Bulletin of Electrochemistry 15 (7-8) July-August 1999, pp 248-251 0256-1654/99/$ 3-50

CONTINUOUS COPPER PLATING OF STEEL WIRES

G N K RAMESH BAPU, J AYYAPPARAJU AND G DEVARAJ*

Central Electrochemical Research Institute, Karaikudi 630 006. INDIA
* Block No 110 # 10 - 597, New Bridge Road, SINGAPORE 080 110

In the present work, a method for continuously coating copper on steel wire is being developed. The pre-treated steels have made to run horizontally through various cells containing cleaning solution, pickling solution, strike bath and plating bath. After a thin coat of nickel, the steel wire was plated using an acid copper bath. A single strand horizontal wire plating unit was fabricated for the purpose. Hull Cell was used to optimise the operating conditions of the selected bath. The current efficiency of the process and the electrical resistivity of the coated wires were also measured. The copper coated steel wires may substitute copper cables in tele-communication and other applications.

Keywords: Copper plating, Hull Cell studies.

INTRODUCTION

Continuous plating is mostly applicable to strips, wires, sheets and other materials having symmetrical shapes as in the case of tubes etc. The continuous movement of wires and sheets in electrolytic baths enable plating to be done at higher current densities [1]. Electro-tinned steel sheets and copper wires [2], electro galvanised steel sheets and wires [3] are the well known industrial processes based on the continuous plating methods.

Copper is a very ductile metal and is the best conductor of electricity next to silver. For tele-communications and other applications copper cables are used. Considering the cost and availability of copper, they have been replaced with copper coated steel wires having 30% to 40% conductivity. As of now, this process is an imported one which uses cyanide based copper electrolytes for thick copper coating of steel wires subsequently used for making telephone cables. The process on plating of copper on steel wires using a non-cyanide bath like sulphate is of recent origin, even in abroad. To overcome the pollution hazards with the cyanide process in the present work, a method for continuously plating copper on steel wire is being developed based on acid copper baths. A single strand horizontal wire plating unit was fabricated for the above purpose. The current efficiency of the process and the electrical resistivity of the plated wires were also reported.

EXPERIMENTAL

Hull Cell studies

To examine the quality, nature of deposits and optimising the deposition parameters such as current density and temperature as employed for continuous plating, experiments were done for 5 minutes using a 267 ml Hull Cell. The steel cathode was mechanically polished, degreased with trichloro ethylene, cleaned in an alkaline solution electrolytically, washed, rinsed and pickled in 10% sulphuric acid. About 5 mm nickel was plated on the pretreated steel, at 4 A/dm^2 at 323 K. These nickel plated steel sheets were used as cathodes for further build up of copper deposits. The deposit patterns at various cell currents (2.5 A, 5.0 A, 7.5 A and 10 A) and temperatures (303, 313, 323, 333 K) were recorded for the acid copper sulphate bath and copper fluoborate bath.

Current efficiency

For determining the current efficiency of the sulphate and fluoborate baths, 1.6 mm dia steel wire of 1 meter length was coiled in the form of a spiral and pretreated. 5 mm nickel was plated over the wire and weighed. Copper was deposited to a thickness of 50, 150 and 250 microns over nickel plated steel wires at 2.5, 5.0, 7.5 and 10 A/dm^2 and again weighed.

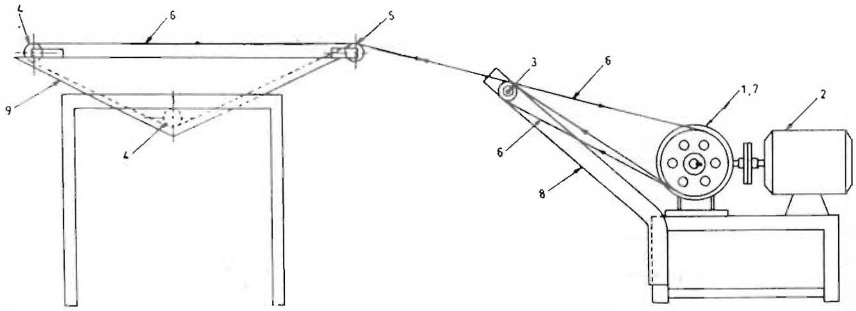

Fig. 1: Experimental setup for continuous plating of copper on steel wires
(1) Reduction gear (2) Motor (3) Steel shaft (4) PVC pulley (5) Brass pulley (6) Steel wire (7) Fly wheel (8) Steel arm (9) Plating tank

From the weight of the copper deposits, current efficiency was obtained using the relation

$$\text{Current efficiency (\%)} = \frac{\text{Weight of copper deposited}}{\text{ece of copper x Coulombs passed}} \times 100$$

Continuous copper plating of steel wires

For continuous plating, the horizontal type experimental cell set up shown in Fig. 1 was used. The pretreated steel wire (1.6 mm dia) was nickel plated over which copper was deposited to a thickness of 175-235 mm using copper sulphate and copper fluoborate baths. The wire was passed through the cell at a speed of 20 to 30 meters per minute and plated at a current density of 20 A/dm^2 at 323 K. The electrolyte was filtered and circulated continuously into the cell opposite to that of the movement of wires. Bagged copper anodes were used.

Electrical resistivity

The coating should be smooth and uniform in thickness through out the tested specimen. Electrical resistivity of copper coated steel wire was measured with a four point resistivity probe attached to a digital microohm meter.

RESULTS AND DISCUSSION

Hull Cell studies - Copper sulphate bath

Effect of cell current

The legends for recording Hull Cell pattern is shown in Fig. 2. In Fig. 3 was shown the deposit patterns obtained for a cell current of 2.5, 5.0, 7.5 and 10 amp. for a duration of 5 minutes at 303 K. Upto 20 A/dm^2 a smooth, uniform and semibright deposit was obtained in all above cases.

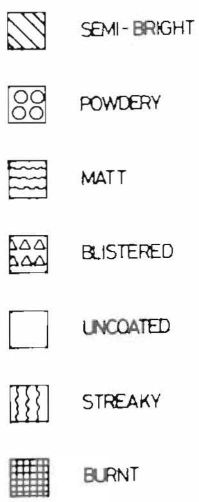

Fig. 2: Codes for recording Hull cell patterns

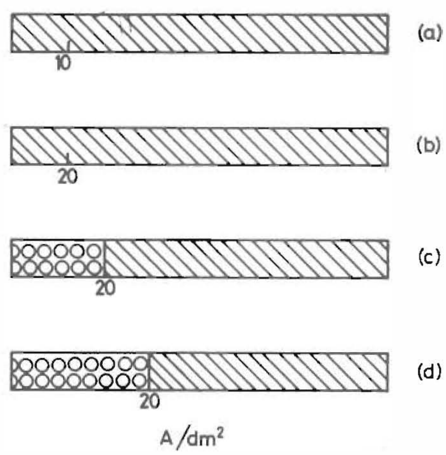

Fig. 3: Effect of cell current on copper sulfate bath
Time = 5 min Temperature = 323 K
(a) 2.5 A (b) 5.0 A (c) 7.5 A (d) 10.0 A

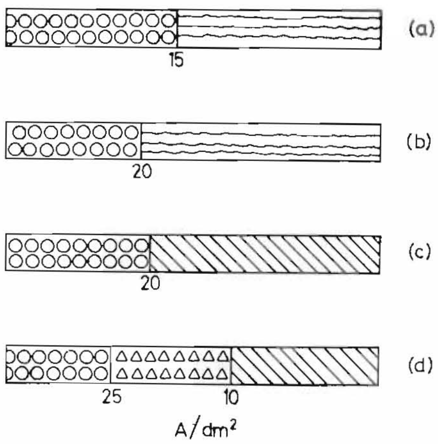

Fig. 4: Effect of temperature on copper sulfate bath
Time = 5 min Cell current = 10 A
(a) 303 K (b) 313 K (c) 323 K (d) 333 K

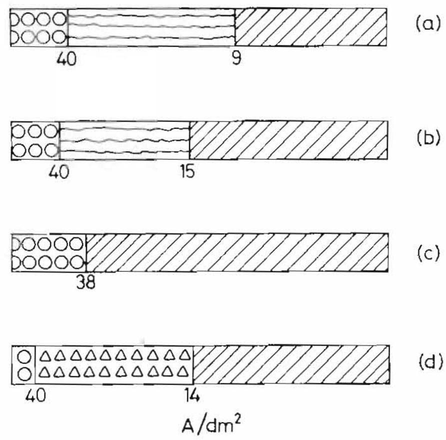

Fig. 6: Effect of temperature on copper fluoborate bath
Time = 5 min Cell current = 10 A
(a) 303 K (b) 313 K (c) 323 K (d) 333 K

Effect of temperature

A cell current of 10 amp was passed for 5 minute at 303, 313, 323 and 333 K and the deposit patterns were shown in Fig. 4. Powdery and blistered regions were seen at 333 K beyond 10 A/dm^2 where as at 303 and 313 K mat and powdery areas were observed. The powdery deposit region got shifted to 20 A/dm^2 with rise of temperature. A semi-bright deposit was noted upto 20 A/dm^{2}at 323 K beyond which resulted powdery regions.

Hull Cell studies - Copper fluoborate bath

Effect of cell current

Similar cell currents as for copper sulphate was passed in the Hull Cell at 323 K. As is seen in Fig. 5, smooth and semi-bright deposits were obtained upto 38 A/dm^2. Fluoborate electrolytes thus found to gave a two fold wide current density for semi bright deposit as for copper sulphate bath.

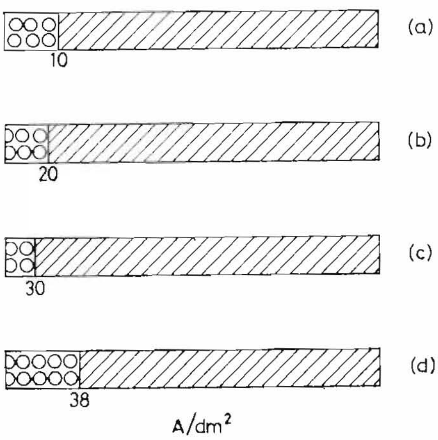

Fig. 5: Effect of cell current on copper fluoborate bath
Time = 5 min Temperature = 323 K
(a) 2.5 A (b) 5.0 A (c) 7.5 A (d) 10.0 A

Effect of temperature

A cell current of 10 amp was passed at 303, 313, 323 and 333 K for 5 minutes. Powdery deposits were invariably present beyond 38 A/dm^2 at all temperature ranges studied (Fig. 6). At 303 K and 313 K mat deposits were formed beyond 10 A/dm^2 whereas at 333 K blistered deposits were seen beyond 14 A/dm^2. A smooth and semi-bright was found upto 38 A/dm^2 at 323 K.

Current efficiency

Current efficiency data of copper sulphate and copper fluoborate bath at 323 K at different current density ranges were shown in Table I with increasing thickness of copper deposits a rough and nodular growth was observed at higher current densities. This could be overcome with continuous circulation and filtering of the electrolytes. This will enable

TABLE I: Current efficiency data at 323 K
Deposit thickness 250 μm

Current density A/dm^2	Current efficiency (%)	
	Sulphate bath	Fluoborate bath
2.5	97.5	98.1
5.0	97.3	96.1
7.5	97.2	95.9
10.0	96.6	95.6

to get smooth uniform deposits. Current efficiency of such deposits were calculated and average values were reported. In copper sulphate bath, it can be found that more than 96% efficiency was achieved even at higher current density of 10 A/dm^2. In the case of fluoborate also current efficiency of 96% and above was achieved at all current densities.

Continuous copper plating of steel wires

The wire was released from the pay-off reels and passes through a cleaning tank, pickling tank, strike nickel solution and copper sulphate bath. A wash and rinse arrangement was provided in between two tanks. The copper plated wire after drying was coiled in take-off reels. At 323 K, the current efficiency of the plating bath was 96% at 10 A/dm^2. Throughout the length of the wire, a smooth, uniform and bright adherent deposit was formed. The solution was filtered continuously and circulated into the tank. The stability of the electrolyte was found to be good since no decomposition of the electrolyte took place during and after operation.

Electrical resistivity

Copper was coated to the extent of 175 mm and 235 mm on 1.6 mm dia steel wires. The resistivity was measured at 303 K using a digital microohm meter. Irrespective of the copper electrolyte used, the resistivity of the 175 mm deposits did not vary much and ranged between 48-55 milliohms per mm^2 per meter. For 235 mm thick copper coated steel wires, the resistivity values had decreased slightly to the range of 39- 44 milliohms per mm^2 per meter. As expected, the conductivity increases with increase of copper deposits on steel wires.

CONCLUSION

A continuous plating experimental cell was fabricated to deposit copper on 1.6 mm dia steel wires. Plating trials were made using copper sulphate and copper fluoborate bath. The deposits were uniform and at 323 K the current efficiency was 96%. Resistivity of the coated wires ranged between 45-55 milli ohms/mm^2/meter for a thickness of 175-235 mm.

Acknowledgement: Authors kindly acknowledge to Department of Science and Technology, New Delhi, for their support and encouragement provided for the project. Authors also express their thanks to the Director, CECRI, for his kind permission to publish this paper.

REFERENCES

1. H Wettwer, *Plating*, **61** (1974) 447
2. W R Johnson, *Plating Surf Finish*, **62** (1975) 52
3. H Geduld, (Ed) *Zinc plating*, Finishing Publications Ltd England (1988)