Removal of copper ions from electroplating rinse water using electrodeionization *

Xiao FENG1, Jun-song GAO1, Zu-cheng WU†‡1,2,3
(1Department of Environmental Engineering, Zhejiang University, Hangzhou 310027, China)
(2State Key Laboratory of Clean Energy Utilization, Zhejiang University, Hangzhou 310027, China)
(3MOE Key Laboratory of Polluted Environment Remediation and Ecological Health, Zhejiang University, Hangzhou 310027, China)
†E-mail: wuzc@zju.edu.cn
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Abstract: An improved configuration of the membrane stack was adopted in the electrodeionization (EDI) cell to prevent precipitation of bivalent metal hydroxide during the running. The operational parameters that influenced the removal of copper ions from the dilute solution were optimized. The result showed that a moderate decrease in the inlet pH value and a moderate increase in the applied voltage could achieve a better removal effect. The steady process of electroplating wastewater treatment could be achieved with a removal efficiency of more than 99.5% and an enrichment factor of 5~14. The concentration of copper in purified water was less than 0.23 mg/L. This demonstrated the applicability of recovering heavy metal ions and purified water from electroplating effluent for industrial reuse.

Key words: Electrodeionization (EDI), Electroplating wastewater, Heavy metal, Precipitation
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INTRODUCTION

Electroplating rinse water is one of the major contributors to heavy metal pollution in surface waters. Treatment and removal of heavy metals have received considerable attention because of their toxicity and association with various health problems (Jüttner et al., 2000; Janssen and Koene, 2002). Copper, well verified in mammals for its role in carcinogenicity, is being widely used in electroplating industries. As only 30%~40% of all metals used in the electroplating process are effectively utilized, the waste effluents are responsible for the supply of heavy metal pollutants to the environment. Therefore, importance should be attached to how to effectively remove metal ions in electroplating wastewater. With this aim in mind, various physicochemical treatment methods have been employed.

Ion exchange has been widely applied for the removal of heavy metal ions from electroplating effluent because it is effective and easy to operate. However, ion exchange resins must be regenerated by additive chemical reagents (acid and alkali) when they are saturated and this causes serious secondary pollution. As an alternative technique, electrodialysis is not economical for treating dilute solution because of its high electrical resistance and the development of concentration polarization phenomena (Korngold et al., 1998).

Electrodeionization (EDI) is a hybrid system combining ion exchange with electrodialysis which is obtained by introducing ion exchange resins into electrodialysis chambers. The combination allows the treatment of very dilute solution (Souilah et al., 2004), and ion exchange resins inside are continuously regenerated electrochemically by hydrogen and hydroxide ions produced by water electrolysis occurring in the two external electrode compartments (Monzie
et al., 2005). Therefore, EDI has been commercially used for the production of deionized water in industries such as microelectronics, power generation and pharmaceuticals.

However, application of the EDI process in the field of wastewater treatment is still at the research stage, and previous EDI stack configurations (Grebencyuk et al., 1998; Koene and Janssen, 2001; Spoor et al., 2002a; 2002b; 2002c; 2002d; Dzyazko and Belyakov, 2004) cannot avoid the precipitation of bivalent metal hydroxide as a result of metal ion reacting with hydroxide ion present in the EDI stack. Consequently, the application of EDI in wastewater treatment has been greatly limited by this drawback.

An improved configuration of the EDI membrane stack that avoids nickel hydroxide precipitation has been previously reported (Chen and Wu, 2005). To further examine the effectiveness of the configuration and optimize operational parameters for testing applicability, we focused on recovering copper ions from electroplating rinse water as well as from purified water for reuse in an EDI operation in the electroplating industry.

MATERIALS AND METHODS

Ion exchange resins and ion exchange membranes

The D001 strongly acid styrene-divinylbenzene cation exchange resin (CER) and D201 strongly alkali styrene-divinylbenzene anion exchange resin (AER) (Hangzhou Resin Co., China), as well as the polyethylene heterogeneous cation exchange membrane (CEM) and polyethylene heterogeneous anion exchange membrane (AEM) (Lin’an Water Treatment Equipment Co., China) were used. Characteristics of the resins and membranes are listed in Table 1.

Prior to use, the membranes were immersed in deionized water for 3 d and the resins were pretreated with the following procedures to remove any contamination:

1. Immersion of CER and AER respectively in to resin volumes of deionized water for 24 h.
2. Immersion of CER in two resin volumes of 1.0 mol/L NaOH solution and AER in two resin volumes of 1.0 mol/L HCl solution for 8 h, respectively, and rinsing in deionized water until the effluents were pH neutral.
3. Immersion of CER in two resin volumes of 1.0 mol/L HCl solution and AER in two resin volumes of 1.0 mol/L NaOH solution for 8 h, respectively, and rinsing in deionized water until the effluents were pH neutral.

Experimental set-up

Fig.1 shows that the experimental set-up consisted of five separate compartments: anode compartment, CER-loaded compartment, concentrate compartment, AER-loaded compartment and cathode compartment. The compartments were separated from one another by four membranes, and the effective area of each membrane was 38.8 cm$^2$. The CER-loaded compartment was separated from the anode compartment and the concentrate compartment by two CEMs, and the AER-loaded compartment was separated from the concentrate compartment and the cathode compartment by two AEMs. The two outer electrode compartments had dimensions of 19.4 cm$\times$2.0 cm$\times$1.4 cm and each contained a Ti substrate RuO$_2$ (Ti/RuO$_2$) net electrode with effective area of 38.8 cm$^2$. The CER-loaded compartment, the concentrate compartment and the AER-loaded compartment had the same dimensions of 19.4 cm$\times$2.0 cm$\times$0.7 cm. One-thousand ml deionized water was circulated through the concentrate compartment and 500 ml of electrode solutions through the anode and cathode compartments, respectively, by using three AP 1200 pumps. Wastewater was fed in turn through the CER-loaded compartment and the AER-loaded compartment. A regulated direct current (DC) power