(b), in the absence of corrosion in-<br>
hibitor, the surface of the copper sample was severely<br>
corroded and many corrosion c  $28(7)$ ,  $2213007$  (4 of 10)<br>
fore corrosion was smooth and uniform. As can be<br>
seen from Figure 5(b), in the absence of corrosion in-<br>
hibitor, the surface of the copper sample was severely<br>
corroded and many corrosion c  $\frac{1}{200}$ ,  $\frac{1}{22000}$  (1.6116)<br>fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosio fore corrosion was smooth and uniform. As can be<br>seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion cracks were observed,<br>indicating th seen from Figure 5(b), in the absence of corrosion in-<br>hibitor, the surface of the copper sample was severely<br>corroded and many corrosion cracks were observed,<br>indicating that the corrosion of copper was relatively<br>serious hibitor, the surface of the copper sample was severely<br>corroded and many corrosion cracks were observed,<br>indicating that the corrosion of copper was relatively<br>serious. When 2-MBT and BTA inhibitors were<br>added separately, corroded and many corrosion cracks were observed,<br>indicating that the corrosion of copper was relatively<br>serious. When 2-MBT and BTA inhibitors were<br>added separately, the surface of copper presented<br>clear fracture traces, indicating that the corrosion of copper was relatively<br>serious. When 2-MBT and BTA inhibitors were<br>added separately, the surface of copper presented<br>clear fracture traces, but the number of cracks de-<br>creased as compared w serious. When 2-MBT and BTA inhibitors were<br>added separately, the surface of copper presented<br>clear fracture traces, but the number of cracks de-<br>creased as compared with that from blank solution. In<br>addition, the corrosio added separately, the surface of copper presented<br>clear fracture traces, but the number of cracks de-<br>creased as compared with that from blank solution. In<br>addition, the corrosion pit became shallow, because<br>2-MBT and BTA ar fracture traces, but the number of cracks de-<br>ased as compared with that from blank solution. In<br>dition, the corrosion pit became shallow, because<br>MBT and BTA had a slight effect on inhibiting<br>oper corrosion. Furthermor creased as compared with that from blank solution. In<br>addition, the corrosion pit became shallow, because<br>2-MBT and BTA had a slight effect on inhibiting<br>copper corrosion. Furthermore, after adding 2-MBT<br>+ MSDS and BTA+MSD addition, the corrosion pit became shallow, because<br>2-MBT and BTA had a slight effect on inhibiting<br>copper corrosion. Furthermore, after adding 2-MBT<br>+ MSDS and BTA+MSDS in the etching solution,<br>there were some visible cor 2-MBT and BTA had a slight effect on inhibiting<br>copper corrosion. Furthermore, after adding 2-MBT<br>+ MSDS and BTA+MSDS in the etching solution,<br>there were some visible corrosion marks on the sur-<br>face of copper, but the cor 电化学(*J. Electrochem.*) 2022, 28(7), 2213007 (4 of 10)<br>have different inhibi-<br>in etching solution. seen from Figure 5(b), in the absence of corrosion in-<br>inhibitor, the inhibi-<br>inhibitor, the surface of the copper sample





**EVALUATE:**<br> **Example 1**<br> **Example 2**<br> **Example 1**<br> **EXECUTE:**<br> **EXEC EXERCT:**<br> **EXERCT INTERFORMATE:**<br> **EXERCT INTERFORMA** and the method in the three inhibitors. Denoted the method in the method in the method of Equino -  $\mathcal{E}_{\text{RSDB}}$  (notice) the method of Equino -  $\mathcal{E}_{\text{RSDB}}$  (notice) (DFT) is used to the collector of copper in the e **EXECUTE:** FURNIFITA-MSDS 2-MBT=T-MSDS<br>
inhibitors. Density functional theory (DFT) is used to<br>
delucate the quantum cheminative of contact and<br>
the calculation method of Eqation (2) is introduced<br>
and with various inhibi and manutor B1A EANNIDS EMB1<sup>197</sup>NDS calculate the quantum chemistry of inhibitors, and<br>
Figure 4 Etch factor of copper in the etching solution without<br>
according to the frontier molecular orbital theory<sup>tty</sup>.<br>
and with v **Example 1** Etch factor of coopter in the calculation method of Eqation (2) is introduced<br>and with various inhibitons (color on line)<br> $\Delta E = E_{\text{LIMO}} - E_{\text{ROMO}}$ <br>where  $E_{\text{ROMO}}$  is the frontier molecular orbital theory<sup>13</sup>

# (28(7), 2213007 (5 of 10)<br>
copper surface is improved.<br> **3.2 Analysis of Corrosion Inhibition Mechanism**<br>
2.2.1 Theoretical Calculations<br>
In order to analyze the relationship between the 3.2 Analysis of Corrosion Inhibition Mechanism<br>3.2 Analysis of Corrosion Inhibition Mechanism<br>3.2.1 Theoretical Calculations<br>In order to analyze the relationship between the<br>structure of three inhibitors and the inhibitio anism

copper surface is improved.<br>
3.2 Analysis of Corrosion Inhibition Mechanism<br>
3.2.1 Theoretical Calculations<br>
In order to analyze the relationship between the<br>
structure of three imhibitors and the inhibition perfor-<br>
name **EXAMPLE 19.1** (5.59 and 11 and 12.1 Theoretical Calculations<br> **EXAMPLE 12.1** Theoret to analyze the relationship between the<br>
structure of three inhibitions and the inhibition perfor-<br>
mance, quantum chemical computation  $(28(7), 2213007(5 \text{ of } 10))$ <br>
copper surface is improved.<br> **3.2. Analysis of Corrosion Inhibition Mechanism**<br>
3.2.1 Theoretical Calculations<br>
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structure of three inhibitors  $\frac{3(7)}{2}$  213007 (5 of 10)<br>
2 **Analysis of Corrosion Inhibition Mechanism**<br>
1.1 Theoretical Calculations<br>
In order to analyze the relationship between the<br>
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nee, qu  $(28(7), 2213007(5 \text{ of } 10))$ <br>
sopper surface is improved.<br> **3.2 Analysis of Corrosion Inhibition Mechanism**<br>
3.2.1 Theoretical Calculations<br>
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structure of three inhibitors a  $(28(7), 2213007(5 \text{ of } 10))$ <br>
copper surface is improved.<br> **3.2 Analysis of Corrosion Inhibition Mechanism**<br>
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copper surface is improved.<br> **3.2 Analysis of Corrosion Inhibition Mechanism**<br>
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copper surface is improved.<br> **3.2 Analysis of Corrosion Inhibition Mechanism**<br>
1.3.2.1 Theoretical Calculations<br>
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copper surface is improved.<br>
3.2 Analysis of Corrosion Inhibition Mech-<br>
anism<br>
3.2.1 Theoretical Calculations<br>
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structure of three inhibitors and 28(7), 2213007 (5 of 10)<br>
copper surface is improved.<br>
3.2 Analysis of Corrosion Inhibition Mech-<br>
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3.2 Analysis of Corrosion Inhibition Mech-<br>
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copper surface is improved.<br>
3.2 Analysis of Corrosion Inhibition Mech-<br>
anism<br>
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In order to analyze the relationship between the<br>
structure of three inhibitors copper surface is improved.<br>
3.2 Analysis of Corrosion Inhibition Mech-<br>
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5.2.1 Theoretical Calculations<br>
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structure of three inhibitors and the inhibiton perfor-<br>
st 3.2 Analysis of Corrosion Inhibition Mech-<br>anism<br>3.2.1 Theoretical Calculations<br>In order to analyze the relationship between the<br>structure of three inhibitors and the inhibition perfor-<br>mance, quantum chemical computation **anism**<br>3.2.1 Theoretical Calculations<br>In order to analyze the relationship between the<br>structure of three inhibitors and the inhibition perfor-<br>mance, quantum chemical computation and molecu-<br>lar dynamics calculation are

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

3.2.1 Theoretical Calculations<br>
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structure of three imhibitors and the imhibition perfor-<br>
interactions and the imhibition perfor-<br>
IFIA:MSDS 2-MDT-MSDS<br>
IFTA:MSDS 2-MDT-MS 3.2.1 Theoretical Calculations<br>
In order to analyze the relationship between the<br>
structure of three inhibitors and the inhibition perfor-<br>
mance, quantum chemical computation and molecu-<br>
lar dynamics calculation are car In order to analyze the relationship between the<br>structure of three inhibitors and the inhibition perfor-<br>mance, quantum chemical computation and molecu-<br>lar dynamics calculation are carried out on the three<br>inhibitors. D structure of three inhibitors and the inhibition perfor-<br>mance, quantum chemical computation and molecular dynamics calculation are carried out on the three<br>inhibitors. Density functional theory (DFT) is used to<br>calculate mance, quantum chemical computation and molecular dynamics calculation are carried out on the three inhibitors. Density functional theory (DFT) is used to calculate the quantum chemistry of inhibitors, and the calculation lar dynamics calculation are carried out on the three<br>inhibitors. Density functional theory (DFT) is used to<br>calculate the quantum chemistry of inhibitors, and<br>the calculation method of Eqation (2) is introduced<br>according inhibitors. Density functional theory (DFT) is used to<br>calculate the quantum chemistry of inhibitors, and<br>the calculation method of Eqation (2) is introduced<br>according to the frontier molecular orbital theory<sup>[17]</sup>:<br> $\Delta E =$ calculate the quantum chemistry of inhibitors, and<br>the calculation method of Eqation (2) is introduced<br>according to the frontier molecular orbital theory<sup>[17]</sup>:<br> $\Delta E = E_{LUMO} - E_{10M0}$  (2)<br>where  $E_{HOMO}$  is the highest occup the calculation method of Eqation (2) is introduced<br>according to the frontier molecular orbital theory<sup>(17)</sup>;<br> $\Delta E = E_{LUMO} - E_{HOMO}$  (2)<br>where  $E_{HOMO}$  is the highest occupied orbital energy,<br> $E_{LUMO}$  is the lowest vacant or







**EXERCT MOND ARE CONSERVED ASSESS ARE CONSERVED ASSESS are also provided at the same of t EXERCT:** A set of the CENE CONSIDE STRACT AND CONDUCT THIS CONDUCT THIS CONDUCT THE CONDUCT THE INTERET AND CONDUCT THE INTERET AND CONDUCT THE INTERET AND CONDUCT THE INTERET AND CONDUCT THIS CONDUCT THE CONDUCT THE CONDUCT THE CONDUCT THE CO Example and the control of the method in the Figure is mainly to electron do the method in the method of the Figure 3 hows the equilibrium contribute is more than the signal of the copper surface is more contribute to eas **Figure 7** HOMO and LUMO electricities is for the more easily ad-<br> **Figure 7** HOMO and LUMO electricities is lower, inhibition molecules<br>
molecule. If  $\Delta F$  value is lower, inhibition molecules<br>
could contribute to easies **Figure 7** HOMO and LUMO calculation exults for different inhibitors (color on line)<br>
molecule. If  $\Delta E$  value is lower, inhibitor molecules teraction between corrosion inhibitor molecules on<br>
could contribute to easier s inhibition. blevule. If  $\Delta E$  value is lower, inhibitor molecules teraction between corrosion inhibitor molecules on<br>
and contribute to easier surface adsorption. The  $\Delta E$  corper surface. The results show that the corrosion<br>
tues of molecule. If  $\Delta E$  value is lower, inhibitor molecules treateion between corrosion inhibitor molecules on could contribute to easier surface adsorption. The  $\Delta E$  corper surface. The results how that the corrosion values

ere, they add to be a set of the copper surface<br>
care of the state of the control of the control on this beneficial to maximize surface<br>
care of the control of the control of correction inhibitor is beneficial to maximize  $\begin{pmatrix}\n\frac{3}{2} & \frac{3}{2} & \frac{3}{$ Corresponding the maximize surface overage the amplitude of external to maximize surface overage the maximization in the surface overage the maximize surface overage the maximize surface overage the maximize surface overa Example 19 and protect the control of the core of the control of the core of the control of the core of the control good corrosion inhibitor molecules on<br>correction between corrosion inhibitor molecules on<br>copper surface. The results show that the corrosion<br>inhibitor molecules are adsorbed on copper surfaces<br>parallel and vertically bef Advertised to the control of the means of the state of the state of the state of the state of the means sure of the binding abilities of corrosion inhibitor molecules on<br>copper surface. The results show that the corrosion<br>inhibitor molecules are adsorbed on copper surfaces<br>parallel and vertically before the equilibrium, how teraction between corrosion inhibitor molecules on<br>copper surface. The results show that the corrosion<br>inhibitor molecules are adsorbed on copper surfaces<br>parallel and vertically before the equilibrium, howev-<br>er, they te energy is an important index to mean  $E_{\text{C}u}$  index  $E_{\text{C}u}$  and  $E_{\text{unlike}}$  represents the corresponding of  $E_{\text{C}u}$  index  $E_{\text{C}u}$  independent of  $E_{\text{C}u}$  and  $E_{\text{in}}$  and  $E_{\text{in}}$  and  $E_{\text{in}}$  and  $E_{\$ between corrosion inhibitor molecules on<br>copper surface. The results show that the corrosion<br>inhibitor molecules are adsorbed on copper surfaces<br>parallel and vertically before the equilibrium, howev-<br>er, they tend to be a teraction between corrosion inhibitor molecules on<br>copper surface. The results show that the corrosion<br>inhibitor molecules are adsorbed on copper surfaces<br>parallel and vertically before the equilibrium, howev-<br>er, they te teraction between corrosion inhibitor molecules on<br>copper surface. The results show that the corrosion<br>inhibitor molecules are adsorbed on copper surfaces<br>parallel and vertically before the equilibrium, howev-<br>er, they te

$$
E_{\text{Cu-inhibitor}} = E_{\text{total}} - (E_{\text{Cu}} + E_{\text{inhibitor}}) \tag{3}
$$



the metal surface.<br>
Figure 8 The equilibrium configurations on copper<br>
Frace for and the clearing transfer resistance increased<sup>[ii]</sup>. Therefore, the<br>
before and after the adsoption of corrosion inhibitor<br>
system: (a, and the metal surface.<br>
Figure SF The equilibrium configurations on copper<br>
Figure SF The cquilibrium configurations on copper<br>
charge transfer resistance increased<sup>[31]</sup>. Therefore, the<br>
before and after the adsorption of co creased, and the clectrical impedance value and<br>
Figure 8 The equilibrium configurations on cooper<br>
Figure 8 The equilibrium configurations on cooper and defined resistance interested.<sup>20</sup>. Therefore, the<br>
before and after Figure 8 The equilibrium configurations on copper<br>
elearns the range transfer resistance increased<sup>[21]</sup>. Therefore, the<br>
bester and after the adsorption of corrosion infibition in diffusion of croresion infibition in dip before and after the adsorption of corrosion inhibitor<br>system: (a, and a,  $2 \times 1 \text{MP1}$ ), MSDS; (c, and  $\phi$ ), MSDS; (c, and capacite between copper electrode and ething solu-<br>experts (a, and a,) 2 MBT (a, and b), DMS; (c,

**Example 12**<br> **Example 12**<br> **Example 12**<br> **Example 12**<br> **Example 12**<br> **Electrochemic on figurations on copper before and after the adsorption of corresion inhibitor system: (a, and a) 2-MBT; (b, b) MSDS; (c, and c) BTA; + Figure 8** The equilibrium configurations on copper before and after the adsorption correction inhibitor system: (a<sub>1</sub> and a<sub>2</sub>) 2-MBT; (b, and b) MSDS; (c, and c) BTA; (d, and d)) BTA + MSDS; (c, and e) 2-MBT + MSDS; and **Eighter S** The equilibrium configurations on copper before and after the adsorption of corrosion inhibitor system: (a, and a)  $2 \text{MBF}$ ; (b, and at b)  $\text{MSTS}$ ; (c, and a)  $\text{SB}$ ; (c) and a)  $\text{SB}$ ; (c) and  $\text{SB}$ ; (a **Eigure 8** The equilibrium configurations on copper before and after the adsorption of coroosion inhibitor system: (a, and a)  $2 \times \text{MBT}$ ; (b, and b) MSDS; (c, and c) BTA; (d, and b) BTA + MSDS; (e, and e)  $2 \times \text{MBT}$  - M reparation content in the impedance of correspondent to the impedance spectra of columnic the metal surface.<br>
Figure 8 Th and the metal surface.<br>
and the electrical impedance value and<br>
inhibitor system (coloronline)<br>
Figure 8 The equilibrium configurations on copper<br>
before and the clearcine in-reasonal in-Pierbore, the<br>
before and after th (a)<br>  $\frac{4}{3}$ <br>  $\frac{4}{3$ Corresion inhibitor since the surface of corresion in the etching solution, displaying the maximum capacitation of corresion inhibitor system: (a, and a) 2-MBT; (b<sub>1</sub> MBT + MSDS; and (f) calculative adsorption energy of c **PERTEMBER 1998**<br> **Example 1998**<br> **Example 1998**<br> **Example 1998**<br> **Example 1999**<br> **Example 2-MBT;** (b<sub>1</sub><br> **CHECT+**<br> **Example** Assumed the corrosion inhibitor system: (a, and a,) 2-MBT; (b,<br>
MBT + MSDS; and (f) calculative adsorption energy of corrosion<br>
MBT + MSDS; and (f) calculative adsorption energy of corrosion<br>
creased, and the electrical i **EVALUATE:**<br> **ENTRALLY AND STATE STANSDER**<br> **ENTRALLY AND STANSDER**<br> **E EXECUTE:**<br> **EXECUTE:** ANSIS EXAMBITIONS AND INTERVISED AND TRIVIS CONDITIONS (and (f) calculative adsorption energy of corrosion MBT + MSDS; and (f) calculative adsorption energy of corrosion creased, and the electrical **EXAMPLE ANDISTED INTERENDE CONDUCT AND SERVED SERVED** e adsorption of corrosion inhibitor system:  $(a_1 \text{ and } a_3)$  2-MBT;  $(b_1 \text{ ABT} + \text{MSDS};$  and (f) calculative adsorption energy of corrosion<br>creased, and the electrical impedance value and<br>charge transfer resistance increased<sup></sup> and and the electrical impedance value and  $\alpha_{3/2}$ -with  $\alpha_{1,00}$ <br>creased, and the electrical impedance value and<br>charge transfer resistance increased<sup>[21]</sup>. Therefore, the<br>addition of corrosion inhibitor inhibits the (b), compared with the electrical impedance value and<br>charge transfer resistance increased<sup>[21]</sup>. Therefore, the<br>addition of corrosion inhibitor inhibits the charge<br>transfer between copper electrode and etching solu-<br>tion creased, and the electrical impedance value and<br>charge transfer resistance increased<sup>[21]</sup>. Therefore, the<br>addition of corrosion inhibitor inhibits the charge<br>transfer between copper electrode and etching solu-<br>tion, and creased, and the electrical impedance value and<br>charge transfer resistance increased<sup>[21]</sup>. Therefore, the<br>addition of corrosion inhibitor inhibits the charge<br>transfer between copper electrode and etching solu-<br>tion, and t creased, and the electrical impedance value and<br>charge transfer resistance increased<sup>[21]</sup>. Therefore, the<br>addition of corrosion inhibitor inhibits the charge<br>transfer between copper electrode and etching solu-<br>tion, and t charge transfer resistance increased<sup>[21]</sup>. Therefore, the<br>addition of corrosion inhibitor inhibits the charge<br>transfer between copper electrode and etching solu-<br>tion, and the results indicating that the adsorption of<br>co

addition of corrosion inhibitor inhibits the charge<br>transfer between copper electrode and etching solu-<br>tion, and the results indicating that the adsorption of<br>corrosion inhibitor molecules on the surface of cop-<br>per elect

$$
IE_{\text{(i)}} = \frac{I_{\text{corr}} - I_{\text{corr}(\text{inh})}}{I_{\text{corr}}} \times 100\%
$$
 (4)

the  $H_{\text{on}}^{\text{th}}$  (*b*  $H_{\text{off}}^{\text{th}}$  (*corrosion in thistical H\_{\text{off}}* the  $\mathcal{Z}_L$  *K* because them.) 2022, 28(7), 2213007 (8 of 10)<br> **Efficiency** is calculated as Equation (4):<br>  $E_{\rm p} = \frac{I_{\rm em} - I_{\rm conf, \rm kph}}{I_{\rm em}} \times 100\%$ <br>  $E_{\rm p} = \frac{I_{\rm em} - I_{\rm conf, \rm kph}}{I_{\rm em}} \times 100\%$ <br>  $\text{where } H_{\rm p}$  rep  $H_0 = \frac{\int_{tan}^{2\pi} \int_{tan}^{2\pi} f(t, \text{E} \text{d}t \text{d}t$  $\frac{d}{dx}$  (*E*  $E$  *C. Betamehem,* 2022, 28(7), 2213007 (8 of 10)<br> *Efficiency* is calculated as Equation (4):<br> *Effeciences* is detectively.<br> *Effeciences* is detectively.<br> *CF*<br> *CF*<br> *CF*<br> *CF*<br> *CF*<br> *CF*<br> *CF*<br> *CF*<br>  $\frac{\text{ft}(E\pi)$ .  $E_{k} = mcL_{one}$ <br>  $\frac{E_{00} - L_{one}L_{on}}{L_{on}}$ <br>  $\frac{E_{00} - L_{on}L_{on}}{L_{on}}$  and Equation (4):<br>  $\frac{E_{01} - L_{on}L_{on}L_{on}}{L_{on}}$  and Equation (4):<br>  $\frac{E_{01} - L_{on}L_{on}L_{on}}{L_{on}}$  and  $\frac{E_{00} - L_{on}L_{on}}{L_{on}}$  and  $\frac{E_{00} - L_{$ Efficiency is calculated as Equation (4):<br>  $W_{\text{in}} = \frac{I_{\text{out}} - I_{\text{out,obs}}}{I_{\text{out}}}$  ×10.9% and  $\frac{1}{2}$  materials  $W_{\text{in}} = \frac{I_{\text{out}} - I_{\text{out,obs}}}{I_{\text{out}}}$  (4) the corresion current density, and the corresion inhibi-<br>  $W_{\text{in$ efficiency is calculated as Figuation (4):<br>
the corrosion current density, and the corrosion inhibi-<br>  $H_{\rm bin} = \frac{I_{\rm max}-I_{\rm out,obs}}{I_{\rm max}} \times 100\%$  (4) the rate increased to 31.1% and 22.2%, respectively.<br>
These values indica  $E_{ij} = \frac{I_{\text{out}} - I_{\text{out,total}}}{I_{\text{out}}} \times 100\%$  (4) tion rate increased to 31.1% and 22.2%, respectively.<br>
Where  $|F_{i0}$  respectively, these values indicate that the synergistic acisin<br>
cy, and  $I_{\text{out}}$  and  $I_{\text{out,det}}$  repr  $u_{\text{tot}} = -\frac{1}{I_{\text{ave}}}$ . A 10079<br>
whow These values indicate that the synepsic action of<br>
where  $I_{\text{ES}}$  represents the corrosion inhibition efficient-<br>
corrosion inhibition scan further impede the same<br>
cry, and  $I_{\text{gen$ where  $E_0$  represents the corrosion inhibition efficien-<br>
corrosion inhibitors can further impede the dissolu-<br>
ey, and  $I_{\text{cent}}$  and (casin represent the self-corrosion cur-<br>
tion reaction of copper electrods and improv

 $E_{\text{to}} = \frac{I_{\text{corr}} - I_{\text{corr}(\text{inh})}}{I_{\text{corr}}} \times 100\%$  (4)<br>
Where  $E_{\text{to}}$  represents the corrosion inhibition efficiency is calculated as Equation (4):<br>  $E_{\text{to}} = \frac{I_{\text{corr}(\text{inh})}}{I_{\text{corr}}} \times 100\%$  (4)<br>
where  $E_{\text{to}}$  repres  $\frac{1}{\sqrt{C_{\text{corr}}}}$  (4) is calculated as Equation (4):<br>
is calculated as Equation (4):<br>  $\frac{1}{\sqrt{C_{\text{corr}}}}$  x100% (4) the corrosion current density, and the corrosion inhibi-<br>  $\frac{1}{\sqrt{C_{\text{corr}}}}$  x100% (4) tion rate increase  $HE_{(i)} = \frac{I_{\text{corr}} - I_{\text{correlation}}}{I_{\text{corr}}}$   $\text{H}(E \neq (I, Electrochem.) 2022, 28(7), 2213007 (8 of 10))$ <br>  $HE_{(i)} = \frac{I_{\text{corr}} - I_{\text{correlation}}}{I_{\text{corr}}} \times 100\%$ (4)
<br>  $W_{\text{free}} = \frac{I_{\text{corr}} - I_{\text{correlation}}}{I_{\text{corr}}} \times 100\%$ (4)
<br>  $W_{\text{here}} = \frac{I_{\text{corr}} - I_{\text{correlation}}}{I_{\text{corr$ (*Exerication*) Efficiency is calculated as Equation (4):<br>
Efficiency is calculated as Equation (4):<br>  $E_{\odot} = \frac{I_{\text{corr}} - I_{\text{correlation}}}{I_{\text{corr}}} \times 100\%$  (4) tion rate increased to 31.1% and 22.2%, respectively.<br>
These values i rents of the copper and the inhibitor, respectively. The Tafel linear region of the polarization curve  $\frac{d}{dx}E^2(J. *Electrochem*))$  2022, 28(7), 2213007 (8 of 10)<br>
efficiency is calculated as Equation (4):<br>  $E_{\Theta} = \frac{I_{\text{corr}} - I_{\text{corr(Sb)}}}{I_{\text{corr}}} \times 100\%$  (4)<br>  $\frac{I_{\text{corr}}}{I_{\text{corr}}}$  (4)<br>  $\frac{I_{\text{corr}} - I_{\text{corr(Sb)}}}{I_{\text{corr}}} \times 100\%$  (4)<br> **Example 19**<br> **Efficiency** is calculated as Equation (4):<br> **Efficiency** is calculated as Equation (4):<br> **If the corrosion current density, and the corrosion inhibi-**<br> **IF**<sub>0</sub>  $E_{\text{long}} = \frac{I_{\text{comp}} - I_{\text{correlation}}}{I_{\text{comp}}} \times 100\%$ <br>  $\text{E}_\text{G} = \frac{E_\text{out} - E_\text{out}}{E_\text{out}}$  as calculated by the corrosion current density, and the corrosion inhibi-<br>  $\text{E}_\text{G} = \frac{E_\text{out} - E_\text{out} - E_\text{out}}{E_\text{out}} \times 100\%$  (4) the corrosion current density, and the corrosion inhi  $28(7)$ ,  $2213007(8 \text{ of } 10)$ <br>the corrosion current density, and the corrosion inhibi-<br>tion rate increased to 31.1% and 22.2%, respectively.<br>These values indicate that the synergistic action of<br>corrosion inhibitors can fu  $28(7)$ ,  $2213007 (8 \text{ of } 10)$ <br>the corrosion current density, and the corrosion inhibi-<br>tion rate increased to 31.1% and 22.2%, respectively.<br>These values indicate that the synergistic action of<br>corrosion inhibitors can fu  $28(7)$ ,  $2213007(8 \text{ of } 10)$ <br>the corrosion current density, and the corrosion inhibi-<br>tion rate increased to 31.1% and 22.2%, respectively.<br>These values indicate that the synergistic action of<br>corrosion inhibitors can fu  $28(7)$ ,  $2213007$  (8 of 10)<br>the corrosion current density, and the corrosion inhibi-<br>tion rate increased to 31.1% and 22.2%, respectively.<br>These values indicate that the synergistic action of<br>corrosion inhibitors can fur  $28(7)$ ,  $2213007$  (8 of 10)<br>the corrosion current density, and the corrosion inhibi-<br>tion rate increased to 31.1% and 22.2%, respectively.<br>These values indicate that the synergistic action of<br>corrosion inhibitors can fur  $28(7)$ ,  $2213007(8 \text{ of } 10)$ <br>the corrosion current density, and the corrosion inhibi-<br>tion rate increased to  $31.1\%$  and  $22.2\%$ , respectively.<br>These values indicate that the synergistic action of<br>corrosion inhibitors  $28(7)$ ,  $2213007(8 \text{ of } 10)$ <br>the corrosion current density, and the corrosion inhibi-<br>tion rate increased to  $31.1\%$  and  $22.2\%$ , respectively.<br>These values indicate that the synergistic action of<br>corrosion inhibitors inhibition. (7), 2213007 (8 of 10)<br>
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(4) the corrosion current density, and the corrosion inhibi-<br>
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n reaction of copper electrodes and improve the<br>
rosion inhibition effect of copper, while the com-<br>
ation of 2-MBT + MSDS has the best corrosion<br>
ibition.<br>
In summary, t

## 4 Conclusions



 $\frac{\text{H}(E^2)(\text{Electrochem.}) 2022, 28(7), 2213007 (9 of 10)}{\text{MSDS as conversion inhibitors were added into the  
acidic etching solution to form the thick copper line  
of PCB. The inhibition mechanism and adsorption  
behavior of the corrosion inhibitors were investigated  
by contact angle measurement, electrochemical test,$  $\frac{\ln \{\&\}\% (J. Electron.) 2022, 28(7), 2213007 (9 of 10))}{\text{MSDS as conversion inhibitors were added into the  
acidic etching solution to form the thick copper line  
of PCB. The inhibition mechanism and adsorption  
behavior of the conversion inhibitors were investigated  
by contact angle measurement, electrochemical test,   
SEM, quantum chemical calculation and molecular  
EM, quantum chemical calculation and molecular$  $\#E\#(J. Electrochem.)$  2022, 28(7), 2213007 (9 of 10)<br>
MSDS as corrosion inhibitors were added into the [7] Zhong Y Q, Zhang W F, Jin L K, Sun B H. Improvement<br>
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acidic etching solution to form the thick copper line<br>
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acidic etching solution to form the thick copper line  $\pm 1$  (EP( $\pm 2$ ),  $\pm 2$ ,  $\pm 2$ **E** *th*<sup>22</sup> (*L Electrochem.) 2022, 28(7), 2213007 (9 of 10)<br>
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acidic etching solution to form the thick copper* MSDS > BTA + MSDS. The 2-MBT, BTA and MS- $\begin{tabular}{|c|c|c|c|} \hline &\textbf{4E} (E\# (L. Electrochem.) 2022, 28(7), 2213007 (9 of 10)\\ \hline \textbf{MSDS as corrosion inhibitors were added into the}&(7) Zhang Y Q, Zhang W F, Jin 1. K, Sun B H. improvement  
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### Acknowledgements:

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## References:

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- Corrosion Sci., 2004, 46(2): 38<sup>2</sup><br> **EFFENCES:**<br>
IEV (100. *ZAL220170012000321* WC).<br>
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In this intertunes on the corrosion Sci. Altang HL, Guo X P. Z **EFICHICES**<br> **EFFICHICS:** THE UNITED TREFORM THE STRATE TO SET AND ANOTHING THE SAMPLE (Big China Michine Press, 2021. 1-11.<br> **Beijing:** China Michine Press, 2021. 1-11.<br> **NACI SOUTOBED TRATE ART ART ART ART ART ART ART A** He W. Electrical information science and technology [M].<br>
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Humg Beijing: China Machine Press, 2021. 1-11.<br>
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	Circuit Information, 2018, 15(2):56-62.<br>
	[8] Guo X M, Huang H L, Liu D. The inhibition mechanism<br>
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	Circuit Information, 2018, 15(2):56-62.<br>
	Giuo X M, Huang H L, Liu D. The inhibition mechanism<br>
	or X M, Huang 16 fine line manufacturing by etching addictive [J]. Printed<br>
	21-rcuit Information, 2018, 15(2):56-62.<br>
	Nuo X M, Huang H L, Liu D. The inhibition mechanism<br>
	and adsorption behavior of three purine derivatives on the<br>
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	ale performance[1]. Collid Surf. A-Physicochem and adsorption behavior of three purine derivatives on the<br>corrosion of copper in alkaline artificial seawater: structure<br>and performance [1]. Colloid Surf. A-Physicochem. Eng.<br>Asp., 2021, 622: 126644.<br>[9] Li L, Zhang X H orrosion of copper in alkaline artificial seawater: structure<br>nd performance[J]. Colloid Surf. A-Physicochem. Eng.<br>sp., 2021, 622: 126644.<br>i. I., Zhang X H, Gong S D, Zhao H X, Bai Y, Li Q S, Ji<br>n. The discussion of descri nd performance[J]. Colloid Surf. A-Physicochem. Eng.<br>sp., 2021, 622: 126644.<br>i. L, Zhang X H, Gong S D, Zhao H X, Bai Y, Li Q S, Ji<br>.. The discussion of descriptors for the QSAR model and<br>onlectular dynamics simulation of Asp., 2021, 622: 126644.<br>
	[9] Li L, Zhang X H, Gong S D, Zhao H X, Bai Y, Li Q S, Ji<br>
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	ives as corrosion inhibitors[J]. Corrosion Sci., 2015
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- ional Natural Science Foundation of China (Nos.<br>
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971020 and 619744020). The voric is sales support-<br>
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[1] He W. Electrical information science and technology[M]<br>
[1] He W. Electrical information science and technology[M]<br> **their arrances on the corresion of corper in 3.5web<br>
26) Heing China Machine Press, 20** .. The discussion of descriptors for the QSAR model and nolecular dynamics simulation of benzimidazole deriva-<br>ves as corrosion inhibitors[J]. Corrosion Sci., 2015, 99:<br>6-88.<br>Sherif E S M, Erasmus R M, Comins J D. Inhibit nolecular dynamics simulation of benzimidazole deriva-<br>ves as corrosion inhibitors[J]. Corrosion Sci., 2015, 99:<br>6-88.<br>Sherif E S M, Erasmus R M, Comins J D. Inhibition of<br>copper corrosion in acidic chloride pickling solut ives as corrosion inhibitors[J]. Corrosion Sci., 2015, 99:<br>
6-88.<br>
Sherif E S M, Erasmus R M, Comins J D. Inhibition of<br>
copper corrosion in acidic chloride pickling solutions by<br>
5-(3-aminophenyl)-tetrazole as a corrosion 76-88.<br>
[10] Sherif E S M, Erasmus R M, Comins J D. Inhibition of<br>
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5-(3-aminophenyl)-tetrazole as a corrosion inhibitor [J].<br>
Corrosion Sci., 2008, 50(12): 3439-34 Sherif E S M, Erasmus R M, Comins J D. Inhibition of<br>copper corrosion in acidic chloride pickling solutions by<br>5-(3-aminophenyl)-tetrazole as a corrosion inhibitor [J].<br>Corrosion Sci., 2008, 50(12): 3439-3445.<br>Lei S S, Wan copper corrosion in acidic chloride pickling solutions by 5-(3-aminophenyl)-tetrazole as a corrosion inhibitor [J].<br>Corrosion Sci., 2008, 50(12): 3439-3445.<br>Lei S S, Wang S L, Li H L, Wang C W, Yang Y D A,<br>Cheng Y S, Li S. 5-(3-aminophenyl)-tetrazole as a corrosion inhibitor [J].<br>Corrosion Sci., 2008, 50(12): 3439-3445.<br>Lei S S, Wang S L, Li H L, Wang C W, Yang Y D A,<br>Cheng Y S, Li S. Effect of benzotriazole and 5-methyl/<br>1-H carboxyl benzot Corrosion Sci., 2008, 50(12): 3439-3445.<br>
[11] Lei S. S. Wang S L, Li H L, Wang C W, Yang Y D A,<br>
Cheng Y S, Li S. Effect of benzotriazole and 5-methyl<br>
1-H carboxyl benzotriazole an chechanical nochanical pol-<br>
ishing of Lei S S, Wang S L, Li H L, Wang C W, Yang Y D A,<br>Cheng Y S, Li S. Effect of benzotriazole and 5-methyl/<br>1-H carboxyl benzotriazole on chemical mechanical pol-<br>ishing of cobalt in H<sub>2</sub>O<sub>2</sub> based slurry [J]. ECS J. Solid<br>Sta Cheng Y S, Li S. Effect of benzotriazole and 5-methyl/<br>1-H carboxyl benzotriazole on chemical mechanical pol-<br>ishing of cobalt in H<sub>2</sub>O<sub>2</sub> based slurry [J]. ECS J. Solid<br>State Sci. Technol., 2021, 10(7): 074002.<br>Moretti G, 1-H carboxyl benzotriazole on chemical mechanical polishing of cobalt in H<sub>2</sub>O<sub>2</sub> based slurry [J]. ECS J. Solid State Sci. Technol., 2021, 10(7): 074002.<br>Moretti G, Guidi F, Grion G. Tryptamine as a green iron corrosion i ishing of cobalt in H<sub>2</sub>O<sub>2</sub> based slurry[1]. ECS J. Solid<br>State Sci. Technol., 2021, 10(7): 074002.<br>[12] Moretti G, Guidi F, Grion G. Tryptamine as a green iron<br>corrosion ishibitor in 0.5 M deareated sulphuric acid[J].<br>Co State Sci. Technol., 2021, 10(7): 074002.<br>
Moretti G, Guidi F, Grion G. Tryptamine as a green iron<br>
corrosion inhibitor in 0.5 M deaerated sulphuric acid[J].<br>
Corrosion Sci., 2004, 46(2): 387-403.<br>
Huang H L, Guo X M. The Moretti G, Guidi F, Grion G. Tryptamine as a green iron<br>corrosion inhibitor in 0.5 M deaerated sulphuric acid[J].<br>Corrosion Sci., 2004, 46(2): 387-403.<br>Huang H L, Guo X M. The Relationship between the in-<br>hibition performa corrosion inhibitor in 0.5 M deaerated sulphuric acid[J].<br>Corrosion Sci., 2004, 46(2): 387-403.<br>Huang H L, Guo X M. The Relationship between the in-<br>hibition performances of three benzo derivatives and<br>their structures on Corrosion Sci., 2004, 46(2): 387-403.<br>
[13] Huang H L, Guo X M. The Relationship between the in-<br>
hibition performances of three benzo derivatives and<br>
their structures on the corrosion of copper in 3.5wt.%<br>
NaCl solution[ Huang H L, Guo X M. The Relationship between the in-<br>hibition performances of three benzo derivatives and<br>their structures on the corrosion of copper in 3.5wt.%<br>NaCl solution[J]. Colloid Surf. A-Physicochem. Eng. Asp.,<br>202 hibition performances of three benzo derivatives and<br>their structures on the corrosion of copper in 3.5wt.%<br>NaCl solution[J]. Colloid Surf. A-Physicochem. Eng. Asp.,<br>2020, 598: 124809.<br>Chiter F, Costa D, Maurice V, Marcus
	- their structures on the corrosion of copper in 3.5wt.%<br>
	NaCl solution[J]. Colloid Surf. A-Physicochem. Eng. Asp.,<br>
	2020, 598: 124809.<br>
	[14] Chiter F, Costa D, Maurice V, Marcus P. DFT investiga-<br>
	tion of 2-mercaptobenzothi NaCl solution [J]. Colloid Surf. A-Physicochem. Eng. Asp.,<br>2020, 598: 124809.<br>Chiter F, Costa D, Maurice V, Marcus P. DFT investiga-<br>ition of 2-mercaptobenzothiazole adsorption on model ox-<br>idized copper surfaces and relat 2020, 598: 124809.<br>Chiter F, Costa D, Maurice V, Marcus P. DFT investiga-<br>tion of 2-mercaptobenzothiazole adsorption on model ox-<br>idized copper surfaces and relationship with corrosion in-<br>inibition[J]. Appl. Surf. Sci., 2
	-
	-
	-
	-

- *E* (*L Electrochem.*) 2022, 28(7), 2213007 (10 of 10)<br> *J.* Mol. Struct., 2010, 959(1-3): 66-74. <br>
2010, 959(1-3): 66-74. <br>
2010, 2010, 959(1-3): 66-74. <br>
2010, 2010, 2010, 2010, 2010, 2010, 2010, 2010, 2010, 2010, 20 (a) the default of the *H*(*k*) and the *H*(*k*) and the *H*(*k*) and the *H*(*k*) and the *H*, Gong Z L, Zhang S T, Gao (21) Tao *Z* H, He W, Wang S X, Zhou G Y. Electrochemical L Z, Tan B C, Chen S J, Guo L. Experimenta <br>
H. *K*etroshem.) 2022, 28(7), 2213007 (10 of 10)<br>
J. Mol. Struct., 2010, 959(1-3): 66-74.<br>
<br>
Chen J, Qiang Y J, Peng S N, Gong Z L, Zhang S T, Gao<br>
<br>
L Z, Tan B C, Chen S J, Guo L. Experimental and com-<br>
<br>
study of cypr (*Lettrochem.*) 2022, 28(7), 2213007 (10 of 10)<br>
J. Mol. Struct., 2010, 959(1-3): 66-74.<br>
Chen J, Qiang Y J, Peng S N, Gong Z L, Zhang S T, Gao [21] Tao Z H, He W, Wang S X, Zhou G Y. Electroche<br>
L Z, Tan B C, Chen S J, G  $\text{#}\{E\}^{\text{26}}(J. \text{ *Electrochem.*}) 2022, 28(7), 2213007 (10 of 10) \text{ }$ <br>
J. Mol. Struct., 2010, 959(1-3): 66-74. <br>
Chen J, Qiang Y J, Peng S N, Gong Z L, Zhang S T, Gao [21] Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical (1) *Hg*<sup>2</sup> (*L Electrochem.*) 2022, 28(7), 2213007 (10 of 10)<br>
J. Mol. Struct., 2010, 959(1-3): 66-74. <br>
(21) Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical<br>
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1. Mol. Struct, 2010, 959(1-3): 66-74.<br>
Chen J, Qiang Y J, Peng S N, Giong Z L, Zhang S T, Giao<br>
1. Z, Tan B C, Chen S J, Gion L. Experimental and com-<br>
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427-449.

- 28(7), 2213007 (10 of 10)<br>
427-449.<br>
[21] Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical<br>
study of cyproconazole as a novel corrosion inhibitor for<br>
copper in acidic solution[J]. Ind. Eng. Chem. Res., 2013,<br>
52(50): 1 study of cyproconazole as a novel corrosion inhibitor for copper in acidic solution [J]. Ind. Eng. Chem. Res., 2013, 52(50): 17891-17899.<br>Aboelnga M M, Awad M K, Gauld J W, Mustafa M R.<br>An assessment to evaluate the validi (2213007 (10 of 10)<br>
427-449.<br>
Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical<br>
study of cyproconazole as a novel corrosion inhibitor for<br>
copper in acidic solution[J]. Ind. Eng. Chem. Res., 2013,<br>
52(50): 17891-17899.<br> 28(7), 2213007 (10 of 10)<br>
427-449.<br>
(21) Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical<br>
study of cyproconazole as a novel corrosion inhibitor for<br>
copper in acidic solution[J]. Ind. Eng. Chem. Res., 2013,<br>
52(50): 17 电化学(*J. Electrochem.*) 2022, 28(7), 2213007 (10 of 10)<br>
66-74. <br>  $427-449.$ <br>  $227-449.$ <br>
	- 1, 2213007 (10 of 10)<br>
	427-449.<br>
	Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical<br>
	study of cyproconazole as a novel corrosion inhibitor for<br>
	copper in acidic solution[J]. Ind. Eng. Chem. Res., 2013,<br>
	52(50): 17891-17899 An assessment to evaluate the validing of the validing of the valid of cyproconazole as a novel corrosion inhibitor for copper in acidic solution[J]. Ind. Eng. Chem. Res., 2013, 52(50): 17891-17899.<br>Aboelnga M M, Awad M K, 9. 2213007 (10 of 10)<br>
	427-449.<br>
	Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical<br>
	study of cyproconazole as a novel corrosion inhibitor for<br>
	copper in acidic solution[J]. Ind. Eng. Chem. Res., 2013,<br>
	52(50): 17891-1789 1, 2213007 (10 of 10)<br>
	427-449.<br>
	Tao Z H, He W, Wang S X, Zhou G Y. Electrochemical<br>
	study of cyproconazole as a novel corrosion inhibitor for<br>
	copper in acidic solution[J]. Ind. Eng. Chem. Res., 2013,<br>
	52(50): 17891-1789

# PCB 酸性蚀刻液中缓蚀剂对厚铜线路制作的影响

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摘要: 以 2- 巯基苯并噻唑(2-MBT)、苯并三氮唑(BTA)和苯氧基乙醇(MSDS)作为缓蚀剂, 研究了其加入在酸性 蚀刻液后对 PCB 厚铜线路的缓蚀效果。通过接触角测试、电化学测试和蚀刻因子得出缓蚀状态,并结合扫描电子 显微镜观察铜表面形貌。通过分子动力学计算和量子化学模拟分析缓蚀剂在铜表面的吸附机理。结果表明, 1. Adhes. Sci. Technol., 2018, 32(19): 2083-2098.<br>
20staba JM, Fram E, Form E, Form E, Form E, Form E, Form E, The Description of Some corresion inhibition by tripleny<br>Instruction of the section of some corresion inhibit Bastidas J.M, Pinilla P, Cano E, Polo J.L, Miguel S. Cop-<br>
nr assessment to evaluate the validity of different meth-<br>
ods for the description of some corresion inhibitors[J]. J.<br>
m sulphuric acid media[I]. Corresion Sci. PCB 厚铜线路制作。

关键词: 缓蚀剂; 协同作用; 厚铜线路; 酸性蚀刻液