铝合金表面锆盐转化膜的制备及其性能

王春霞[a]，杨晓燕[b]
（南昌航空大学 a. 材料科学与工程学院；b. 环境与化学工程学院，江西 南昌 330063）

[摘 要] 为提高铝合金涂膜的结合力及耐蚀性，在铝合金表面制备了锆盐转化膜。通过盐雾试验、电化学试验、膜微观结构与涂膜结合力测试，研究了锆盐转化膜的耐蚀性与漆膜的结合力，并与通用的铬酸盐转化膜和无铬转化膜进行对比。结果表明：锆盐转化膜120 h盐雾试验的耐蚀等级达8级，在3.5%NaCl溶液中铝合金的自腐蚀电位明显正移，腐蚀电流密度大大降低；转化膜层均匀多孔，含有Al，O，Zr和Mg元素，且与漆膜结合力良好。

[关键词] 锆盐转化膜；铝合金；盐雾试验；电化学试验；涂膜；结合力
[中图分类号] TG174.45 [文献标识码] A [文章编号] 1001－1560(2010)02－0036－02

0 前 言

铝合金化学性质十分活泼，在碱性与酸性条件下容易发生腐蚀，必须经化学转化、阳极氧化、微弧氧化、化学镀和电镀等表面处理后，才能满足工业生产需求。在众多的处理方法中，化学转化处理因工艺简单，设备投资少，运行成本低而备受青睐。目前，铝合金表面化学转化膜有铬酸盐和无铬转化膜2大类。铬酸盐钝化膜虽然耐蚀性好，但因六价铬的强毒性及对环境的严重破坏，其应用越来越受到限制。近年来，铝合金表面无铬转化膜的研究与应用，已取得了一定的进展[1～6]。本工作就铝合金涂装前无铬锆盐转化膜的制备与相关性能进行了研究。

1 试 验

1.1 基材及处理

试样基材为LF1防锈铝合金，成分见表1，尺寸为70 mm×25 mm×1 mm。

表1 LF1防锈铝合金的化学成分 %

元素	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
w	0.40	0.40	0.10	0.40～1.00	4.00～4.90	0.25	0.15	0.05～0.25	余量

前处理：打磨（320号水砂纸打磨除去表面Al_2O_3膜）→碱性除油（50 g/L NaOH，20 g/L Na_3PO_4，20 g/L Na_2CO_3，1 g/L 十二烷基硫酸钠，50～60 ℃，时间3～5 min）→热水洗→冷水洗→碱蚀（70 g/L NaOH，30 g/L Na_2CO_3，65～75 ℃，时间1～3 min）→水洗→出光（300 mL/L HNO_3，100 mL/L HF，室温，时间3～5 s）→水洗→化学转化处理（pH值4.0～4.5，30～40 ℃，时间5～10 min）→水洗→性能测试。

1.2 转化膜层的制备

以氟锆酸钾为基本成膜剂，再选取氧化剂、辅助成膜物质、缓蚀剂、成膜促进剂、pH缓冲剂、铝离子配位剂（稳定剂）、润湿剂等研制工艺配方。为了更好地体现优化后的锆盐转化膜性能，与铬酸盐转化膜、国外无铬转化膜（NCP）进行了比较。3种化学转化工艺见表2。

表2 铬酸盐、NCP和锆盐3种化学转化工艺

配方	组分	条件
铬酸盐（上海某公司提供）	6.5 g/L Na_2CrO_7，5.0 g/L $K_3Fe(CN)_6$，1.0 g/L NaF，2.5 g/L KBF_4，添加剂适量	pH值1.2～1.8，室温，时间3～5 min
国外无铬（NCP）	NCP浓缩液5%	pH值4.0～4.5，24～49 ℃，时间3～10 min
锆盐转化液	0.8 g/L K_2ZrF_6，10 mL/L H_2O_2，0.5 g/L $MgSO_4$，0.2 mL/L H_3PO_4，0.9 g/L单宁酸	pH值4.0～4.5，30～40 ℃，5～10 min

1.3 性能检测

(1)采用标准ASTM B117－03进行盐雾试验，并根据标准GB 6461－86评定耐蚀性等级。

(2)采用电化学工作站CHI660c测试塔菲尔极化曲线，工作电极面积为10 mm×10 mm，辅助电极为铂电极，参比电极为饱和甘汞电极（SCE），介质为3.5%NaCl溶液，室温，动扫描速率为0.1 mV/s。测试结果

[收稿日期] 2009－10－09
[基金项目] 江西省科技厅火炬示范工程项目（CB200702202）
[通信作者] 杨晓燕，电话：0791－3953375，13870851117，E-mail：yxy501@sohu.com

利用相应的计算机软件，求出自腐蚀电位 E_{corr}、自腐蚀电流密度 J_{corr}。

(3)采用标准 GB 9286－88 划格法进行结合力检测。

(4)采用 Quanta2000 型号电子扫描显微镜(SEM)观察转化膜外貌特征，利用俄歇能谱议(EDS)检测转化膜成分。

2 结果与讨论

2.1 3 种转化膜耐盐雾性能

3 种转化膜及 LF1 防锈铝合金盐雾试验结果见表 3。

表 3 3 种转化膜和 LF1 铝合金盐雾腐蚀试验结果 级

t(盐雾)/h	锆盐	铬酸盐	NCP	LF1 防锈铝合金
48	10	10	10	3(大量点蚀)
72	10	10	10	1
96	9	10	10	0
120	8	10	10	0
144	6	10	10	0
168	5	10	9	0

注：等级值越小，表示质量越差，10 级表示无缺陷。

耐盐雾腐蚀试验结果显示：铬酸盐转化膜耐蚀性最好，NCP 与锆盐其次，LF1 防锈铝合金试样最差。锆盐转化膜经 120 h 盐雾腐蚀，表面无明显点蚀，仅有极少量污斑，评定为 8 级，与铬酸盐和 NCP 转化膜的耐蚀性差距不大。

2.2 极化性能

3 种转化膜和 LF1 防锈铝合金在质量分数 3.5% 的 NaCl 溶液中的极化曲线见图 1。采用计算机软件计算的自腐蚀电位 E_{corr}和自腐蚀电流密度 J_{corr}见表 4。

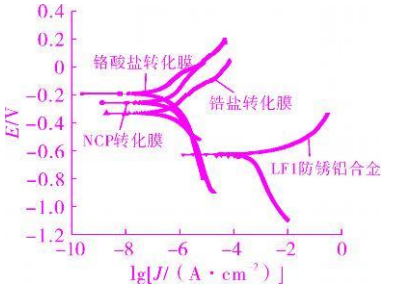


图 1 4 种试样在 3.5 %NaCl 溶液中的极化曲线

表 4 4 种试样在 3.5%NaCl 溶液中的 E_{corr}和 J_{corr}

试样	E_{corr}/V	J_{corr}/(μA·cm^{-2})
LF1 防锈铝合金	−0.630	5.47
锆盐转化膜	−0.324	0.64
NCP 转化膜	−0.254	0.34
铬酸盐转化膜	−0.207	0.08

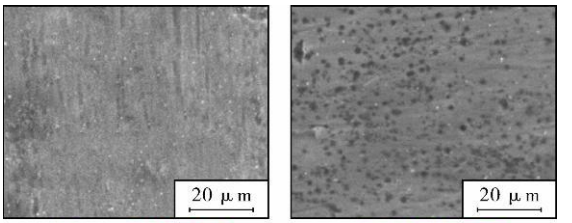
由图 1 和表 4 可知，3 种转化膜的自腐蚀电流密度明显低于 LF1 防锈铝合金，且自腐蚀电位也明显正移。由此说明：经过处理的试样在 3.5%NaCl 溶液中具有较好的耐蚀性，其中锆盐转化膜的耐蚀性较铬酸和 NCP 转化膜的差，这与盐雾试验结果一致。若投入生产需进一步提高该转化膜的耐蚀性。

2.3 涂装结合力

铝合金试样表面喷涂氨基漆，130 ℃下烘烤 1 h 后，采用 GB 9286－88 法划格，格间距 1.5 mm，纵、横线各 8 条，用强力胶布粘贴后用力揭起，重复 3 ~5 次，观察方格内膜层的脱落情况。结合力评定结果显示：LF1 防锈铝合金、铬酸盐、锆盐、NCP 膜的结合等级分别为 3，0，0，1 级(注：0 级最好，5 级最差)。由此可知，LF1 防锈铝合金上的漆膜部分脱落，结合力较差。NCP 转化膜涂层也有少量脱落，而铬酸盐转化膜和锆盐转化膜涂层均无脱落，结合力较好，符合一般生产质量要求。

2.4 转化膜微观组织及成分

LF1 防锈铝合金和锆盐转化膜微观形貌见图 2。



(a) LF1防锈铝合金　(b) 锆盐转化膜

图 2 LF1 防锈铝合金及其锆盐转化膜微观形貌

由图 2 可知：LF1 铝合金表面自然氧化膜比较致密，膜孔较少，故自然氧化膜与漆膜结合力较差；锆盐转化膜表面均匀分布的许多膜孔，大大增强了与漆膜的结合力，因而提高了耐蚀性能。

锆盐转化膜元素含量见表 5。

表 5 锆盐转化膜元素含量

元素	w/%	A/%
O	7.34	11.79
Al	89.38	85.04
Zr	2.83	2.76
Mg	0.45	0.41

由表 5 可知，锆盐转化膜中含量最多的是 Al，其次是 O，还含有少量 Zr 和 Mg，这说明K_2ZrF_6和 $MgSO_4$参与了成膜。

(下转第 69 页)

3 结 论

(1)采用聚合物溶胶-凝胶法在抛光的钛基体上制备 IrO_2-Ta_2O_5 氧化物涂层,得到了涂层厚度和组分分布均匀的氧化物阳极标样。

(2)XRF 测量中发射法比吸收法灵敏度高,偏差小。

(3)XRF 的测量结果与 SEM 的相近,偏差小,可靠度高。

[参 考 文 献]

[1] Krysa J, Kule L, Mraz R, et al. Effect of coating thickness and surface treatment of titanium on the properties of IrO_2-Ta_2O_5 anodes[J]. Journal of Applied Electrochemistry, 1996, 26(10): 999 ~1 005.

[2] Elam J W, Baker D A, Martinson A B F. Atomic layer deposition of indium tin oxide thin films using nonhalogenated precursors[J]. Journal of Physical Chemistry C, 2008, 112(6): 1 938 ~1 945.

[3] Mitsuhiro I, Hiroshi S, Tomohito K, et al. Preparation and physical and electrochemical properties of carbon-supported Pt-Ru (Pt-Ru/C) samples using the polygonal barrel-sputtering method[J]. Journal of Physical Chemistry C, 2008, 112(5): 1 479 ~1 492.

[4] 罗立强. X 射线光谱分析的现状与趋势[J]. 光谱学与光谱分析, 2006, 26(1): 189 ~191.

[5] 吉 昂, 卓尚军. X 射线荧光光谱分析[J]. 分析试验室, 2001, 20(4): 103 ~108.

[6] 胡吉明, 吴继勋, 孟惠民, 等. Ti 基 IrO_2 + Ta_2O_5 涂层中氧化物附着量的 XRF 分析[J]. 材料保护, 2000, 33(4): 43 ~44.

[7] Masatsugu M, Ryuichi O, Morio M. Effects of cathodizing on the morphology and composition of IrO_2-Ta_2O_5/Ti anodes[J]. Electrochimica Acta, 2000, 46: 402 ~403.

[8] Xu L K, Xin Y L, Wang J T. A comparative study on IrO_2-Ta_2O_5 coated titanium electrodes prepared with different methods[J]. Electrochimica Acta, 2009, 54: 1 820 ~1 825.

[9] 初立英, 许立坤, 吴连波, 等. 草酸浸蚀对氧化物阳极形貌及电催化性能的影响[J]. 金属学报, 2005, 41(7): 763 ~768.

[10] HG/T 2471 - 2001, 电解槽金属阳极涂层隔膜法金属阳极电解槽[S].

[11] 陶光仪, 吉 昌, 卓尚军. 计算多层膜组分和厚度的软件 FPMULTI 及其应用[J]. 光谱学与光谱分析, 1999, 19(2): 215 ~218.

[12] 韩小元, 卓尚军, 王佩玲. X 射线荧光光谱法表征薄膜进展[J]. 光谱学与光谱分析, 2006, 26(1): 159 ~165.

[13] Eric M, Didier D. Surface modification of titanium substrates for the preparation of noble metal coated anodes[J]. Electrochimica Acta, 2000, 46: 629 ~636.

[14] De Boer D K G, Borstrok J J, Leenaers A J G, et al. X-ray spectrometry[J]. Analytical Chemistry, 1993, 22: 33 ~38.

[编辑: 郑 霞]

(上接第 37 页)

3 结 论

锆盐转化膜使 LF1 防锈铝合金在 3.5%NaCl 溶液中自腐蚀电位明显正移,腐蚀电流密度大大降低,可通过 120 h 盐雾试验,耐蚀等级为 8 级;与漆膜的结合力达 1 级以上。

锆盐转化膜层均匀,且孔数量较多,增强了与漆膜的结合力,提高了膜层的耐蚀性,转化膜中含量最多的是 Al,其次是 O,Zr,Mg。

[参 考 文 献]

[1] Smit M A, Hunter J A, Shamman J D B, et al. Effect of organic additives on the performance of titanium-based conversion coatings[J]. Corrosion Science, 2003, 45(9): 1 903 ~1 920.

[2] Nordlien J H, Walmsley J C, Sterberg H, et al. Formation of a zirconium-titanium based conversion layer on AA6060 aluminium[J]. Surface and Coatings Technology, 2002, 153(1): 73 ~78.

[3] Hinton B R W, Arnott D R, Ryan N E. Cerium conversion coatings for the corrosion protection of aluminum[J]. Mater Forum, 1986, 9(3): 162 ~173.

[4] Bethencourt M, Botana F J, Cano M J, et al. Advanced generation of green conversion coatings for aluminium alloys[J]. Applied Surface Science, 2004, 238(1 ~4): 278 ~281.

[5] 陈 溯, 陈晓帆, 刘传烨, 等. 铝合金表面稀土转化膜工艺研究[J]. 材料保护, 2003, 36(8): 33 ~36.

[6] 邹洪庆. 铸铝合金锆系非铬化学成膜处理工艺应用[J]. 材料保护, 2001, 34(2): 29 ~30.

[编辑: 段金弟]

prepared under air, argon and nitrogen gas were examined, and the bio-compatibility of the modified surface prepared under nitrogen gas was evaluated. Results show that the surface modification leads to a noticeable increase of hardness of the Ti alloy, due to the formation of modified layers consisting of TiC and graphite. The modified surface showed significantly increased wear resistance than Ti alloy substrate and retained excellent corrosion resistance. At the same time, the modified surface prepared under argon or nitrogen gas had less surface cracks than the one obtained in air. In particular, the modified surface prepared under the protection of nitrogen gas had excellent wear resistance and good bio-compatibility as well as strong metallurgical bonding with the Ti alloy substrate.

Key words: surface modification; biomedical materials; titanium alloy; transient electric energy; protective atmosphere; friction wear; corrosion resistance; bio-compatibility

Preparation and Inhibitive Performance of Extracted Fluid of Bamboo Leaves

ZHENG Xing-wen[a], GONG Min[b], ZOU Zhen[b], WEI Wei[b], HUANG Wen-heng[b] (a. Department of Chemistry, b. Department of Material and Chemical Engineering, Sichuan Institute of Technology, Zigong 643000, China). *Cailiao Baohu* 2010,43(02), 21~23(Ch). Bamboo leaves were soaked in 15% (mass fraction) H_2SO_4, and the resulting extracted fluid was formulated as inhibitive solution for Q235 carbon steel. The effects of the soaking time and concentration of extracted fluid of bamboo leaves on the corrosion behavior of Q235 steel in sulfuric acid were investigated by using electrochemical test, weight-loss test and immersion corrosion test. Results show that the inhibitive solution with a concentration of 0.1 g/mL, diluted from the extracted fluid of a certain amount of bamboo leaves soaked in 15% H_2SO_4 for 306 min, has good inhibitive behavior for the carbon steel in H_2SO_4. The inhibitive solution formulated from the extracted fluid of bamboo leaves had an inhibitive efficiency of above 96% for Q235 steel in H_2SO_4. As a kind of anodic-type inhibitive agents, it functioned through geometrical covering, and its inhibitive efficiency increased with increased concentration. Besides, the adsorption of the extracted fluid of bamboo leaves on the surface of carbon steel immersed in sulfuric acid followed El-Awady dynamic model and Flory-Huggins adsorption isotherm equation.

Key words: inhibitor; extracted fluid of bamboo leaves; H_2SO_4; Q235 steel; inhibitive performance; adsorption dynamics

Preparation and Corrosion Resistance of Zr-Al-Ni-Cu Bulk Metallic Glass

WANG Yan-Fang[1], ZHANG Xu[1], LI Li[1], SHI Zhi-qiang[1], WU Tong-xia[2] (1. Department of Materials Science and Engineering, China University of Petroleum at Dongying, Dongying 257061, China; 2. Shandong Shida Shenghua Chemical Company Ltd., Dongying 257061, China). *Cailiao Baohu* 2010,43(02),24~25(Ch). $Zr_{55}Al_{10}Ni_5Cu_{30}$ bulk metallic glass was prepared by using copper mold suction technique. The structure and thermal stability of the bulk metallic glass was investigated by means of X-ray diffraction and differential scanning calorimetry plus differential thermal analysis, and its corrosion resistance was evaluated by conducting electrochemical corrosion test and salt spray corrosion test. Results show that the as-prepared $Zr_{55}Al_{10}Ni_5Cu_{30}$ alloys exhibit amorphous structure and high glass forming ability, and have good thermal stability and excellent corrosion resistance. They had a corrosion potential of −500 mV and a corrosion current density of only 12.6 nA · cm^{-2}, and showed no weight loss after being sprayed in 3.5% NaCl for 144 h.

Key words: corrosion resistance; bulk metallic glass; $Zr_{55}Al_{10}Ni_5Cu_{30}$; copper mold suction; thermodynamic characteristics

Effect of HCO_3^- on Corrosion Behavior of J55 Steel

ZHANG Jun, ZHAO Wen-zhen, LAI Wei-ya (Department of Materials Physics and Chemistry, Xi'an Jiaotong University, Xi'an 710049, China). *Cailiao Baohu* 2010,43(02),26~28(Ch). The effect of the concentration of HCO_3^- on corrosion behavior of J55 steel was studied by using a potentiodynamic polarization curve measurement system and a scanning electron microscope, where J55 steel was tested in aqueous solution of $NaHCO_3$ with varied concentrations. Results show that under the present experimental conditions, HCO_3^- accelerates corrosion of the steel at a concentration below 0.06 mol/L, and it inhibits corrosion of the steel at a concentration above 0.06 mol/L. With the increase of concentration of HCO_3^-, both the secondary passivation rate and range were increased, the passivation current was reduced, and the rupture potential was reduced in a range of 1.00~1.15 V. At the same time, the cathodic reaction rate increased with increasing concentration of HCO_3^-, and an abrupt change of polarization current occurred when polarization potential was about −0.9 V. The main cathodic reaction for J55 steel in aqueous solution of $NaHCO_3$ could be expressed as: $O_2 + 4HCO_3^- + 4e \rightarrow 4CO_3^{2-} + 2H_2O$. The cathodic reaction $O_2 + 2H_2O + 4e \rightarrow 4OH^-$ only might appear at a polarization potential above −0.9 V.

Key words: corrosion behavior; J55 steel; HCO_3^-; electrochemical test

Effect of Three Kinds of Major Salts on Properties of Electroless Ni-P Coating on AZ31 Magnesium Alloy

YUAN Liang, MA Li-qun, YANG Meng, HE Zhong-chen, DING Yi (College of Materials Science and Engineering, Nanjing Polytechnical University, Nanjing 210009, China). *Cailiao Baohu* 2010,43(02),29~32(Ch). Electroless Ni-P alloy coatings were prepared on the surface of AZ31 magnesium alloy from the baths containing three different types of major salts including nickel sulfate hexahydrate, nickel carbonate basic tetrahydrate and nickel acetate tetrahydrate. The morphology, phosphorus content and phase composition of the coatings were studied by means of scanning electron microscopy, energy dispersive spectrometry and X-ray diffraction. The corrosion resistance of the coatings was evaluated by measuring both electrokinetic polarization curves and alternating current impedance spectra in aqueous solution of 3.5% NaCl. Results show that the Ni-P coatings obtained from the baths containing three kinds of major salts are all high-P coatings with a P content of more than 10 wt%, and have different micro-morphologies. The Ni-P coating prepared from the bath containing $Ni(CH_3COO)_2 \cdot 4H_2O$ had micro-cracks, and those prepared from the baths containing $NiSO_4 \cdot 6H_2O$ and $NiCO_3 \cdot 2Ni(OH)_2 \cdot 4H_2O$ were smooth and compact. The former coating contained a small amount of nano-sized crystals, and the latter two coatings were amorphous. Besides, the Ni-P coating obtained in the presence of $Ni(CH_3COO)_2 \cdot 4H_2O$ as the major salt had the poorest corrosion resistance, while that obtained in the presence of $NiCO_3 \cdot 2Ni(OH)_2 \cdot 4H_2O$ as the major salt showed the best corrosion resistance.

Key words: AZ31 magnesium alloy; $Ni(CH_3COO)_2 \cdot 4H_2O$; $NiSO_4 \cdot 6H_2O$; $NiCO_3 \cdot 2Ni(OH)_2 \cdot 4H_2O$; corrosion resistance

Factors Affecting Adhesion of Electroless Nickel Coating on Titanium Alloy

NING Zheng, ZHAO Qing, CHEN Qing-long, ZHU Wen-hui, WANG Shuai-xing (Key Discipline Laboratory of Light Alloy Processing Science and Technology for National Defense, Nanchang University of Aeronautics, Nanchang 330063, China). *Cailiao Baohu* 2010,43(02),33~35(Ch). Electroless Ni coating was prepared on the surface of Ti alloy TC4. The effects of activation, Ni pre-plating and heat-treatment on the adhesion of the Ni coating to Ti alloy substrate were investigated. Results indicate that the ratio of HF and HCl has significant effect on activation of the surface of Ti alloy. Fresh surface of TC4 was obtained after being activated in mixed acid of 26 mL/L HF + 58 mL/L HCl. The Ni coating prepared after dipping activation and pre-Ni plating had good adhesion to the Ti alloy substrate. The Ni coating heat-treated at 300 ℃ for 1 h had remarkably increased adhesion to the Ti alloy substrate.

Key words: titanium alloy; electroless nickel plating; adhesion

Preparation and Performance of Zirconium Salt Conversion Film on Aluminum Alloy

WANG Chun-xia[a], YANG Xiao-yan[b] (a. School of Material Science and Engineering, b. Institute of Environment and Chemical

Engineering, Nanchang University of Aeronautical Technology, Nanchang 330063, China). *Cailiao Baohu* 2010,43(02),36 ~ 37(Ch). Conversion film of zirconium salt was prepared on the surface of Al alloy so as to improve the corrosion resistance. The corrosion resistance of the conversion film of zirconium salt was evaluated by conducting salt - spray tests and electrochemical tests. The adhesion of the conversion film to lacquer coatings was examined, and its microstructure was observed as well. Moreover, the conversion film of zirconium salt was compared with conventional conversion film of chromates and Cr-free conversion film as well. Results indicate that the corrosion resistance of the zirconium salt on Al alloy is ranked as grade 8 after 120 h of salt-spray tests. It led to obvious positive shift of corrosion potential and significant decrease of corrosion current density of Al alloy in 3.5% NaCl. In one word, the as-prepared conversion film of zirconium salt on Al alloy was uniform and porous. Composed of elements including Al, O, Zr and Mg, it had good adhesion to lacquer coatings.

Key words: zirconium salt conversion film; Al alloy; salt-spray tests; electrochemical tests; coatings; adhesion

Effect of Content of Glucose on Properties of Pre-Plated Electroless Copper Coating on Steel

CAI Jie, ZHANG Ye, YAO Yu-huan(Department of Chemistry & Life Science, Maoming College, Maoming 525000, China). *Cailiao Baohu* 2010,43(02),38 ~ 40(Ch). Orthogonal tests were carried out to select additives suitable for copper pre-plating on iron and steel. The optimized plating parameters were determined, and the effect of content of glucose on the properties of pre-plated Cu coating was investigated. It was found that glucose as a new additive could improve the quality of the pre-plated Cu coating, and it showed the best performance at a dosage of 70 g/L. The established plating process had the advantages of reasonable bath composition, environmental protection and low cost. The resulting Cu coating had good adhesion to substrate and good mechanical properties as well. At a pH value of 1.5 and atmospheric temperature, the established pre-plating process could be used to replace cyanide-based Cu pre-plating for iron and steel, making it feasible to conduct electroless copper pre-plating on steel A3 under acidic condition.

Key words: electroless copper pre-plating; acidic; iron and steel; glucose

Mechanism, Factors and Control Method of Naphthenic Acid-Induced Corrosion of Oil-Refining System

ZHANG Wei(Department of Mechanical and Electrical Engineering, Luoyang Institute of Technology, Luoyang 471023, China). *Cailiao Baohu* 2010,43(02),41 ~ 44(Ch). A review was provided of the research progress about corrosion mechanism and control of oil-refining systems induced by naphthenic acid. It was pointed out that corrosion by naphthenic acid in processing crude oil with high acid value needed to be dealt with urgently. Based on the analysis of corrosion mechanism of naphthenic acid, the major factors affecting corrosion, including the type and distribution of naphthenic acid, operation temperature, fluid velocity and flow pattern as well as pressure, were discussed. The existent problems and development direction of corrosion of oil-refining systems induced by naphthenic acid were also introduced.

Key words: corrosion by naphthenic acid; oil-refining system; factors; control method; development direction

Electrochemical Corrosion and External Current Cathodic Protection of Ships

JIANG Yan-lan, QU Liang-sheng(Naval Institute of Aeronautical Engineering, Yantai 264001, China). *Cailiao Baohu* 2010,43(02),45 ~ 46(Ch). A review was given about the principle of cathodic protection and its application and development in protection of electrochemical corrosion of ships in seawater. The causes leading to electrochemical corrosion of ships were also introduced. Besides, the development trend of the cathodic protection technique was discussed. It was pointed out that the electrochemical corrosion of ships in marine environment seriously impacted the improvement of combat effectiveness of troops. Fortunately, external current cathodic protection could be applied to effectively prevent the electrochemical corrosion of ships, which had been widely used to protect ships in marine environment at home and abroad.

Key words: external current method; cathodic protection; ships; corrosion

Microstructure and Wear Resistance of Laser Remelted Plasma Sprayed Ni-Based Alloy Coating on Copper Alloy

MA Wen-you, CHEN Xing-chi, ZHOU Ke-song, LIU Min, LI Fu-hai(Guangzhou Research Institute of Non-Ferrous Metals, Guangzhou 510651, China). *Cailiao Baohu* 2010,43(02),47 ~ 49(Ch). Self-melted NiCrFeWBC alloy coating was prepared on the surface of Cu alloy by plasma spraying. The plasma sprayed Ni-based alloy coating was then remelted by laser so as to improve the heat conductive behavior, wear resistance and corrosion resistance. The effects of laser remelting on the microstructure and wear resistance of the plasma sprayed Ni-based alloy coating were investigated by using modern analytical techniques. It was found that the layered structure and porosities of plasma sprayed Ni-based alloy coating entirely disappeared after laser remelting, and the dense and homogeneous laser cladding layer was metallurgically bonded with Cu alloy substrate. At the same time, the laser cladding layer appeared as equiaxed crystal, dendritic crystal and cellular crystal from outside to inside, and contained precipitated particles of WC, W_2C and Ni_3B. Moreover, the laser cladding layer which was dominated by abrasive wear showed much better wear resistance than Cu alloy substrate and plasma sprayed Ni-based alloy coating.

Key words: laser cladding; thermal spraying; copper alloy; NiCrFeWBC alloy; wear resistance

Effect of Content of Aminoacetic Acid on Morphologies and Properties of Anodizing Coating on Magnesium Alloy

CHANG Li-min, LIU Dan(Department of Chemistry, Jilin Normal University, Siping 136000, China). *Cailiao Baohu* 2010,43(02),50 ~ 52(Ch). Anodizing coating was prepared on magnesium alloy by electrodeposition with aminoacetic acid as an additive. The surface and cross-section morphologies of the anodizing coating were observed by using a scanning electron microscope and an optical microscope. The corrosion resistance of the anodic oxide coating was evaluated by measurement of polarization curves (Tafel) and electrochemical impedance spectra. Results show that the anodizing coating prepared on Mg alloy in the presence of aminoacetic acid is uniform, smooth and compact. Compared to the anodizing coating obtained in the absence of aminoacetic acid, that obtained in the presence of aminoacetic acid had positively shifted corrosion potential and smaller corrosion current. In particular, the anodizing coating prepared in the presence of 7.5 g/L aminoacetic acid, with a corrosion current of $1.18 \times 10^{-7} A/cm^2$, showed the best corrosion resistance.

Key words: magnesium alloy; anodizing coating; aminoacetic acid; morphologies; properties

Development of a New Apparatus for Dynamic Simulation of Corrosion Induced by Naphthenic Acid

ZHOU Jian-long[1], LI Xiao-gang[1], CHENG Xue-qun[1], HU Yang[1], LIU Xiao-hui[2], ZHENG Jun-he[2], SHAN Guang-bin[2], LIU Wan-li[3](1. School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, China; 2. Qingdao Institute of Safety and Engineering, Sinopec, Qingdao 266071, China; 3. Beijing Kingtech Company Ltd., Beijing 100094, China). *Cailiao Baohu* 2010,43(02),53 ~ 56(Ch). In view of the importance and prevalence of corrosion induced by naphthenic acid (NA) in refinery industry, a new apparatus had been developed for dynamic simulation and monitoring of NA-induced corrosion. The apparatus, made up of cyclic test unit, temperature controlling unit, PLC controlling unit and PC monitoring unit, had the advantages of remote control, safety, fast response and visualization. It could be well performed to investigate the interactive effects among temperature, velocity, erosion angle, material, oil type and inhibitor, facilitating research of NA-induced corrosion behavior of materials at elevated temperatures. In particular, the sample chamber was designed in such a manner that it could well simulate the erosion process of vapor-liquid phases and hence could supply significant references