Research Article

A Review on Methods used to determine Fractal Dimension Analysis of AFM Images of Thin Film

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ABSTRACT

This aims the applications in the field of surface analysis and study of structure of different materials. The purpose of this examination is to additionally research the ultra-structural details of the surface of thin film using atomic force microscopy (AFM) images. The fractal dimension, gave quantitative qualities that describe the scale properties of surface geometry. Detailed identification of the surface geometry was obtained using statistical parameters. The analyzed AFM images confirm a fractal nature of the surface, which is not taken into account by classical surface statistical parameters. In this paper, we present a review on different methods used to determine fractal dimension of AFM images of thin film.

KEYWORDS:Fractal dimension, AFM images, Thin Film.

I. INTRODUCTION

Thin films, having thickness from 1 nm to 1000 nm are extensively used in different branches of science and technology (Fang et al.,1996).Their properties are being studied both experimentally and theoretically. The thin film preparation is a high technological process which requires high control on the deposition condition.

Cadmium Sulphide is a suitable window layer for solar cells and also finds applications as optical filters and multilayer light emitting diodes, photo detectors, thin film field effect transistors, gas sensors, and transparent conducting semiconductor for optoelectronic devices. Among the various known methods to synthesis cds thin films; the reliable, simple and cost effective route is one using the chemical bath deposition (CBD) technique.

The wide technological applications of cds type materials make the PL studies important. Some of the important applications of PL are lamp phosphors and display devices, xerography and IR detectors etc. The effect of alloying of cds, cdse and other II-VI group compounds on the PL and PC properties has attracted the interest of research workers in recent years. The rare earth ions are well known to form efficient luminescent centers as they show.

In this paper we study fractal dimension of analysis of AFM images of thin film by different fractal dimension analysis methods.

II. FRACTAL DIMENSION

The fractal dimension is an important characteristic of fractals because it has got information about their geometric structure. In 1982, fractal geometry was first introduced by (Mandelbrot,1983)which is useful for the study of complex structures. Many complex objects founds in nature such as coastlines, mountains and clouds. These objects are too complex to possess characteristic sizes and to be described by traditional Euclidean geometry.

Definition: The dimension is simply the exponent of the number of self-similar pieces with magnification factor N into which the figure may be broken. So we can write

$$dimension = \frac{log(number\ of\ self - similar\ pieces)}{log(magnification\ factor)}$$

MATHEMATICALFORMULATION OF FRACTAL DIMENSION:

Fractal dimension D can be defined in the form;

$$1 = N_r(A).r^D$$

Where;

D= Fractal dimension,

A= bounded set in Euclidean $n - spcae$,

$N_r(A)$ = Distinct non-overlapping subsets,

Taking logarithm on both sides, we have to find

$$D = \frac{\log N_r(A)}{\log(\frac{1}{r})} \qquad (1)$$

The D can only be calculated for deterministic fractals.

For example, A line can be break into 2,3……etc. self-similar subsets with ratio 2, 3…. respectively. Then the dimension of a line is 1 because for different values of $N_r(A)$ and $\frac{1}{r}$ the equation (1) is satisfied only when D=1.

$$D = \frac{log\, N_r(A)}{log(\frac{1}{r})} = \frac{log\ 2}{log2} = 1$$

Again, a square can be break into 4,9…..etc. self-similar subsets with ratio 2, 3….respectively. Then the dimension of a square is 2 because for different values of $N_r(A)$ and $\frac{1}{r}$ the equation (1) is satisfied only when D=2.

$$D = \frac{log\, N_r(A)}{log(\frac{1}{r})} = \frac{log\ 4}{log2} = \frac{log2^2}{log2} = \frac{2log2}{log2} = 2$$

Similarly, a cube can be break into 8,27…..etc. self-similar subsets with ratio 2,3….respectively. Then the dimension of a cube is 3 becausefor different
values of $N_r(A)$ and $\frac{1}{r}$ the equation (1) is satisfied only when D=3.

$$D = \frac{log\, N_r(A)}{log(\frac{1}{r})} = \frac{log\ 8}{log2} = \frac{log2^3}{log2} = \frac{3log2}{log2} = 3$$

II. METHODS OF DETERMINATION OF FRACTAL DIMENSION

The non-integer fractal dimension associated with any fractal gives an indication of how much area a fractal object occupies the shape in which it is contained.

Review of literature shows that there are a number of ways to determine the fractal dimension of a given image or object. The different methods for calculating fractal dimension are the Fourier power spectrum of image intensity surfaces by (Pentland,1984). (Peleg et al.,1984) adoptedMandelbrot idea of the $\varepsilon - blanket$ method. (Clarke,1986) used the concept of triangular prism surface method.

(Ju et al., 2009) introducesa new algorithm called the divisior-step method. Recently, some authors developed the popular reticular cell – counting method which improved upon by incorporating probability theory. Later, (Kellar et al., 1989) proposed probability box countingand (Chen et al.,1993) gave evenmore interesting theories. (Sarkar et al., 1994)modified method named Box counting method.

(Lopes et al., 2009)summarized and classified those methods into three major categories: the box – counting (BC) methods, the fractional Brownian motion methods and the area measurement methods.

(Bisoi et al., 2001)studied thecell counting method. Recently, (Li et al., 2009)developed a box-counting based method for the improvement of the FD estimation.

The interest in fractal image coding has been steadily growing. (P. Podsiadloetal., 2000) developed anew fractal method, which is known as partitioned iterated function system (FD-PIFS).

In recent years, many researchers have used IFS theory to obtain fractal dimension of attractors analysis of AFM images of thin film has been extensively studied.

All the above methods box counting method and power spectrum method are very interesting and accurate. However, we have discussed some ofthefew methods which are related to our research work:-

1. BOX COUNTING METHOD:

Box- counting method is the one of most popular method for finding the fractal dimension of one dimension and two dimensional data. This method is originated by (Voss,1986)by incorporating probability theory. In this method, a grid of n −dimensional boxes or hyper-cubes are formed on the fractal surface and then count how many boxes of the grid are covering part of the image. For fractal analysis of images, the fractal surface is covered with cubes. The fractal surface is covered with boxes of size $N \times N$ where, N is a power of 2. Using the box counting method a graph is plotted between $logN$ on the$Y - axis$ and value of $log\delta$ on the $X - axis$.The slope β of the line shows the fractal dimension of the image. The fractal dimension is defined by -

$$Fractal\ Dimension = -\beta$$

Dimension calculated by box counting method is known as the box or Minkowski dimension. For a smooth one-dimensional curve. It is expected that

$$N = LogN/Log\delta$$

Where,
L is the length of the curve.
$N$is the number of nonempty boxes.
δ is the size of the box.

2. POWER SPECTRUM METHOD:

Power spectrum method is based on the fractional Brownian motion. In this method Fourior transformed image is formed. Fourier transformed image is formed by analysis of fractal image. The power spectrum determined and then all these power spectra are averaged. Fractal dimension can be determined by the following formula;

$$D_F = \frac{7}{2} - \frac{\beta}{2},$$

Where, β is the spectral exponent.
The index β is related to the Fourior transform Dimension, D_F. The value of the spectral βandD_F, can be found out for the input signal by fitting a least squares error line to the data.

3. TRIANGULAR PRISM METHOD:-

The triangular prism method utilizes imaginary three-dimensional prisms constructed from the image, and then compares the total prism surface area with the step size used to derive the prisms in adouble logarithmic regression. The slope of the regression is then used to estimate thefractal dimension. Specifically, a triangular prism is constructed by connecting four adjacent pixels which is the pixel intensity value and the height of each corner pixel is the pixel intensity value and the height of the center takes the average of the four corner pixels. The step size is the number of pixels on a side. Given a step size, triangular prisms are constructed across the image and the total surface area of all triangular prisms calculated. The procedure is repeated for each step size. A double –log regression between the total prim surface area (A) and the area of step size (S^2) is estimated to derive the slope B, where fractal dimensions $D = 2 - B$.

III. CONCLUSION

In this paper we studied fractal dimension of analysis of AFM images of thin film by box counting, power spectrum and triangular prism method. It was found that fractal dimension by all the three methods are more or less equal. Box counting method is the easiest one among all the three methods.

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