ABSTRACT

Irregular Shapes in Electro Deposition and Random Phenomena: A Fractal Approach

The concept of fractals and fractal geometry is studied in detail and different methods of characterization of irregular shapes also studied. The growth of dendritic and fractal patterns using both electrodeposition and electroless deposition is studied and selected cases are analysed for characterization of the irregular shapes grown.

The cell operating conditions play an important role in determining the nature and shape of metal deposition both in electrodeposition and electroless deposition. During the study it was observed that dendritic patterns of Nickel cannot be grown using electrodeposition at room temperature. Careful systematic investigations revealed that the DLA like conditions required for the growth and development of dendritic patterns cannot be realized at room temperature for electrodeposition of Nickel. In view of this series of experiments were conducted to explore the growth of dendritic patterns under different temperature conditions using copper sulphate as electrolyte for deposition of copper dendrites. The study suggested that at room temperature DLA like conditions cannot be realized for electrodeposition of Nickel, however in a narrow cavity it should be possible to produce DLA like conditions in electroless deposition of Nickel. Therefore we conducted
preliminary experiments for electroless deposition of Nickel using electroless deposition technique and we successfully grew dendritic patterns of Nickel. Electroless deposition of nickel is not reported in literature till date and we are the first to produce the electroless deposition of nickel in the form of dendritic patterns exhibiting fractal character and self-similarity [1 – 5].

Techniques for determination of fractal dimension using box counting technique are developed and implemented on selected dendritic patterns deposited using electrodeposition and electroless deposition technique. Real time growth process was also monitored using suitable time steps and different parameters like current through the cell and branch lengths and average size were monitored. No serious information came out of this part of study except for few important findings discussed above. The variations of electric current versus time through the electrodeposition cell are presented and one representative case of size of branch versus time is also included for the sake of completeness.

The thesis is organized in five chapters with the first chapter covering the overview of the field of fractals and related concepts and different types of fractals like natural fractals, artificial fractals and mathematical fractals. With the help of typical examples the concept of limited scale invariance and scale invariance overall length scales is discussed. The relevance of the fractal concept to biological images and natural objects is also included [6 – 8]. Mathematical concepts like Koch curve, Sierpinski triangle and Hilbert curve
are also discussed. Some relevant application of the concept of fractal in science and technology are also covered.

Second chapter deals with detailed discussion of different methods and techniques used for the estimation of fractal dimension of irregular shapes and patterns in different situations after a brief account of relation of fractals with nature. Box counting technique is the most commonly used method of determination of fractal dimension of objects in a plane. The related power law and power law exponent is also discussed and the implementation technique described using illustration with actual copper fractal grown. Some critical aspects like choice and selection of the origin in the implementation of the box counting technique are also included. The implementation of box counting technique for irregular curves is also discussed, however in such cases at times, Richardson’s plot technique or ruler method work well. Divider compass method, ruler method, mass radius method, area perimeter method and the concept of Hausdorff method are also included in addition to the introduction to the concept of self similarity and scale invariance in second chapter [9 – 13].

Third chapter deals with the actual implementation of the electrodeposition of dendritic patterns using electrodeposition cell in circular geometry. Necessary concept and initial background is also included. Details of design and construction of the electrodeposition cell in circular cell geometry are discussed. As the underlying principle for the growth of dendritic patterns in electrodeposition is the Diffusion Limited Aggregation (DLA) a brief account of DLA is also presented [14 – 17]. The experimental setup used for
study of electrodeposition in circular cell geometry at different cell operating temperature is also presented. Time course of change of current, actual growth of electrodeposits and the analysis of the deposited pattern for fractal dimensions is presented at different temperature and details of findings are discussed.

Chapter four is devoted to Electrodeposition of lead and zinc at room temperature. Electrodeposition of lead in circular cell geometry is studied at different cell operating voltages of 3, 5, 7 and 10 Volts and the change of current with respect to time is presented. Few stages of each of the electrodeposits obtained during aforesaid experiments are also presented along with the fractal analysis tables and plots for determination of the fractal dimension to find out the irregularity of shape in terms of structure and texture. The fractal dimensions obtained and the findings presented and results discussed [18 – 20]. Electrodeposition of Zinc is also studied using cell operating voltage of 5, 7 and 10 volts. Few selected stages of electrodeposits in each case are presented to show the time course of development of the shape of grown patterns. Fractal analysis of the final growth (last stage) is presented in the form of tables and graphs used in the determination of fractal dimensions. Fractal dimension of the electrodeposits of zinc obtained at 5, 7 and 10 volts are presented and the findings and results discussed.

Chapter five presents the study of electroless deposition of lead, nickel and copper, using electroless deposition cell in planar cell geometry [21 – 23]. The design and construction of electroless deposition cell is presented and the
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electroless deposits obtained are presented along with the fractal analysis of the deposited dendritic patterns that possess fractal character. The branching patterns grown in electroless deposition exhibit fine branching patterns, an electron microscope image of electroless deposition of copper is shown wherein branches are in the range of 10 to 30 microns. We are proud for reporting for the first time the electroless deposition of Nickel and presenting fractal characterization of such electroless deposits of nickel. Tables and log(N) log(r) plots for selected deposits analysed and fractal dimension are presented also findings and results discussed.