ISSN : 2393-8188 (print)
2393-8196 (online)
www.milliyasrcollege.org.journal.php

Time History Evolution Of Zinc Dendritic Pattern: A Fractal Approach

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Abstract: In this paper concept of fractal and time history evolution of fractal dimension of complex zinc metal dendritic pattern discussed and studied from the 0.25 molar zinc acetate electrolyte solution at specific cell operating conditions using circular cell geometry .It is found from the characterization of selected dendritic patterns that it possesses self-similarity and scale invariance which is demonstrated using Log (N) versus Log(r) plot in box count technique and slope of this plot estimated the fractal dimensions.

Keywords: Dendritic Pattern, DLA, Fractal Dimension.

1. INTRODUCTION

Electro-deposition in circular cell geometry under the different operating condition produces dendritic patterns or tree like patterns which shows scaling behaviour and fractal characteristics. Experimental studies of growth of fractals and dendritic patterns are well suited in electro-deposition processes [1]-[3]. Physicists took keen interest in the study of fractals and related studies after the boom of fractals [4]-[6], which began in 1980. Electro-deposition and viscous fingering [7],[8] have received the major attention. The concept of fractal and non-fractal aggregation is applicable in physics especially in dendritic growth, flocculation, coagulation, turbulence [9],[10], polymerization [11],[12] and crystallization. Gelation process also exhibits self-similarity and fractal character in many cases. To explain the complexity of irregular shapes that could not otherwise be quantified was explained by very useful different fractal models. The concept of fractal model is being effectively used for the random events like prices of shares in the share market [13],[14] and forecasting. Self-similar patterns [15] and fractal character is also observed in some of solidification processes. Patterns formed by discharge of liquids like water into the soil or flows through coffee grains or materials in the form of fine particles, are described by fractals known as percolation clusters [16],[17].

2. RESULTS AND DISCUSSION

The time history of evolution of the dendritic patterns presented here is for growth at a cell operating voltage of 7 V DC and Zinc Acetate $Zn(O_2CCH_3)_2$ solution of 0.25 molar. The still camera was kept ready and photographs have been taken approximately in the interval of 0.3-0.4 minute initially due to fast growth and at later stage the growth start stabilizing so photograph take at interval of 3-4 min approximately. Fig.1 below shows these frames indicating different stage of growth of the electro deposition. The first frame at t = 0 is not included and the first frame which is shown the Fig.1 is of approximate after 4 minute.

After taking the photograph, it is edited to remove the outer anode in the form circular shape removed for the further analysis of the image then the images were converted to 2 bit black and white images, selecting suitable threshold. The final images after processing are shown below in Fig. 2.

It was observed that from the fully-grown pattern at approximately t = 16 minute, there are very thick primary, secondary and tertiary branches of irregular pattern are seen, however many prominent main primary branches could be identified.

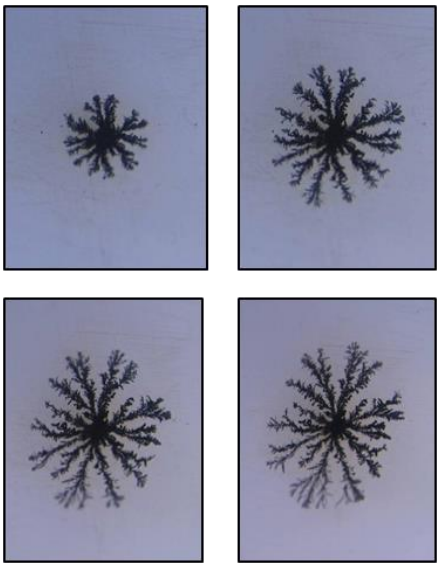

Fig. *Original image Sequence of 0.25 molar Zinc Acetate $Zn(O_2CCH_3)_2$ under operating condition of 7V*

Growth is constant during the stages with very thick primary branches and major formation of secondary branches takes place during this stages. To study the variation in branching patterns, we analyzed the dendritic patterns using the box-counting techniques for the characterization of the patterns in terms of the fractal dimension. The fractal dimension was found for the different stages during the growth of the branching dendritic pattern.

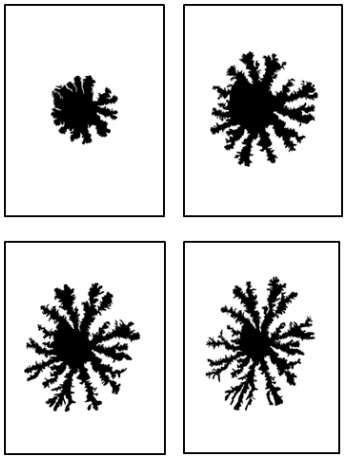

Fig. 2 *Two color bit image Sequence of 0.25 molar Zinc Acetate $Zn(O_2CCH_3)_2$ under operating condition of 7V*

The box counting technique was used to analyze these files using different sizes of the box (r) and the number of boxes needed to cover the pattern was recorded as N. By taking Log (N) on the y-axis and Log (r) on the axis of x, a graph was then plotted. Final plots are shown in Fig.3 to 6.

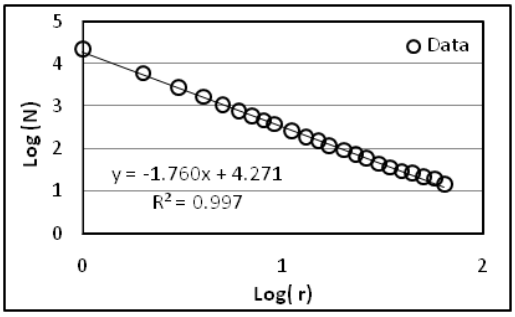

Fig. 3 *Plot of Log(N) versus Log(r) for first image of Fig.1*

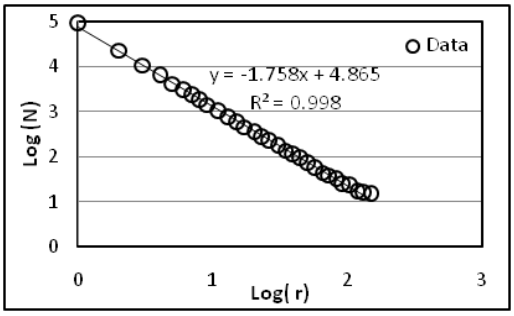

Fig.4 *Plot of Log(N) versus Log(r) for first image of Fig.1*

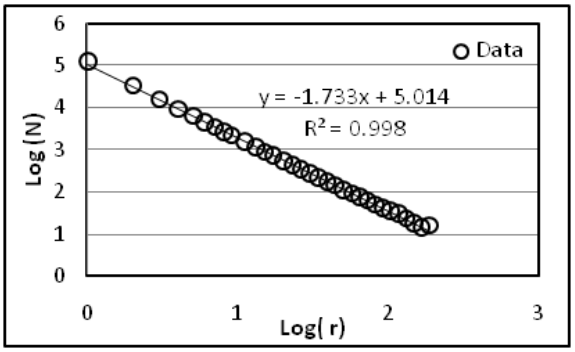

Fig. 5 *Plot of Log(N) versus Log(r) for first image of Fig.1*

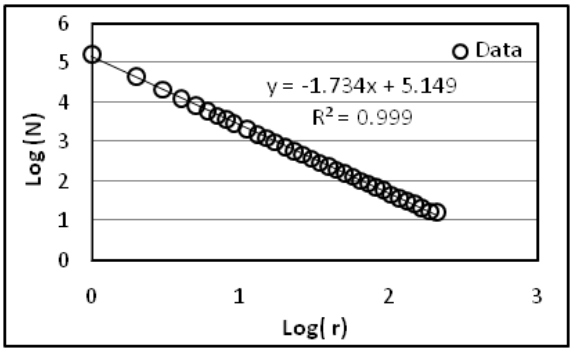

Fig. 6 *Plot of Log(N) versus Log(r) for first image of Fig.1*

It is observed that all the data points lie near to a straight line that is shown by the corresponding value of R^2. Frames 16, 21,23 and 25 are analyzed for fractal dimension as frame 1 is the starting frame with no growth and other initial frames has very limited growth to be analyzed.

Table 1 Stage-wise fractal dimension of Zinc Acetate $Zn(O_2CCH_3)_2$ of 0.25 molar under operating condition of 7V of Fig.1

Frame No.	Fig. No.	Time (min)	Dimension	R^2 value
1	-	0.00	-	-
16	3	4.00	1.760	0.997
21	4	8.00	1.758	0.998
23	5	12.00	1.733	0.998
25	6	16.00	1.734	0.999

The equation of best fitting straight line to the data points and the R^2 value is given in the inset of the plot. The outcomes obtained are presented in Table –1.

It is seen from Table –1that the fractal dimension decreases with the progress of the growth. The patterns are photograph at the time interval of approximately 0.3-0.4 minute initially due to fast growth and at later stage the growth start stabilizing so photograph take at interval of 3-4 min approximately and very much resemble the DLA patterns, this is also manifest from the fact that the fractal dimension of the dendritic patterns lie near to 1.730-1.760 that is the DLA characteristic. From the Table-1 it is seen

that the value of R^2 is very near to unity indicating that the Log (N)-Log (r) plot best fits to a straight line. This result shows that the fractal character of the dendritic pattern applies over a wide range of length scale.

3. CONCLUSIONS

It is seen from Table-1 that the fractal dimension is not stabilized with the progress of the growth. The patterns are photographed at the time interval of approximately 0.3-0.4 minute and very much resemble the DLA patterns, this is also manifest from the fact that the fractal dimension of the dendritic patterns lie near to 1.750 that is the DLA characteristic From the Table –1 it is seen that the value of R^2 is very close to unity indicating that the Log (N)-Log (r) plot best fits to a straight line. This result shows that the fractal character of the dendritic pattern applies over a wide range of length scale.

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