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Research Article

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Current Density Distribution Studies in Manifold Dimensions

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ABSTRACT

The geometric parameters determining the distribution were the interelectrode gap, electrode length, transverse section and length of the electrolyte manifold. These results are useful for estimating the performance of the stack. The current distribution becomes more uneven when the distance between the electrode (Anode-Cathode) increases or decreases. however comparing the parts of A and C, show prominent current distribution only at small in deviated position of A and C. It can be observed that an increase in electrode gap has changes on current distribution and Throwing Power [TP] and also on current Efficiency [CE] as decreases, the effect of interelectrode gap on the current distribution is more pronounced than effect of electrode length. This study showed that the effect of interelectrode distance on the rate of metal deposition on a cathode can be satisfactorily described by the model.

Keywords: Current Distribution, Throwing Power, electrolytic deposition of Zn, Position of electrode, Current efficiency.

INTRODUCTION

The properties of a surface coating obtained by electrolytic deposition on many factor and in many cases optimal plating conditions must be determined empirically. One of the most important factors affecting the quality of a deposit is the current density during deposition. To study this effect and to determine optimal plating conditions in practice, many electrodepositers use a cell, structure composed of two non-parallel electrodes and glass walls. Since the cathode is tilted with respect to the anode, a wide variation in current densities along the cathode surface can be obtained[22] in a single experiment; thereby permitting the observation of the quality of deposits produced over a wide range of plating conditions.

To estimate the local current density [13] on the cathode in Haring –Blum [1] cell empirical formulae are used in practice. These formulae, however do not take into account the influence of electrochemical kinetics and mass transport, i.e. they strictly apply to primary current distribution conditions only. In the view of obtained results and ease of implementation for the solution of typical current distribution problem in applied electrochemical cells.

In a rectangular electrolytic cell with plane electrode parallel to each other and covering the end walls completely the current density is in general the same at all points. The current lines are perpendicular to the electrodes in the same manner as the field lines in capacitors except near the edge. Under most practical conditions of electroplating, however, a different geometry prevails and accordingly the current density is not uniform. A special instance is shown schematically, where the electrodes cover only a certain portion of the end walls of a rectangular path. The current density at the edge of the electrode is higher than elsewhere, since the current lines pass in part outside the space between the electrodes. Likewise, non-uniform current distribution results if the electrodes are not plane.

Consequently, as explained by numerous authors, notably by Forester [2], Haring and Blum [1], Gardam [3] and Hoar and Agar [4], the current distribution in the electrolytic cell is determined by linear and non-linear dimensions such as breath of electrodes, distance between cathode and anode, and distance between crests and troughs of profiled electrodes. Numerous geometrical arrangements of electrodes have been considered .It is therefore the objective of the paper to supplement investigations in this respect.

EXPERIMENTAL SECTION

Fig (1.) depicts the experimental arrangement of the electrolyte of $ZnSO_4$. $7H_2O$ (MERCK) and electrode of segment, 5 x 2.6cm wide. At opposite side of Anode as Zn electrode in order to minimize concentration loss of Zn. The data acquisition was performed using digitized controlled and which was used to apply a constant current. The electric connections were made at the points of A and C. Several points were carried out for different amperes in different space in order to compare the results.

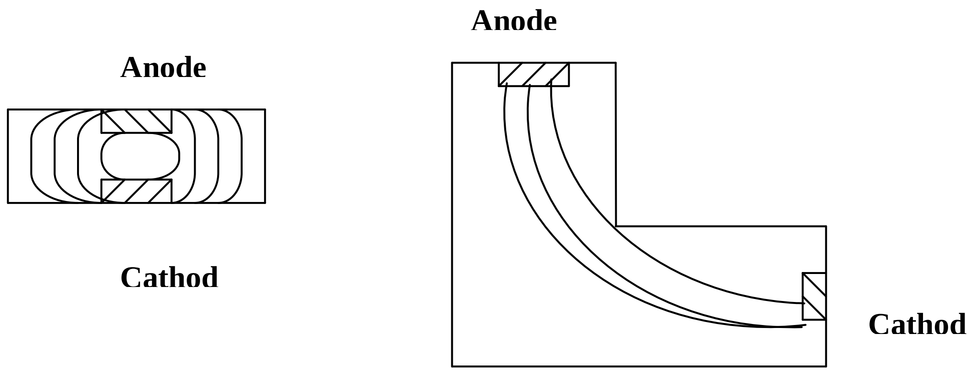

Fig.1. Metal deposit at various positions of Cathode

3. A novel determination of Throwing Power [TP]:

The effect of electrode distance on the rate of metal deposition on cathodic surface was studied in a novel compartment cell which contains A and C kept at different position apart also changed .the experimental results were correlated with the recently proposed with ESTIR[21]- [Electrochemical Science and Technology Information Resource/ elechem.blogspot.com /(http://electrochem.cwru.edu/estir/), which assumes that each position of electrodes processes occurs under small CE difference such that linear forms setting a increasing growth in CE.TP of the system was also analyzed according to a new definition of TP index derived from mass distribution(Current distribution)model.

The operating amperes were also found to have significant effect on TP. This study showed that effect of inter electrode distance on the rate of metal deposition on a cathode can be satisfactorily described the model and that the proposed TP index provide a convenient and effective basis of quantitative and comparative study of TP of this plating system.

Uniform plating thickness or metal distribution is usually a desirable property of plating deposit .It is often desirable and necessary to provide a quantitative measure of the degree of uniformity of metal distribution of electrodeposits on the cathodic surface. This is very often described by graphical mapping of the current or by the mass distribution or the thickness of the metal deposited over the surface of the cathodic workspace/piece.

Kardus and Foulke [6] recently reviewed the application of the mass-transfer theory to such problems. Vagrumyn and Solovova[5] gave a fairly comprehensive and critical description of the various experimental methods used for such study .The degree of uniformity of the electrode deposit is very much dependent on the current distribution and is often referred to by electroplates as its TP.A simple empirical TP index was first proposed by Haring and secondly with Blum. This computation of the proposed TP index involves experimental determination of the ratio [Cn/Cf-deposition at near &far cathode] of the amount metal deposited on the electrode .Cathodic surfaces placed at different distances from anode.

Haring –Blum [1] empirical TP index and the corresponding equation is

$$\text{TP}(\%) = [\frac{K-C}{K+C-2}]\times 100 \text{ -------------------------(1)}$$

TP-Throwing Power K -current distribution ratio C -metal distribution ratio= $\frac{C_n}{C_f}$

C_n -Deposit Weight at near cathode C_f - Deposit Weight at far cathode

This recent model described the experimental system in which various processes occur at both electrodes.

Then the current distribution model was found to give good correlation of the experimental data obtained using Haring –Blum [1] cell with only one Anode and One Cathode. The proposed TP index and cell voltages provided a convenient basis for comparing the different location of systems.

Although the model provides a more meaningful and realistic description of TP of plating and mass distribution of electrodeposits. The experimental method having single cathode at a time was found to be very novel and time consuming one. Besides there would also experimental errors due to inevitable difference in the conditions that are supposed to be maintained constant between runs.

This paper describes the use of novel electro deposition and plating in which every deposition mass ratio on cathode is maintained same current density but different distances from the anode could be simultaneously determined in one single experimental run. This helps minimize the experimental error and also reduce the number of experimental runs required to establish the mass distribution equation and to evaluate the TP of the system. The experimental results obtained for Zn deposition system are reported.

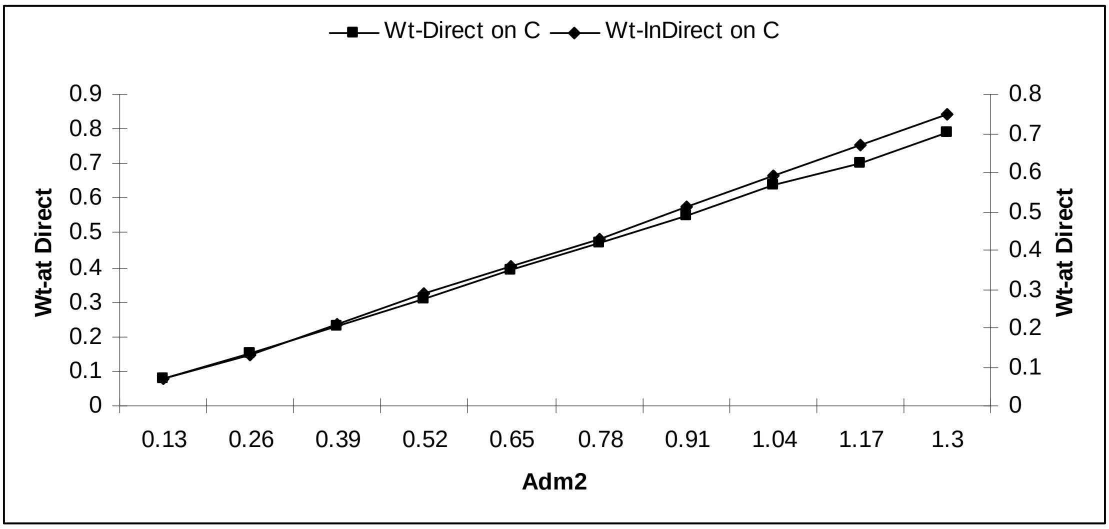

Fig.2. (a) mass of metal deposit in various Adm^2 – at Direct & InDirect position of Cathode

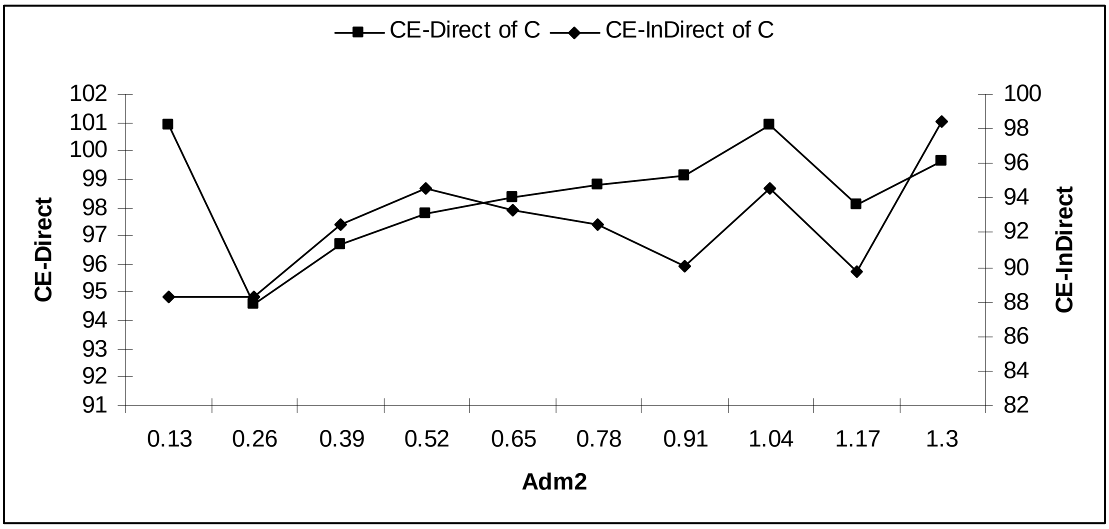

Fig.2 (b) Current Efficiency of metal deposit in various Adm^2 –at Direct & InDirect position of Cathode

4. Effect of electrode distance on mass deposition rate:

Fig.2. (a) gives a typical plot of mass of metal deposit at various amperes of current levels at two different positions of the Anode .The values of TP, CE were studied. The mass rate of deposition was calculated from the correlations and compared with appropriate experimental values as shown in **Fig**.2 (a) The corresponding values obtained for the system in the previous study using Haring –Blum [1] cells. This shows significant improvement in the accuracy of the experimental data obtained with new designed cell. These result reaffirmed the adequacy of the model in describing the mass distribution of the metal deposit on a cathodic work space/piece.

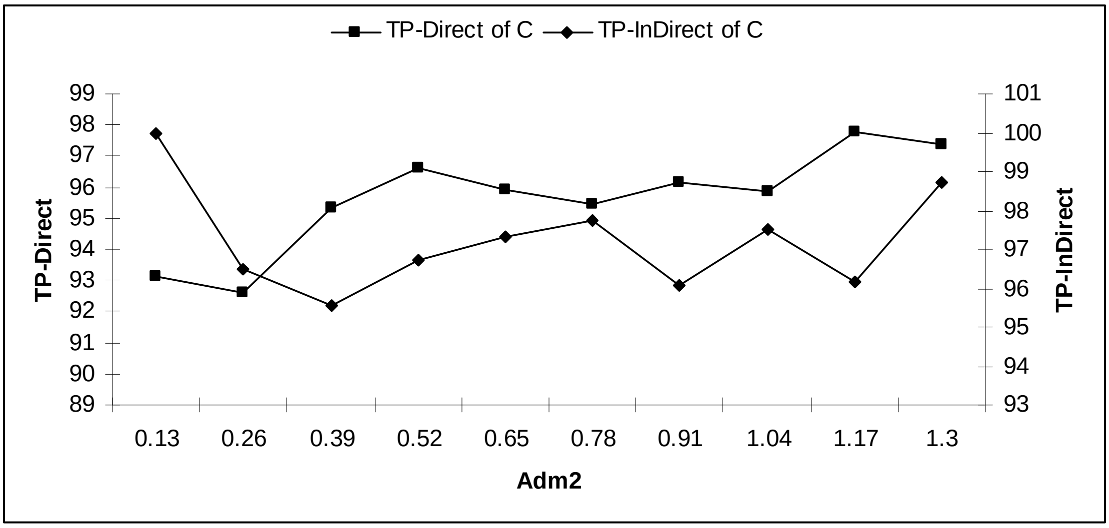

Fig.2. (c) TP of Current of metal deposit in various Adm^2 – at Direct & InDirect position of Cathode

CE of metal deposition at various position in the cell system is plotted pictorially in Fig.2 (b) It gave slight variation is in CE modes. TP of the system was calculated according to equation (1) for various cells current and the values are plotted in Fig.2(c). This result show that TP decrease with increase in current and the effect of cell voltage were differ at location. These shows that the results obtained the two sides were comparable except the new designed cell facilitate the experimental procedure considerably and also provides more accurate experimental data for correlation as reflected by the difference in the mean values of ratio of calculated to experimental rates of metal deposition obtained.

It is important to note that electrodeposition. Under Galvanostatic conditions should be carried out with caution especially with a system which exhibit significant cell voltage/current effect. A slight change in the Bath characteristic such as resistance could reduce TP considerably.

RESULTS AND DISCUSSION

Typical result of current distribution at the electrode for different value when the experimental arrangement presents one electrode at different location. The experimental current densities show the derivation of linear flow in deposition of ions. The distributions are independent of total current and close agreement of position of electrode and small difference between experimental points and the theoretical calculations is observed. The experimental measurements also represent mean value of current density at points of Anode and Cathode.

CONCLUSION

A close agreement for primary current distribution, cell voltage and CE were obtained for a novel model [Fig. (1)] electrochemical cell. Observing CE produce uneven current distribution in this system .The current distributions are more pronounced for position of electrodes and higher values of parameters, which characterize the geometry of the system.

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REFERENCES

[1].H. Haring. and W. Blum.*Trans.electrochem.Soc.Journal*. **1923**.44.313.
[2]. F .Forester, "elektrochemic Waessriger Loesungen", 3rd Ed, **1923** .p.487.J.A.Barth, Leipzig
[3].Gardam.G.E. *Trans.Faraday.Soc*. **1937**.34.698.
[4]. T.P. Hoar. and J.N. *Agar.Disc.Faraday.Soc.* **1947**.1,162.
[5]. A.T.Vagramayan. and Z.A., Soloveva "Technology of electrodeposition", **1961**.ch.10. (Translated by A. Behr)Robert Drapper
[6]O.Kardos and D.G.Foulke "Advances in electrochemistry and electrochemical engineering ", C.W.Tobies, **1962**.Editor.p.145.Wiley-Interscience .Newyork
[7] W.W.Mullins and J.Sckarka. *J.Appl.Phy*.**1963**.34.323.
[8] K.I.Popov; S.M.Pesic; P.M.Zivkovic; *J.Serb.chem.Soc*.1**9**67 (4)273-278(2002).JSCS-2948
[9] K.I.Popov; P.M.Zivkovic; N.D.Nikolic *J.Serb.chem.Soc*.**1976** (0).-1-18-(2011)
[10]G.P.Power and J.M.Ritchie "Modern Aspects of Electrochemistry".vol.11. B.E.Conway and J.O'.M.Bockris,Editors. **1975**. Ch.5.Plenum.Press .New York and London.
[11].James.L.Blue, *The Bell system Technology journal*, Feb.**1980**.Vol.59.No.2.
[12]. M Matushita. Y.Hakayama; Y.Sawada.Phy.Rev.A.**1985**.32.3814
[13]. F.W.Hewes, "Cathodic Protection Theory and Practice," V. Ashworth and C.J.L. Booker, eds., Wiley (Horwood), Chichester, West Sussex, **1986**. p. 226.
[14]. D.G.Grier. ; D.A .Kesseler; L.M.Sander. *Phy.Rev.Lett*.**1987**.59.2315.
[15]. S.K., Rangarajan. V.Yengnanarayanan.*Electrochem Acta.* **1997**.42.153
[16]. P Marshall.; .P Mocako. H.L.Swinney.; J.M.Huth..*Phy.Rev.E*.**1999**.59.2157.
[17]. R.Kotzand; M.Carlen, *Electrochimica Acta*; **2000**.45.2483-2498
[18] F.Sagubs.; .M.Q.: Lopez-Solvans; *J.Claret. Phy.Rep*.**2000**.337.97
[19]S.Vassili.; Sochinkov and Shlomo Efrima, *J.Phy.chem.B*.**2002**.106.11993-11999.
[20] A.I.Moslii.; N.P.Poddubnyi.; A.Zh Medvedev. *Journal of electrokhimiya*-**2006**.Vol.42.No.2.pp.183-189.

[21].http://elechem.blogspot.com/ and http://filesden.com/files/2011/7/23/3171906/ELECHEM7Z-desinged by Dr.M Kanagasabapathy, Assistant Professor in Department of Chemistry ,Rajapalayam Rajus' College, Madurai Kamaraj University, Rajapalayam

[22]. M .Kanagasabapathy and Sobha Jayakrishnan *J. Chem. Sci*. Vol. 123, No. 3, May **2011**, pp. 357–364

[23].D.K.Gupta and Jinendra Singh, *J.Chem.Pharm.Res.*,**2010**,2(2):126-129

[24].V.R.Rathi,S.D.Nirmal and S.J.Kokate, *J.Chem.Pharm.Res*.,**2010**,2(2):97-100

[25].Ramesh Yamgar,Prasad Kamat and Sudhir Sawant, *J.Chem.Pharm.Res.*, **2010**,2(5):216-224

[26].Anuj Nuwal,S.L.Kakani and M.L.Kalra, *J.Chem.Pharm.Res.*,**2010**,2(5):131-152

[27]Yatri.R.Shah,Parimal.M.Prajapati and Dhrubo Jyoti Sen, *J.Chem.Pharm.Res.*,**2010**,2(1):147-154