

Study on corrosion resistance of 06Cr19Ni10 austenitic antibacterial stainless steel of copper indium molybdenum alloy layer

Cheng Gao¹, Dong Chen², Yin Wang³, Bo Gao^{4*}

Guilin University of Electronic Technology

Guilin 541004, China

E-mail: 116710709@qq.com

Keyword: Austenitic stainless steel; Corrosion resistance; Alloy infiltration layer

Abstract. The corrosion resistance of copper indium-molybdenum alloy layer was briefly introduced. In the acidic solution (0.5mol/L sulfuric acid solution), alkaline solution (0.5mol/L sodium hydroxide solution) and neutral solution (3.5% sodium chloride solution) in the stainless steel substrate and infiltration of copper indium molybdenum alloy layer of the type of electrochemical corrosion test, and the corrosion of the reasons for the analysis. The results show that: In an acidic solution, the corrosion rate of copper indium molybdenum is much higher than that of matrix; In the alkaline solution, the sample with copper indium molybdenum has better corrosion resistance; In the neutral salt solution, the corrosion resistant properties of copper indium molybdenum are lower than the corrosion resistance of the matrix.

Introduction

Austenitic stainless steel is the stainless steel with austenitic tissue at normal temperature, it has the properties of non-magnetic, high toughness and high plasticity[1]. Due to the medical and health care, electrical appliances, and industrial manufacturing, and other fields has a huge demand on stainless steel, so its work environment is complex, often will encounter acid, alkali, salt and other corrosive medium. In this condition, stainless steel is prone to Electrochemical corrosion. By the double glow ion permeability metal technology[2] in 06Cr19Ni10 austenitic stainless steel surface of copper indium - molybdenum altogether infiltration, to sample and matrix in the corrosion of acid, alkali, salt solution environment situation analysis. through the polarization curve method[3] discriminant permeability molybdenum copper indium with the original base material of stainless steel corrosion resistance of high and low, and the corrosion mechanism is analyzed.

Copper-indium-molybdenum alloy layer corrosion resistance experiment detection method

Electrochemical corrosion tests were carried out on stainless steel and substrate containing copper indium molybdenum alloy in acid solution (0.5mol/L sulfuric acid solution), alkaline solution (0.5mol/L sodium hydroxide solution) and neutral solution (3.5% sodium chloride solution). The test equipment is a PS-268A electrochemical corrosion instrument (shown in Fig. 1). Corrosion test device diagram shown in Fig. 2.



Fig.1 PS-268A electrochemistry corrosion instrument

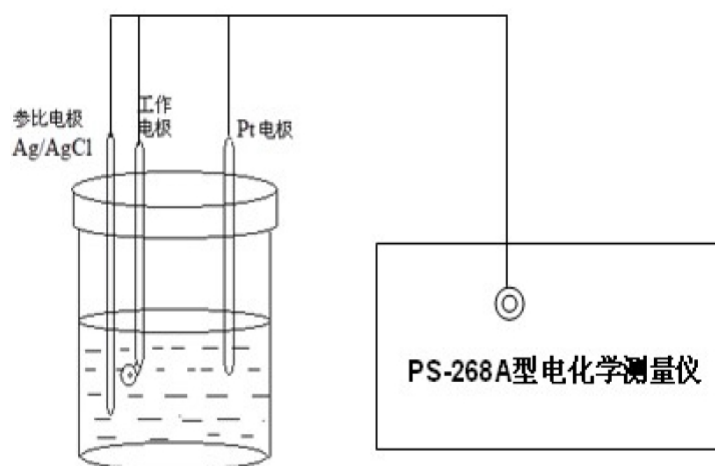


Fig.2 Schematic drawing of corrosion test

The polarization curve obtained by PS-268A electrochemical measuring instrument was analyzed by Tafel linear extrapolation method[1]. The corrosion polarization curve was linearly fitted and the corrosion current density i_{corr} was obtained. According to Faraday's law:

$$v = 3.73 \times 10^{-4} M i_{corr} / n . \quad (1.1)$$

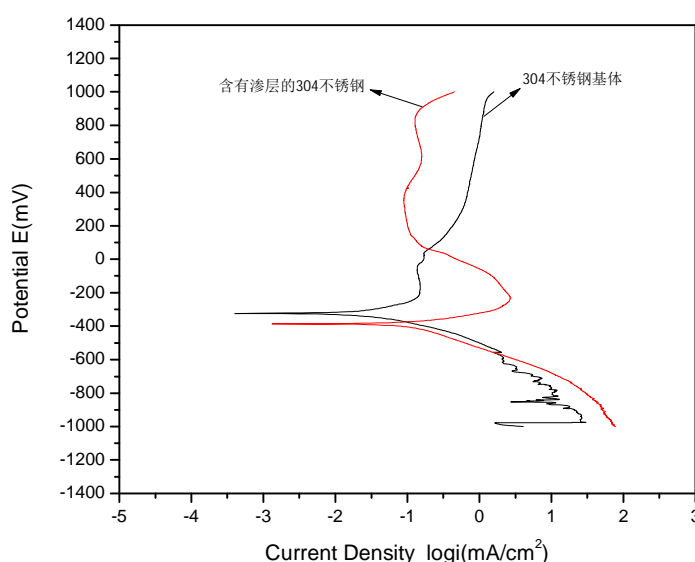
Where v is the corrosion rate (unit: $\text{g}/\text{m}^2 \cdot \text{h}$), M is the atomic weight of the metal, n is the metal atom, and i_{corr} is the self-etching current density.

In this experiment, the polarization curves of the cathode and anode were obtained by electrochemical test. Then, the parameters under different corrosive liquids were obtained according to the polarization curve, according to the corrosion rate obtained by the above formula. According to the obtained corrosion rate The corrosion resistance of the stainless steel after the change is judged.

Corrosion resistance of samples in 0.5mol/L H₂SO₄ solutionTable 1 Electrochemical corrosion results of samples in H₂SO₄ solution

sample	free corrosion potential E_k /mV	maintaining passivity current density i_p /(mA·cm ⁻²)	Critical passive current density i_b /(mA·cm ⁻²)	self-corrosion current density I_{corr} /(mA·cm ⁻²)	corrosion rate v /(g·m ⁻² ·h ⁻¹)
Matrix	-324	0.118960	0.000400	0.027266	0.000183
Samples after infiltration	-386	0.125199	0.001320	0.096728	0.000627

The polarization curves of the matrix sample and the doped copper-indium-molybdenum sample in 0.5mol/L H₂SO₄ solution are shown in Fig. 3, The free corrosion potentials E_k , self-corrosion current density I_{corr} , dimensional current density i_p and critical passive current density i_b were obtained by Tafel linear extrapolation method[3]. The electrochemical test results are shown in Table 1.

Fig.3 Polarization curves of samples in 0.5mol/L H₂SO₄ solution

In general, corrosion potential can be used as a standard to judge the corrosion resistance of metal materials in the medium. The higher the free corrosion potential of materials, the better the corrosion resistance of materials in this medium[4]. critical current is often used as a criterion for determining whether the material is susceptible to passivation. The smaller the critical current density is, the material is susceptible to passivation. After metal passivation, a layer of oxide film is often formed. The existence of this oxide film is beneficial to the corrosion of metal resistance medium, The passivation current is the parameter that characterizes the stability of the oxide film. The greater the passivation current density, the more stable the oxide film, the passivation current is the parameter that characterizes the stability of the oxide film[5], the greater the maintaining passivity current density, the more stable the oxide film. It can be seen from table 1 that the self-corrosion potential of the samples of the matrix and after the double-glow plasma percolation

copper-indium-molybdenum is -324mv and -384mv respectively. The corrosion resistance of the infiltrated sample in dilute sulfuric acid solution decreased slightly. According to Fig. 3, the current density of the matrix sample decreases with the increase of the potential in the cathode polarization stage, and enters the anodic polarization phase when the potential rises to -324mV. After the Stainless steel surface infiltration copper indium molybdenum, the free corrosion potential is reduced to -384mV, critical current density in the state of the passivation by $0.000400\text{mA}\cdot\text{cm}^{-2}$ to $0.001320\text{mA}\cdot\text{cm}^{-2}$, entered the stage of passivation later than base material, but both are from the activation phase through the passivation stage to the final stable passivation stage.

From table 1, it can be seen that the corrosion rate of the stainless steel matrix after the infiltration copper indium molybdenum is changed from $0.000183\text{v}/(\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1})$ to $0.000627\text{v}/(\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1})$, which indicates that the corrosion resistance of the sample in 0.5mol/L H₂SO₄ solution is slightly lower than that of the stainless steel substrate.

Study on Corrosion Resistance of Sample in 0.5mol/L NaOH Solution

Table 2 Electrochemical corrosion results of samples in NaOH solution

sample	free corrosion potential E_k/mV	maintaining passivity current density $i_p/(\text{mA}\cdot\text{cm}^{-2})$	Critical passive current density $i_b/(\text{mA}\cdot\text{cm}^{-2})$	self-corrosion current density $I_{\text{corr}}/(\text{mA}\cdot\text{cm}^{-2})$	corrosion rate $\text{v}/(\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1})$
Matrix	-503	0.316002	0.028000	0.016444	0.000107
Samples after infiltration	-487	0.320000	0.027800	0.001199	0.000008

It can be seen from Table 2 and Fig. 4 that during the cathodic polarization phase, the current density of the matrix material decreases with the increase of the potential, and after the potential reaches the corrosion potential of -503mV, the polarization curve begins to enter the anodic polarization stage. The current density increases with the potential increase, increased to $0.028000\text{mA}\cdot\text{cm}^{-2}$, the curve began to passivation phenomenon, the current density reached $0.316002\text{mA}\cdot\text{cm}^{-2}$, into the stable passivation stage, but the passivation interval is small, passivation interval of about 118mV.

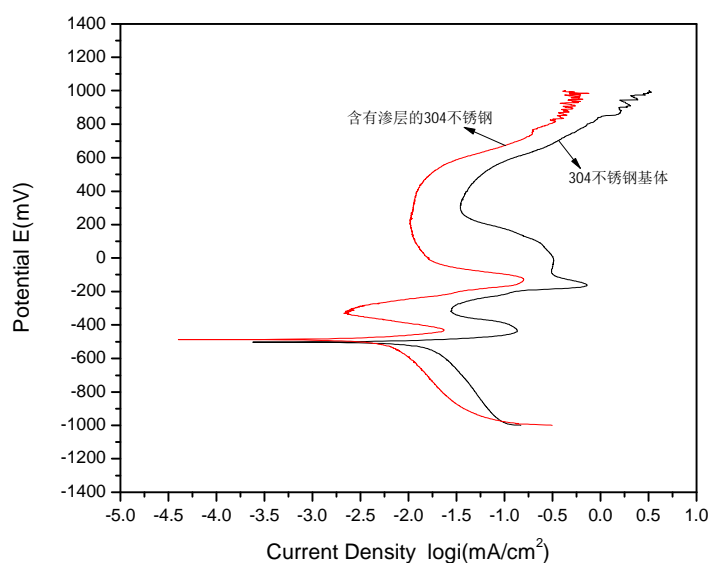


Fig. 4 Polarization curves of samples in 0.5mol/L NaOH solution

It can be seen from Table 2 that the self-corrosion potential of the copper-indium-molybdenum sample is slightly higher than that of the base material, and both the blunt current density and the dummy current density are close to each other, the corrosion rate is only the base material 0.07 times, and the passivation interval is larger than the matrix material. This indicates that the corrosion rate of the sample in the NaOH solution is not much lower than that of the matrix material, and the corrosion rate is much lower than that of the matrix material. The corrosion resistance in NaOH solution is slightly improved. The reason may be that the activity of metal elements in NaOH solution is reduced, indium and molybdenum itself has a certain corrosion resistance, so that its corrosion resistance has been enhanced.

Study on Corrosion Resistance of Specimens in 3.5% NaCl Solution

Table 3 Electrochemical corrosion results of samples in NaCl solution

sample	free corrosion potential E_k /mV	maintaining passivity current density i_p / (mA·cm ⁻²)	Critical passive current density i_b / (mA·cm ⁻²)	self-corrosion current density I_{corr} / (mA·cm ⁻²)	corrosion rate v / (g·m ⁻² ·h ⁻¹)
Matrix	-285	-	-	0.002347	0.000015
Samples after infiltration	-449	1.309604	0.012080	0.004240	0.000029

The polarization curves of the samples in the 3.5% NaCl solution are shown in Fig. 5, and the corrosion parameters are shown in Table 3.

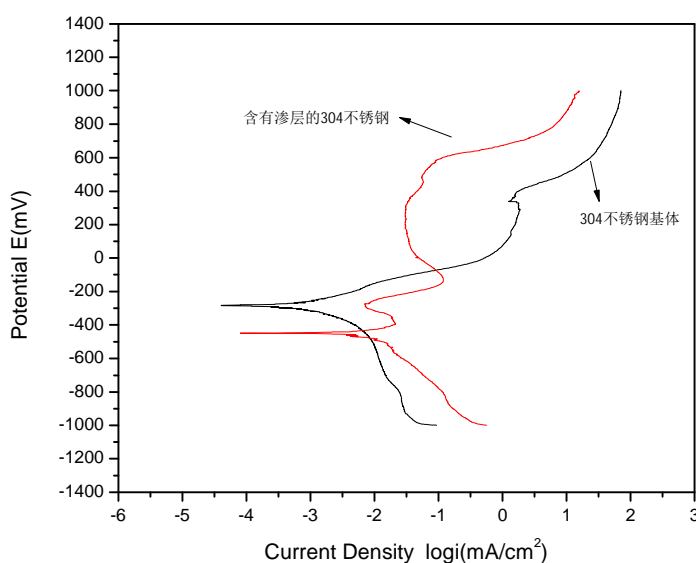


Fig. 5 Polarization curves of samples in 3.5% NaCl solution

It can be seen from table 3 that the self-corrosion potential of the matrix and post-osmotic sample is -285mv and -449mv respectively. From the thermodynamic analysis, the self-corrosion potential of the sample after infiltration is obviously decreased. Therefore, the corrosion resistance of the sample after infiltration in NaCl solution is reduced. It is shown in Fig. 5 that during the cathodic polarization process, the current density of the matrix decreases with the increase of the potential, and the potential rises to -285mV and enters the anodic polarization phase. In the anodic polarization phase, the current density increases with increasing potential and no passivation occurs.

Stainless steel surface infiltration copper indium molybdenum, the corrosion potential drop to -449mv, current density of $0.012080\text{mA}\cdot\text{cm}^{-2}$ after the curve began to appear passivation phenomenon, current density of $1.309604\text{mA}\cdot\text{cm}^{-2}$, entered a stage of stable passivation and the passivation range is about 201mv. The self-corrosion potential of the sample after infiltration is lower than that of the substrate material, but its corrosion speed is only 1.9 times that of the substrate material. The reason may be that, in general, the chloride ion radius is lesser, strong penetrating power, according to the point defect model[6], when chloride ions instead of the oxide film on the oxygen ions after fill anionic vacancy, cause charge imbalance, in order to maintain a neutral state, it is bound to produce a cationic vacancy, as a result, it caused the imbalance of the charge, eventually led to the passivation membrane dissolved gradually, lose protection on the surface, and indium easily formed a dense layer of the surface oxide film, and the formation of molybdenum carbides in the surface, make the surface space the passivation film oxygen vacancy has been reduced, weakened the Cl^- adsorption on the surface of metal, thereby reducing the influence of Cl^- on metal elements, reduce the risk of the soluble chloride formed, reduces the speed of the passivation membrane dissolved.

Conclusion

After performing the above analyses, the following conclusions can be summarized:

(1) In the acidic solution, the corrosion resistance of the copper indium molybdenum sample is lower than that of the matrix, and the corrosion rate is about 3.4 times of that of the matrix.

(2) In the alkaline solution, the copper indium molybdenum sample has better corrosion resistance than the matrix, and its passivation interval is larger than the matrix material.

(3) In the neutral solution, the self-corrosion potential of the sample after infiltration is lower than that of the matrix material, but the corrosion rate is 1.9 times that of the matrix.

References

- [1] Jinyang Zheng, Yaxian Li, Ping Xu, Li Ma, Cunjian Miao, et al. Influence factors of mechanical property for strain strengthening austenitic stainless steel[J], Journal of PLA University of Science and Technology (Natural Science Edition), 2011, 12(5): 513-519.
- [2] Yuan Gao, Zhong Xu, et al. Effect and Application of Double Glow Discharge Surface Alloying Process[J], China Surface Engineering, 2006, 19(4): 1-7.
- [3] Ying Zhou, Xiaolu, Ma Shun Gao, et al. Determination of Corrosion Rate of Magnesium Electrode by Tafel Extrapolation[J], Science and Technology, 2016, 5: 88.
- [4] Weijie Xie, Di Li, Yanling Hu, et al. Prediction of Corrosion Damage of LY12CZ Aluminum Alloy by Self - etching Potential[J], JOURNAL OF CHINESE SOCIETY FOR CORROSION AND PROTECTION, 1999, 19(2): 95-99.
- [5] R. Winston. Rivi. Yulige Corrosion Manual (original version 2) (fine) [M]. Chemical Industry Press, 2005.
- [6] Zuojia Liu, Xuequn Cheng, Xiaogang Li, et al. Application of Point Defect Model in 2205 Duplex Stainless Steel[J], JOURNAL OF CHINESE SOCIETY FOR CORROSION AND PROTECTION, 2013, 4(2): 90-96.