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〈연구논문〉

THE EFFECT OF PULSE CURRENT ON THE CURRENT EFFICIENCY OF CHROMIUM PLATING IN SRHS BATH

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ABSTRACT

Pulse current was employed to the chromium electroplating bath of self-regulating high speed in the following range of conditions; 10-80°C, 0-400A/dm^2, 10-100KHz. The current efficiency was compared with that of a conventional direct current plating in respect of current density and electrode interdistance.

The effect of pulse current was found to increase the current efficiency at least 10-20 percent more than the conventional direct current plating in the high current density more than 100A/dm^2 and at 3-4mm of electrode interdistance.

The surface appearance was also studied and known to be of great influenced by pulse frequency.

요 약

SRHS (Self-Regulating High Speed) 크롬도금욕을 사용하여 도금욕온도 10-80℃, 전류밀도 0-400 A/m^{2}의 직류전해도금에서의 전류효율 및 표면광택을 조사였으며, 동일도금욕 조건에서 펄스 주파수 10-100,000Hz의 펄스전해도금 경우와 비교검토하여 다음과 같은 결론을 얻었다.

(1) 20℃의 욕온도의 경우 5-100Hz의 주파수의 펄스전해도금에서 직류전해도금보다 40%의 높은 전류효율 값을 나타내었다.

(2) 75℃의 욕온도에서는 10-100,000Hz의 전주파수 범위와 25℃에서는 500Hz이상의 주파수 범위에서 펄스 전해도금의 전류효율은 직류전해 도금보다 낮은 값을 보였다.

(3) 직류 전해도금조건에서 광택 및 반광택 표면은 펄스 전해도금으로 무광택으로 변하며, 펄스 주파수가 10,000Hz이상되면 직류전해 도금의 동일 표면광택을 다시 나타났다.

1. INTRODUCTION

In the recent years, there has been a considerable demand for increasing the productivity in the electroplating process, which necessitated modification of the plating bath (1) (2) and its operating conditions (3) (4) (5) to allow plating process at higher speeds. The increase in the plating speed has been further emphasized on the

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chromium plating process which is usually applied to industrial uses with a thick electrodeposit.

A recent study(6) has shown that the application of pulse current (P.C.) allowed high current density in the plating process in comparison with direct current (D.C.), which has a bearing on the speed of plating.

The present work was undertaken to develop a high speed chromium plating system by employing P.C. in stead of D.C. in the Self-regulating High Speed (SRHS) chromium bath.

2. EXPERIMENTAL

Hot-rolled mild steel of 2 mm thick sheet was used as the substrate. The cathode was made of 7.5 cm x 15 cm panels, cut from the sheet. The anode was a commercial purity lead sheet and positioned in paralled with cathode with 2 cm inter-electrode distance in the plating bath. The steel panel was taken through the usual pretreating sequences and then plated in the SRHS bath containing 250 g/L CrO_3, 20 g/L K_2SiF_6 and 7.5 g/L $SrSO_4$.

Provision was made for the uniform thickness of the deposit on the cathode using PVC jig which consisted of baffled sheet with punched holes. The electrodeposit was remained within the variation of 5 percent in thickness over the plated surface of 5 cm diameter.

The current was obtained from a programmable power supply system which is specially made for this study. The pulse frequency was measured with the oscilloscope.

Preliminary experiments were conducted with D.C. plating to investigate the effect of process variables, such as bath temperature (20°C-80°C) and current density (25 A/dm^2-400 A/dm^2) on the current efficiency and surface appearance. The bath temperature was controlled within ±0.5°C through the constant temperature tank.

In order to increase the plating speed with square pulse current, the average pulse current of 140 A/dm^2 was applied in the frequency range from 0.1 Hz to 100KHz to the plating baths of 20°C and 75°C respectively. The current efficiency was calculated by measuring the thickness of deposit with the electrolytic thickness guage, Couloscope (Fisher S 8e5).

The surface appearance was also examined by a naked eye.

3. RESULTS AND DISCUSSION

3.1 Effect of D.C. Supply on the Current Efficiency and the Surface

Fig. 1 shows the effect of bath temperature and currenct density of D.C. supply on the current efficiency. The current efficiency was decreased with bath temperature, while increased with current density. Similar results were observed in Sargent bath (1) (7) and SRHS bath (1) (2) (8) by several investigators, and explained by the variation of hydrogen overvoltage on the cathode (7) (8) (9).

The surface appearance of electrodeposits is also illustrated in Fig. 2. Fig. 2 shows a close relation between the bath temperature and current density. A bright appearance is shown two region above the current density of 25 A/dm^2. A wide range of current density above 140 A/dm^2 was applicable for bright surface at the bath temperature range of 70°C to 75°C. Semi-bright deposits are shown over the current density 70-400 A/dm^2 at the bath temperature lower than 25°C. And other plating conditions

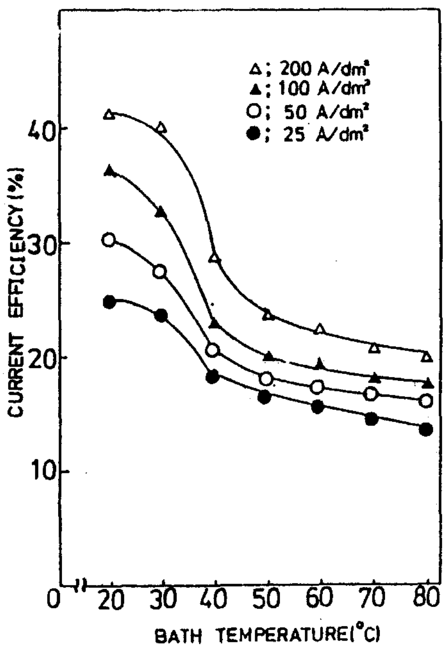


Fig. 1 Effect of bath temperature and current density on the cathode current efficiency by DC supply

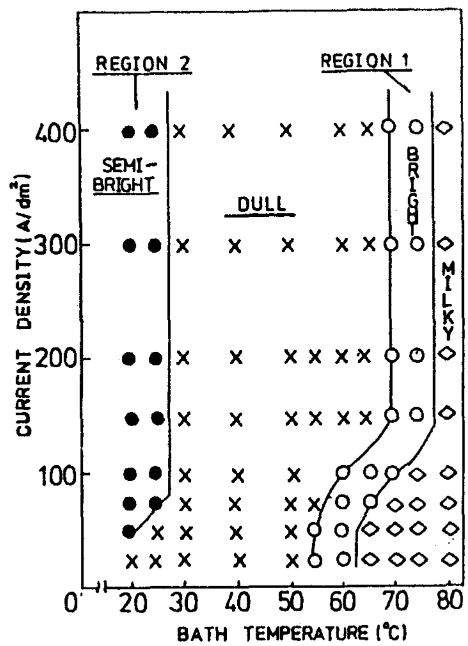


Fig. 2 Effect of bath temperature and current density on the surface appearance of electrodeposits by DC supply.

gave the milky and dull appearance as shown in Fig. 2.

3.2 Effect of P.C. supply on the Current Efficiency and Surface Appearance

The study on the effect of pulse frequency was confined to two bath temperatures of 75°C and 20°C at a high current density of 140 A/dm^{-2} whose conditions corresponded respectively to the bright and semi-bright region in Fig. 2.

3.2.1. Pulse Frequency on Current Efficiency

The influence of pulse frequency on the current efficiency is shown in Figs. 3 and 4. They show that there is no systematic variation of current efficiency with pulse frequency or bath temperatures. But the comparison of two bath temperatures indicates that the current efficiency is higher at 20°C than at 75°C over all the frequency region, but the same value of current efficiency as D.C. is shonw when the pulse frequency exceeded 50 KHz at both temperatures.

The current efficiency increases to such an extent that it goen up to over 50 percent at the frequency range of 5 Hz to 100 Hz as shown in Fig. 3 at the plating temperature of 20°C. The increase current efficiency might be attributed to the decrease in concentration polarization because the off-time duration was long enough to nullify the concentration gradient. However, the chromium layer obtained on these conditions, had poor adhesion on the substrate with dull appearance as illustrated in Fig. 6(b).

On the other hand, current efficiency drops to 30% and then increases as the frequency increases. This declined current efficiency was

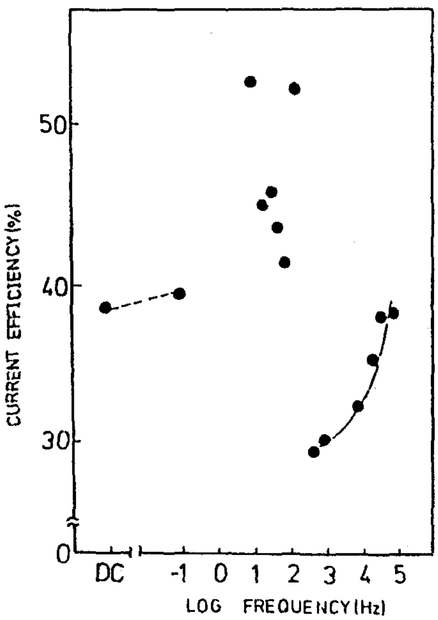


Fig. 3 Effect of pulse frequency on the current efficiency by p.c. supply in SRHS bath at 20°C (average current density; 140A/dm², plating time; 10 min.)

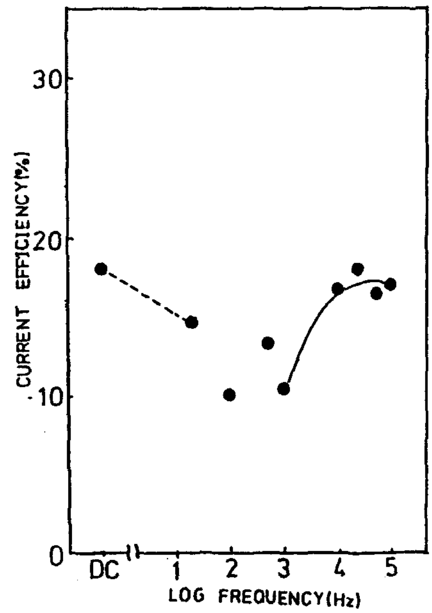


Fig. 4 Effect of pulse frequency on the current efficiency by p.c. supply in SRHS bath at 75°C. (average current density; 140A/dm², plating time: 10 min.)

consistent with other studies (11)(12) and it was considered that the application of pulse brought about the instantaneous depletion of plating ion and low overvoltage over the cathode surface.

3.2.2. Pulse Effect on Surface Appearance

The influence of pulse frequency in P.C. plating has been studied at a given average current density of 140 A/dm² in both plating temperatures, 75°C and 20°C. Fig. 5 shows that application of pulse current brought about a dull surface from the bright or semibright one of the direct current, but the same appearance as D.C. plating has been renewed by the high frequency above 10 KHz.

Some literatures reported that the interruption (6) of pulse and ripple(10) of plating current influenced the surface brightness in the process of chromium plating with the Sargent

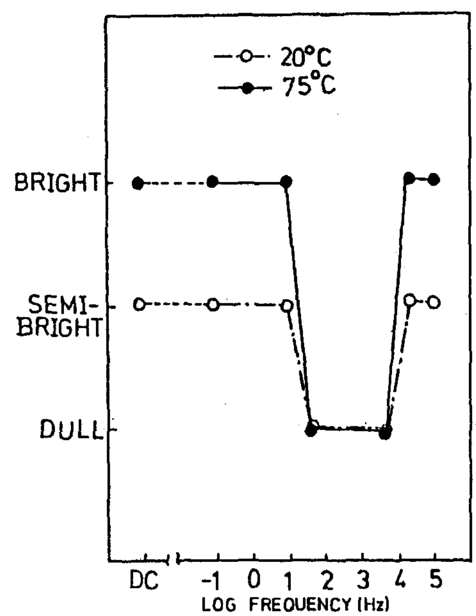
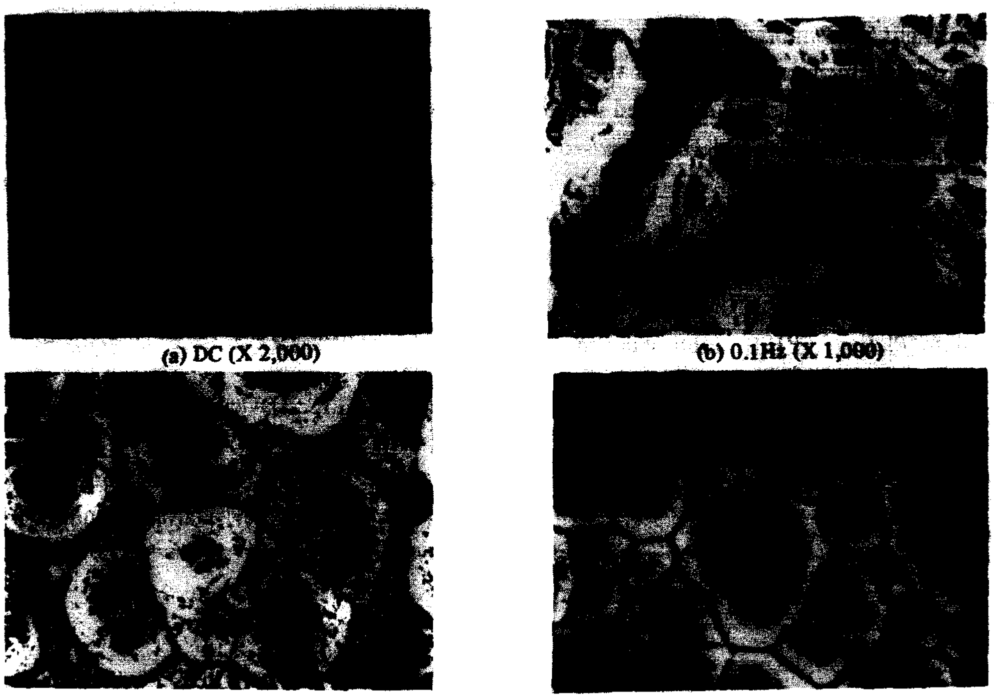


Fig. 5. Effect of pulse frequency on the surface appearance of electrodeposits by p.c. supply of 140 average current density.



(a) DC (X 2,000) (b) 0.1Hz (X 1,000)

(c) 100Hz (X 2,000) (d) 50KHz (X 2,000)

Fig. 6. Surface morphology of Cr plated specimen with various current frequency conditons (bath temperature: 20°C, average current density; 140 A/dm^2, plating time; 10 min.)

bath. No work has been performed on the systematic pulse frequency study on the surface brightness with SRHS bath. Fig. 6 is the micrographs of surface morphology on deposits plated in the different pulse frequencies. Dull appearance was characterized by the obscure contour of grains, while bright by the apparant contour of grains.

The surface appearance might be controlled by the growth characteristics of the electrodeposits duirng plating process. It was observed that pulse character was not available above 50 KHz pulse frequency, because of the capacitance effect of a charging up of the double layer on the cathode surface.

4. CONCLUSIONS

A wide spectrum of pulse frequency up to 100 KHz was employed to investigate the influence of pulse frequency on the current efficiency and surface appearance in the pulse current plating with an average current density of 140 A/dm^2 in the SRhS bath at 75°C and 20°C. Following conclusions are made by comparing with direct current plating.

(1) In the pulse plating of 5-100 Hz at 20°C bath, the current efficiency of pulse current plating is superior to that of direct current plating by up to 40 percent.

(2) Pulse current plating shows the lower current efficiency than direct current plating both at 75°C for all frequency range and at 20°C above 500 Hz.

(3) Bright or semibright surface was turned to dull by introducing the pulse, but the surface of direct current plating was recovered when the pulse frequency exceeded 10 KHz.

REFERENCES

(1) R.E. Such and J.K. Dennis, "Nickel and Chromium Plating", P190, John Wiley & Sons Pub. Co., N.Y. (1972)

(2) N.V. Parthasaradhy, R. Subramanian and V.M. Rose, Metal Finishing, 57, 67(1970)

(3) M.A. LaBoda, Plating and Surface Finishing, 66, 50 (1979)

(4) R.D. Bedi, Plating, 55, 238 (1968)

(5) R.D. Bedi, and G. Dubpernell, Plating 55, 246 (1968)

(6) J.CI. Puippe and N. Ibl, Plating and Surface finishing, 67, 68(1980)

(7) S. Igawa Metal Finishing of Japan, 23, 13 (1972)

(8) V.M. Rose and N.V. Parthasaradhy, Metal Finishing, 57, 76 (1970)

(9) N.E. Ryan, Metal Finishing, 57, 46 (1965)

(10) G.R. Davies, Trans. Inst. Met. Fin., 51, 47 (1973)

(11) V.A. Lamb, Plating, 56, 909 (1969)

(12) A. Knodler, Galvanotechnik, 61, 290 (1970)