Analysis of Fractal Growth in Electrodeposition Cell

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Research Article

Abstract: The theory of fractals arose from the geometry of irregular self-similar shapes. the dimensions of such shapes are not necessarily whole number but the fractions. These dimensions arc called 'Fractal dimension'. Depending on the geometry and the nature of problem different techniques are employed to determine the Fractal dimension. The present work includes the growth or fractal shapes from the electro deposition technique and the determination of the fractal dimensions of such shapes resulting from growth under different conditions. The electrodeposits are obtained under controlled conditions of applied field, current. etc. The variation of shapes and the structure and texture of deposits is reflected in the fractal dimensions of the growth and helps in understanding the DLA growth process.

Keywords: Electro deposition Fractals.. Self similarity.

Introduction

Electrochemical deposition technique was used for growth of dendrites using different metals. The characteristics of patterns obtained using copper sulphate solution are presented. Fractal shapes grown under controlled conditions provide quantitative in formation and deeper insight about the process governing the growth, namely the diffusion limited aggregation (DLA)[1]. Appropriate choice of shape of electrode and geometry allow for controlling the proportion of aggregation. The deposits obtained are photographed and then are digitized and converted into a matrix for further processing. Computer program are developed to handle such a data and perform the desired type of counting. Different techniques are employed for characterization of fractal dimension. For the present case, box-counting method was employed[2]. The fractal dimensions obtained for good DLA pattern are 1.66. Growth under strong fields gives rise to excessive branching and the shapes so obtained deviate more from the DLA as is seen from the change in fractal dimension[3].

Experimental

Different type of electro deposition cells are constructed using standard methods. The cell has to be flexible in the sense that changing or electrodes should not come in the way or photography, and at the same time for realistic two dimensional growth, as small as the level of solution in the should be used as possible. As the electrolyte level is increased this results in three dimensional growth. Compounds of copper, Zinc, Nickel. Cobalt, Lead, Silver, Tin are used to obtain the growth patterns. While using the solution of copper sulphate in the cells deposition begins slowly and after few minutes a self-similar pattern gradually appears in the cell. An increase in voltage results in faster rates or deposition and at higher applied voltages the increased in electric field causes increased branching or the deposits[4]. Fig. 1 shows it growth obtained using copper sulphate solutions at moderate operating voltage. After certain stage, the applied voltage in increased. This is clearly seen in the figure as after certain stage growth, the branching is suddenly increased. Different solution and concentration a cell geometries require different operating voltage for good two-dimensional DLA growth, at higher voltages the effect of ballistic growth tends to dominate. We varied the voltage from 2.5 V to 30 V during various trials. Photographs of patterns are taken with the help of sensitive SLR camera with close up attachment.

Effect of Concentration

Concentration of solution played all important roles in shaping the pattern. We found that slight change in concentration create a considerable change in the branching pattern. This is in agreement with the fact that at higher concentration more ions tend to move toward cathode making the situation deviate more and more from true DLA[5] and at last deposits with more branches result. We used the solutions or different concentrations starting from 0.1 M to 1M.

Effect of Current

Above experiment is repeated by changing the current also, we found that constant current produces essentially better patterns. We varied the current from 0.1

A to 3 A, In certain cases like Nickel, excessive current is needed which in turn results in heating at the growth site[6]. The solution also heats up and the material of the cell tends to deform as the depositions take long time ill such cases. Also at higher currents bubbling is vigorous at the deposition site and keeps on dislodging freshly grown tender branches.

Description of cell

The cell used for the deposition studies was made from acrylic sheet of 1.5 mm thickness. Milky coloured sheet was used for photography against the light. On the one square foot sheet around border was made, about 6 inches in diameter, using the same material and appropriate adhesive. At the centre of the cavity a 0.8 mm hole was drilled to accommodate the cathode. The cathode material was carbon obtained from pencil (for thin cathodes the material does not matter much except for micro surface structure supporting crystalline growth). The anode was made from a block of carbon 12 mm thick, cutting a hole of about 3 inch diameter in it. The electrodes were placed in position and small quantity of solution was poured into the cell for form a thin layer of the electrolyte. Behind the milky cell a lamp was placed to illuminate the cell, with the light of the other side photographs with good contrast were obtained.

Determination of Fractal Dimension

The photographs after digitizing were stored in computer file in the form of a matrix [7]. The presence of image (mass) at a location was represented by one (1) and the absence of image (no mass) was shown by zero (0). This file was then used for further analysis by placing boxes of different sizes on the matrix and finding out whether the box is occupied or not. The boxes which are occupied were counted as ‘n’ and the size of the box (side) was noted as r. The above procedure was implemented by a computer program developed in Turbo basic for speed. The boxes of different sizes are used and a table of n, r, log (n), log(r) is stored in the output file. This file is directly imported in a spreadsheet for plotting the graph of log (n) versus log (r) the slope of which gives the fractal dimension in fig. 2. Least square fit [8] was also applied to the data this shows very good correlations the slope obtained from the fitting gives the fractal dimension. The points in the figure are actual points plotted and the line joining them is the least square fit to the data. The figure shown (1) is for growth of copper and very much resembles DLA growth and has a dimension of 1.6.

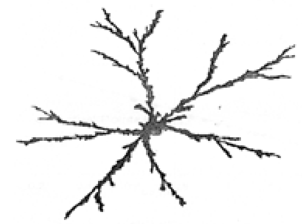

Fig 1.0 fractal growth for copper
scale 1cm=3 cm

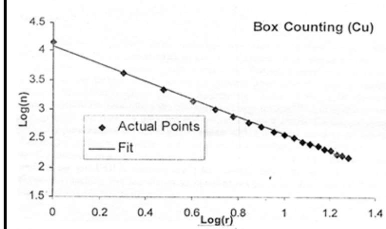

FIGURE : 2

Discussion and conclusion

With the availability of fast computational tools and efficient software the bulky time consuming task of characterizing of irregular shapes with fractal dimension has now become simple using the technique discussed above. Repeated trials may be carried to reduce statistical variation arising from the starting point. At low applied voltage the growth is slow and the resulting shapes are more close to the DLA patterns with fractal dimension of 1.6. At relatively higher applied voltages the growth is faster with more of branching. The treatment of data or such growths also exhibits scale invariance over appreciable range confirming the fractal nature, of course the patterns are more compact with higher fractal dimensions indicating deviation from DlA.

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