

ELECTROWINNING OF NICKEL FROM CHLORIDE ELECTROLYTE

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Electrowinning of nickel is carried out either from sulphate or chloride electrolyte. The chloride route is attractive from the view points of better energy conservation and utilisation of chlorine liberated at the anode. Bench scale studies on electrowinning of nickel from nickel chloride electrolyte are reported and parameters like electrolyte-pH, current density, temperature and addition agent like boric acid are examined. Aspects relating to energy consumption of the process are also discussed.

Keywords: Nickel, electrowinning and chloride bath

INTRODUCTION

In the extraction of nickel from its minerals, electrowinning plays an important role from the view points of energy conservation and pollution abatement. Moreover, the purity of metal extracted could be improved considerably. Though, electrowinning of nickel can be carried out either from chloride or sulphate electrolyte [1-5], there is much scope for further energy reduction in the chloride route. In addition to the metal deposited in a purer form at the cathode, the chlorine gas liberated at the anode can be recycled for useful purposes. Nickel winning is very sensitive to the pH of the electrolyte and when it is carried out in chloride electrolyte the maintenance of pH is not so difficult as in the case of sulphate electrolyte.

The objective of the present work is to carry out experiments on electrowinning of nickel from chloride electrolyte and to optimise the conditions like current, density, pH, temperature and addition agent.

EXPERIMENTAL

Electrowinning of nickel was carried out in a diaphragm cell of 750 ml capacity employing nickel chloride as electrolyte of 60 g l^{-1} Ni concentration. The cathode was stainless steel strip of 5×2 cm and the anode was graphite of same dimension. The graphite was placed in a perforated PVC box converted with polyester cloth. Experiments were carried out at different electrolyte conditions, pH ranging from 0.5 to 2.0 and temperature from 303K to 353K. The current density was varied from 100 to 400 A m^{-2} . Experiments were also carried

out to study the effect of boric acid as a constituent in the electrolyte. In all experiments, the duration of electrolysis was for four hours. At the end of each experiment, the nickel deposit was stripped, weighed and the current efficiency was determined. All chemicals used were of Analar grade.

RESULTS AND DISCUSSION

Fig. 1 shows the effect of current density on current efficiency for nickel deposition. When the current density is increased from 100 A m^{-2} to 400 A m^{-2} , the current efficiency was found to decrease from 78% to 68% at 303K. However,

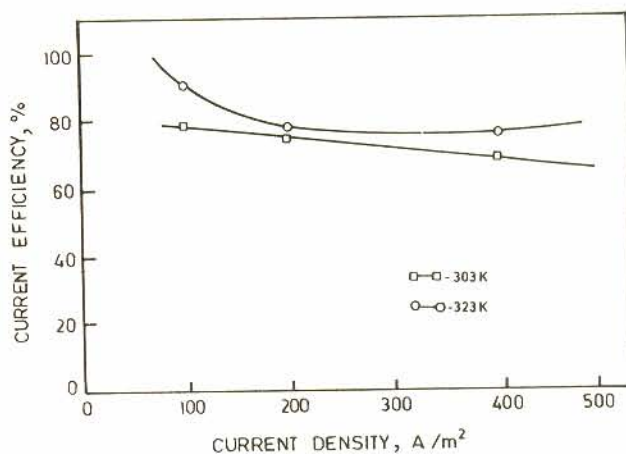


Fig. 1: Effect of current density on current efficiency for electrowinning of nickel at a pH of 1.5 and 60 g l^{-1} nickel concentration

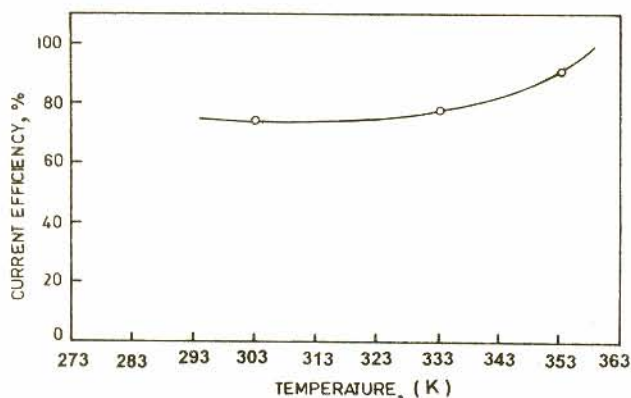


Fig. 2: Effect of temperature on current efficiency for electrowinning of nickel at a pH of 1.5 and 200 Am^{-2}

when the temperature of electrolysis is increased to 333K, the current efficiency was 90% at 100 Am^{-2} which decreased to 76% at 400 Am^{-2} . It is to be noted that higher temperature of electrolysis results in higher current efficiency. Since the nickel deposition potential is close to that of hydrogen evolution which is always a competing cathode reaction, current efficiency is lower at 400 Am^{-2} . Fig. 2 shows the effect of temperature on current efficiency at 200 Am^{-2} and pH of 1.5. When the temperature of electrolysis is increased from 303K to 333K, the current efficiency is found to increase. Cathode potential measurements at 303K and 333K indicated a reduction in potential from 0.84V to 0.64V which lowers the tendency for hydrogen evolution leading to increase in current efficiency for nickel deposition.

Fig. 3 depicts the effect of electrolyte pH on current efficiency. With increase of pH from 0.5 to 2.0, current efficiency was found to increase up to a pH of 1.5. Further increase of pH does not have significant effect. Lowering of pH facilitates promotion of hydrogen evolution reaction

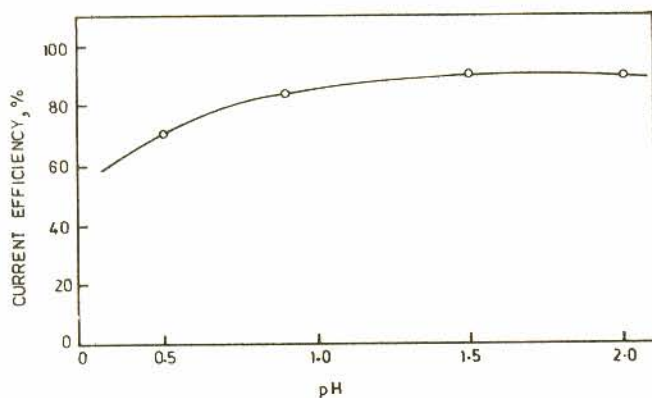


Fig. 3: Effect of pH on current efficiency for electrowinning of nickel at 100 Am^{-2} at 333 K

TABLE I: Operating conditions employed for electrowinning of nickel

Electrolyte	Nickel chloride, Ni^{2+} : 60 gpl
pH	1.5
Current density	200 Am^{-2}
Temperature	333 K
Anode	Graphite (placed in perforated PVC box covered with polyester cloth)
Cathode	Stainless steel
Duration	4 hours
Cell voltage	2.47 V
Current efficiency	78%
Energy consumption	2.95 kwh/kg

leading to decrease of current efficiency. Further, higher pH conditions (2.7-4.0) normally employed in sulphate solutions are found to be not suitable for nickel chloride solutions because of its tendency for precipitation as nickel hydroxide [6]. The electrowinning conditions found suitable are given in Table I.

Boric acid addition does not result in improvement of current efficiency in the pH range of 0.5-2.0. This is due to the fact that chloride ion is well known for its specific adsorption on the electrode surface [7], inhibiting the effect of boric acid. Further, the aspect like complexation of boric acid with nickel in the chloride medium should be considered in this context. It is reported [8] that in electrowinning of nickel from a nickel sulphate bath of pH 2.7 and at 333 K the bath voltage is about 3.6V when the current density is $200\text{--}220 \text{ Am}^{-2}$ [8]. But in case of chloride bath of pH 1.5, the voltage is only 2.47V under similar conditions. The comparative voltage components for both sulphate and chloride bath is given in Table II. Higher reversibility of the electrode reactions and improved conductivity of the electrolyte are major factors which contribute for lowering of cell voltage in the chloride electrowinning. Moreover, diffusion coefficient measurements reported for NiSO_4 and NiCl_2 solutions should be considered in this context [6]. The energy consumption computed at various experimental conditions are given in Table III. As the conductivity of the electrolyte increases with temperature, electrowinning at higher temperatures lead to lower energy consumption as a

TABLE II: Comparison of voltage components

Voltage component	Sulphate bath	Chloride bath
Cathode potential, V (NHE)	0.6	0.56
Anode potential, V (NHE)	2.0	1.56
IR drop, V	1.0	0.35
Cell voltage, V	3.6	2.47

TABLE III: Energy consumption for electrowinning of nickel

No	Current density AM^{-2}	Temperature K	Electrolyte pH	Cell Voltage V	Current efficiency %	Energy consumption kWh/kg
1.	100	303	1.5	2.04	77.6	2.43
2.	100	333	0.5	1.70	71.4	2.21
3.	100	333	1.0	1.90	83.6	2.10
4.	100	333	1.5	1.85	90.0	1.90
5.	100	333	2.0	1.80	89.2	1.87
6.	200	303	1.5	2.67	74.0	3.35
7.	200	333	1.5	2.47	78.0	2.95
8.	400	303	1.5	2.90	68.0	3.80
9.	400	333	1.5	2.65	76.0	3.10

result of lower cell voltage. Further operation at optimum pH and current density results in higher current efficiency for nickel deposition leading to lower energy consumption of the process.

CONCLUSION

Among the two well known routes for electrowinning of nickel, chloride route has been studied in the present work. The parameters like pH of the electrolyte and influence of boric acid as a constituent in the electrolyte have been examined for better nickel deposition with respect to quality and quantity. Lower energy consumption associated with the chloride route is mainly due to better conductivity of the electrolyte and higher reversibility of electrode reactions. The addition of boric acid is not found to be beneficial in improving the current efficiency under the conditions employed.

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