OPEN ACCESS

*International Journal Of Modern Engineering Research (IJMER)*

# Electro deposition of Zinc from Zinc Sulphate and its Fractal Characterization.

[1]Shaikh Ifra Fatema, *[1]J. M. Pathan, [1]A. R. Khan [1]Gulam Rabbani

[1]*Dept. of Electronics and Physics, Maulana Azad College, Aurangabad (MS), India.*

***ABSTRACT:*** *Growth of dendritic patterns using electrodeposition of zinc in the form of branching patterns is studied using circular cell geometry and the electrolyte used is 1 M zinc sulphate solution. The electrodeposits so obtained have crystalline appearance and the deposits are in the form of wide leaves with secondary and tertiary branches at the characteristic angles in accordance with the crystal structure. The growth of electrodeposits and the shape and branching pattern gets modified as the size of the deposit increase and branches tend to approach outer anode. Characterization of dendritic patterns at different stages of development in terms of fractal dimensions is presented. It is shown that electrodeposits of zinc obtained from zinc sulphate solution possess self similarity and scale invariance and have fractal character*

***Keywords:*** *DLA, Electrodeposition, Fractal, Fractal Dimension, Fractal Geometry, Self-similarity.*

## I. INTRODUCTION

Concept of Fractals and fractal geometry opened new eras in characterization of irregular shapes and pattern and made it possible to characterize irregular shapes like those obtained in electrodeposition under certain special cases. Electro deposition in circular cell geometry under certain operating conditions results in formation of dendritic patterns showing scaling behaviour and Fractal Characteristics. The main process giving rise to such branching patterns is the Diffusion Limited Aggregation (DLA) of ions under a week electric field. The patterns so obtained are also known as DLA patterns, this phenomenon is found to explain formation of many irregular shapes in nature. Diffusion controlled pattern formation have been recent topic of interest, amongst them the Electro deposition, viscous fingering, dendritic crystal growth, and DLA (Diffusion Limited Aggregation) [1, 2, 3] have received the major attention.

The concept of fractal and non fractal aggregation is applicable in physics especially in turbulence [4, 5], polymerization,[6,7]. Flocculation, coagulation, dendritic growth, crystallization. Gelation process also exhibit self-similarity and fractal character in many cases. The practical importance and fundamental principle of Diffusion limited growth processes has motivated extensive studies in the past years. Electro-deposition processes [8, 9] are well suited for experimental studies of growth of fractals and dendritic patterns. The boom Fractals and related studies began in the 1980s and Physicists took keen interest in this area. Different Fractal models were later proposed and were found to be very useful in explaining complexity of irregular shapes that could not otherwise be quantified. For the purpose of forcasting the trends of the random events like prices of shares in the share market, the concept of Fractal model is being effectively used [10, 11]. Circular cell geometry is used with circular outer electrode acting as anode and the middle electrode (at the centre of the circular anode) works as cathode. Cell operating conditions like applied voltage and the concentration of the electrolyte mainly govern the shape of resulting dendritic deposits. It was found that the complexity of the shape of the growth and the branching patterns depend more on the electric field conditions under a given set of conditions. It was also found that the concentration of the solution strongly influences the structure and textures of electro deposition [12]. Few dendritic patterns obtained under different cell operating conditions and their characterization is presented. We studied the electro deposition using Zinc sulphate as an electrolyte to deposit zinc. It is observed that as the process is governed by random walk like processes [13], there is tendency of self avoiding. As a result, the growth is prominent on the outer side of growth i.e. around the tips of the branches. As a result of this, as the growth proceeds, the thickness of the branched does not appreciably grow as the cluster grows. Results of the study at different stages of growth at cell operating voltage of 5Vare presented.

## II. ELECTRODEPOSITION OF ZINC FROM ZINC SULPHATE SOLUTION

The growth of electrodeposition of zinc from 1 M zinc sulphate solution is studied different stages of electrodeposition are studied from the point of view of fractal dimensions and irregularity of shape in terms of structure and texture. Fractal dimensions of irregular patterns describes the degree of irregularity associated with that shape in terms of structure and texture. The electrodeposition of zinc in circular cell geometry using 1 molar zinc sulphate solution showed that the growth commences at relatively lower voltages as compared to copper and at higher cell operating voltages the growth becomes in the form of fine strands rapidly growing towards the anode. At lower voltages the growth is in the form of leafy patterns showing branches and sub branches at the characteristic angles. The leafy branches are broad and have a tendency to grow in a direction the growth began and formation of the new secondary and tertiary branches is controlled by the crystalline lattice pattern. This is the reason why all the branches do not grow in the same plane, this gives rise to a problem that when viewed from above, the flat branches are seen as broad and the branches developed in vertical plane appear as fine narrow line. The electrodeposited growth has bright metallic luster and crystalline appearance. While photographing the growing pattern, the surfaces facing the camera reflect more and appear more whitish as compared to the rest of the electrodeposit.

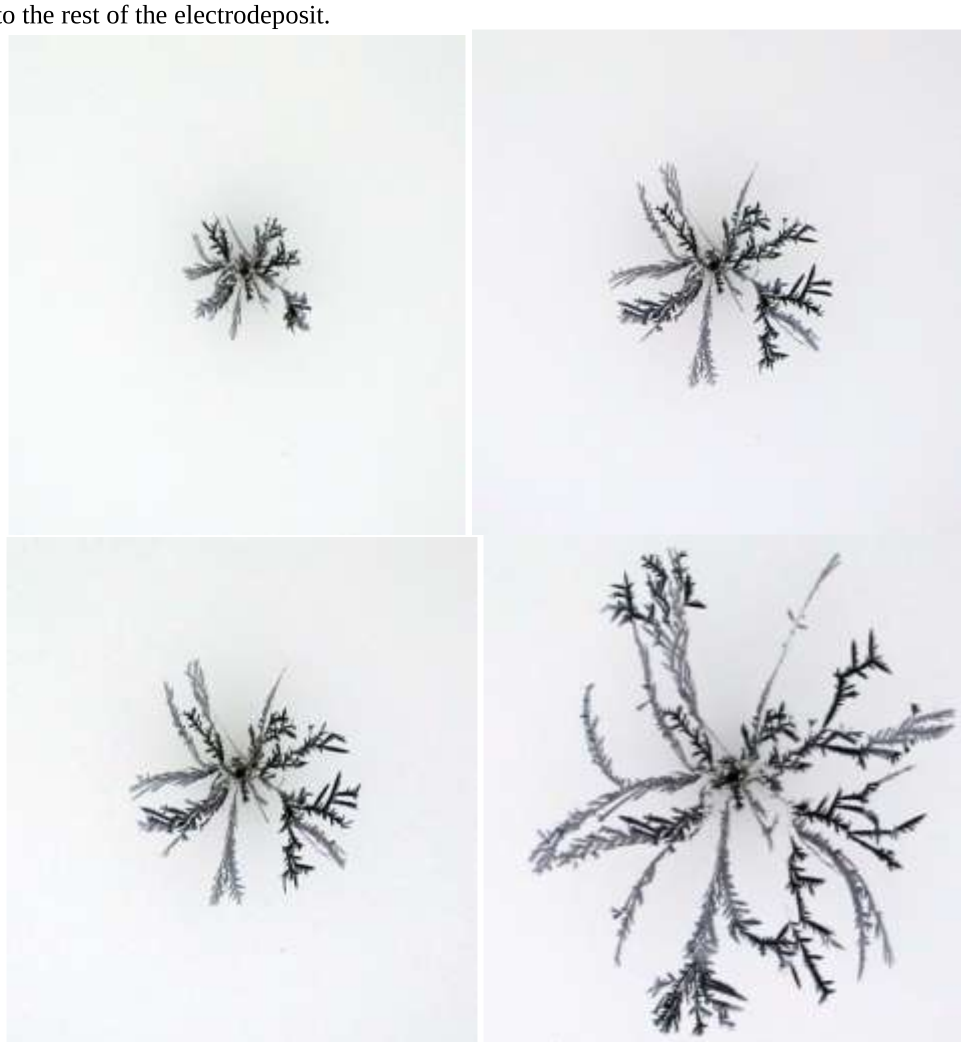

**Fig. 1** Four stages of growth of electrodeposits of Zn from 1 M Zinc sulphate solution at cell operating voltage of 5

This difference of angles between branches causes the difference in contrast from point to point in the electrodeposit. A typical electrodeposit obtained using 1 molar zinc sulphate solution is shown in Fig. 1 were four different stages of growth taken at interval of 1.5 minutes are shown. The presence of secondary and tertiary branches is clearly seen and the different in contrast for different regions of the growth patterns is also visible. As the branches grow in size, at times they tend to fall down because of their weight and thus the branch is bent or turned at some point. Before folding the branch was proceeding in its original direction in straight manner, after it turned it changed the direction as is seen from the vertical folded branch.

The developed stage of electrodeposition of Fig. 1 at a time of 6 minutes after the commencement of the electrodeposition is shown in Fig. 1 as the last image at the bottom. All the branches have developed in the form of dendritic leaves with secondary and tertiary branches in specific directions making same angle with the main branch. If the branches grow in vertical plane, the leafy branches tend to be unstable and roll around and are bent forming curved branches. As the growth becomes larger in size, the space between the actual metallic growth and the outer anode is substantially reduce, this reduction in the distance between the growth attached to the cathode and anode causes substantial increase in the local electric field at the growing tips of the electrodeposit. This excess of electric field modifies further growth pattern. In the high electric field conditions the branching is enhances and growth becomes faster with increased current.

The current through the electrodeposition cell increases initially at a faster rate and then after some time it increases more or less linearly with time. Keeping all the cell operating conditions such as circular anode diameter, molarity of the electrolyte, cell operating voltage and the temperature etc constant when experiments were conducted at three different cell operating voltages, the current through the cell was higher at the higher cell operating voltages. The current through the cell as a function of time for three different cell operating voltages of 5, 7 and 10 V are shown in Table – 1 and the same is presented graphically in Fig. 2.

**Table – 1** Current through electrodeposition cell at different cell operating voltages.

| Time (minutes) | Current in mA at different Cell operating voltages | | |
|---|---|---|---|
| | 5 V | 7 V | 10 V |
| 0 | 15 | 32 | 71 |
| 0.5 | 20 | 58 | 134 |
| 1 | 22 | 67 | 153 |
| 2 | 25 | 77 | 188 |
| 3 | 26 | 87 | 229 |
| 4 | 28 | 95 | 267 |
| 5 | 29 | 106 | 312 |
| 6 | 30 | 117 | 348 |
| 7 | 31 | 136 | - |
| 8 | 31 | 151 | - |
| 9 | 32 | - | - |

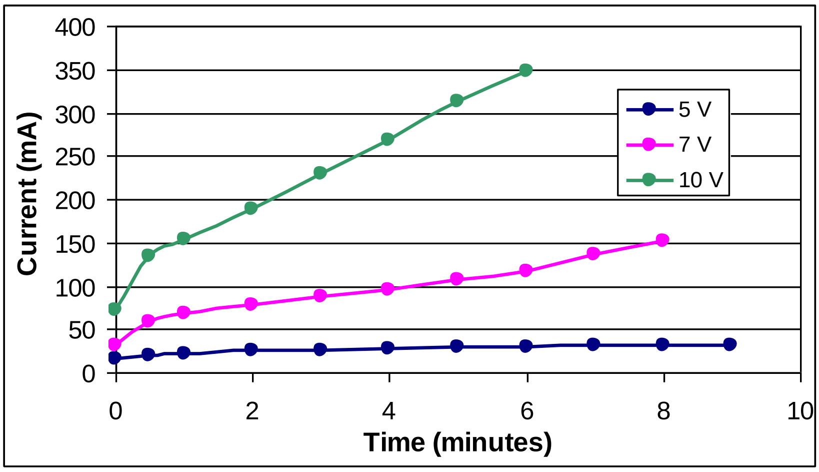


**Fig. 2** Current through the electrodeposition cell as a function of time for three different cell operating voltages for 1 M Zinc sulphate solution as electrolyte.

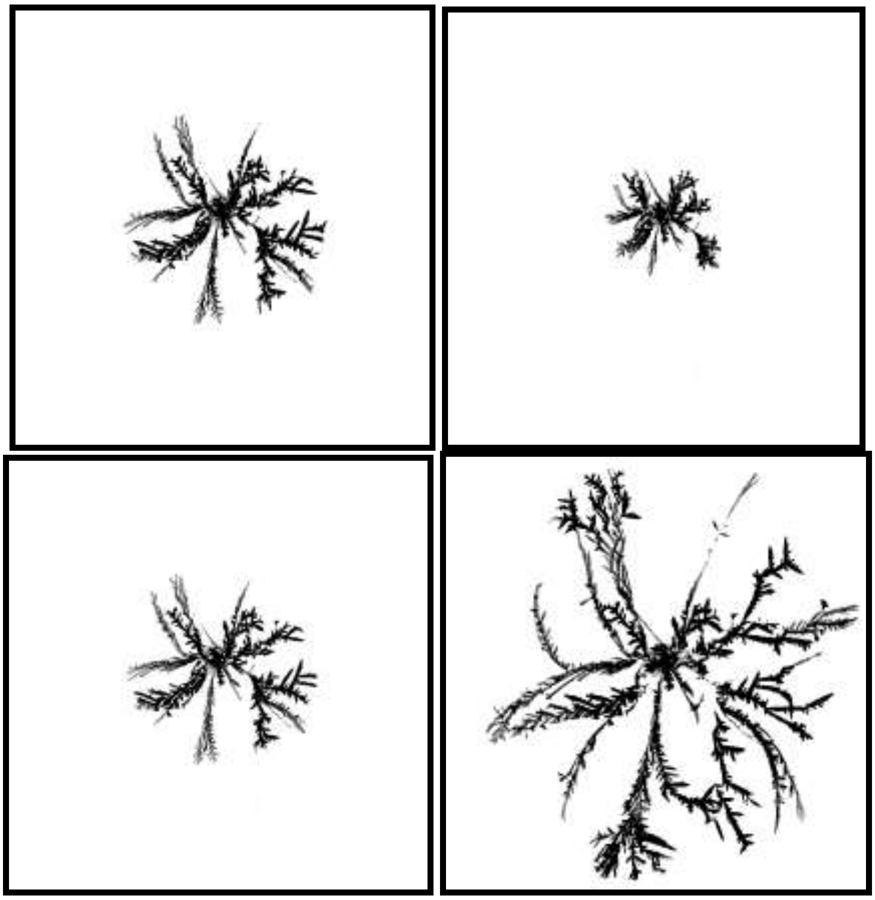

**Fig. 3** Four stages of growth of electrodeposits of Zn from 1 M Zinc sulphate solution at cell operating voltage of 5 V after converting into two colour bitmaps.

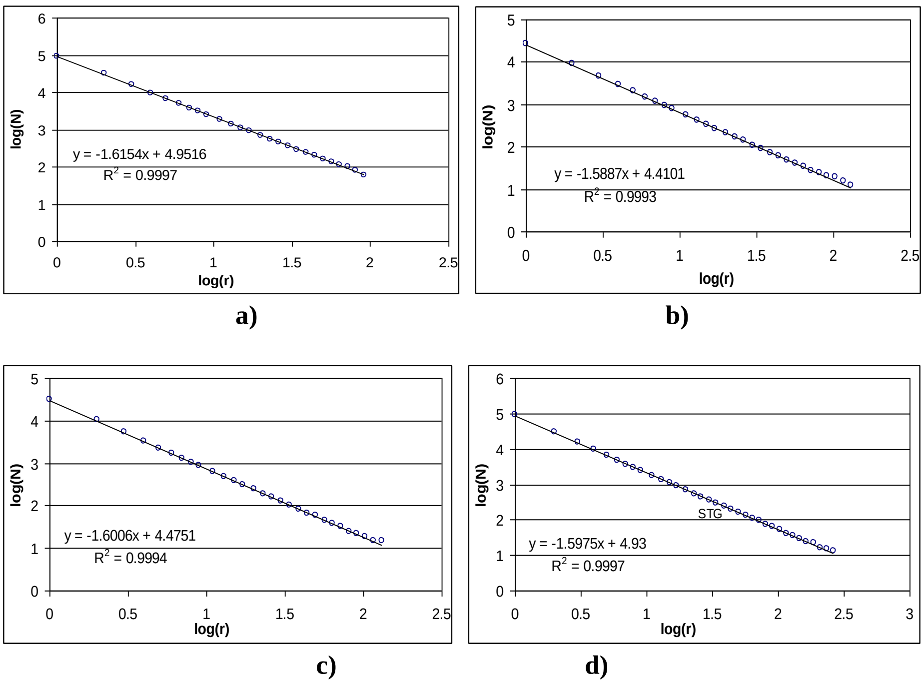


**Fig. 4** Showing the log(N) versus log(r) plots for the four stages of electrodeposition of zinc from ZnSO4 solution respectively.

The four images of different stages of electrodeposition were converted to two colour bitmap images for the purpose of implementation of the box counting technique to obtain the power law exponent and the fractal dimension to study the degree of complexity of shape in terms of structure and texture of the image. The two colour bitmap images obtained from images of Fig. 1 are shown in Fig. 3.

The four images were subjected to box counting using a computer program to find out the number of boxes (N) of size (r) required to completely cover the image, the box sizes here are in pixels and the unit of box size does not play a role in estimation of power law exponent or fractal dimension. The log (N) versus log(r) plots for the four patterns are shown in Fig. 4. The points plotted are the actual data obtained from box counting and the straight line joining these point is the best fitting straight line to this data obtained using methods of least squares and the equation shown in the inset is the equation of this fitted straight line. The power law exponent is obtained from this best fitting straight line taking the slope which is the coefficient of x in the equation.

The Fractal dimension of the pattern analysed is equal to negative of the slope which represents the degree of complexity of shape associated with the pattern analysed. It is found that the slopes of all these patterns are more or less identical and hence the fractal dimension indicating similar degree of complexity of shape.

## III. CONCLUSION

It is successfully demonstrated that the electrodeposits of zinc obtained from 1 M zinc sulphate solution under conditions discussed possess self similarity and scale invariance and exhibit fractal character. It is also shown that the irregular shapes like the dendritic patterns shown in Fig. 1 can be characterized by using fractal geometry and the fractal dimension that describes the complexity of shape associated with the pattern analyzed. The fractal dimension is an index to the complexity of shape associated with the structure and texture of the irregular shape. It is shown that the four electrodeposited patterns are very much different in appearance however the degree of complexity associated with the patterns is not much different as the fractal dimensions are in the range of 1.5887 to 1.6154. A higher fractal dimension represents a higher degree of complexity and vice versa.

## REFERENCES


[1]. Sander Leonard M., ‘Fractal Growth,’ Scientific American, 94 (1987).

[2]. Sander L. M., ‘Diffusion Limitted Aggregation,’ Contemporary Physics, 41,203 (2000).

[3]. Witten T. & Sander L. M., Phys Rev lett. 47, 1400 (1981).

[4]. Meron Ehud, Phys Rep, 218, 1 (1992).

[5]. Cross M C & Hohenberg P C, Rev Mod Phys, 65**,**851 (1993).

[6]. Family F. & Landau D. P. edited ‘kinetics of aggregation and gelation’ (Noth-Holland, Amsterdam)( 1984).

[7]. Starzyk C F, Polimery, 37, 298 (1992).

[8]. Heinz O.P, Hartmut J. and Diemar S., ‘Chaos and Fractals’ New Frontiers of Science, 697(New York: Springer-Verlag)(1992).

[9]. Pablo F.J. Deleon,Ezequiel v. Albano, and Salvarezza R.C., ‘ Interface dynamics of copper electrodeposition Phys Rev E 66, 042601(2002).

[10]. Razdan Ashok, ‘Bombay Stock Exchange Index’ Pramana – J. of physics, 58, 3, .537 (2002).

[11]. Mandelbrot B B.,‘Fractals and scaling in finance’ (Springer, New York, 1997 edition).

[12]. Shaikh Y H ’ Ph.D Thesis ‘Studies in Growth Pattern and Fractals’ Dr. B.A.M.arathwada University, Aurangabad (2001).

[13]. Alexander S and Orbach R, J. Phys. Lett, 43 L625, 1984