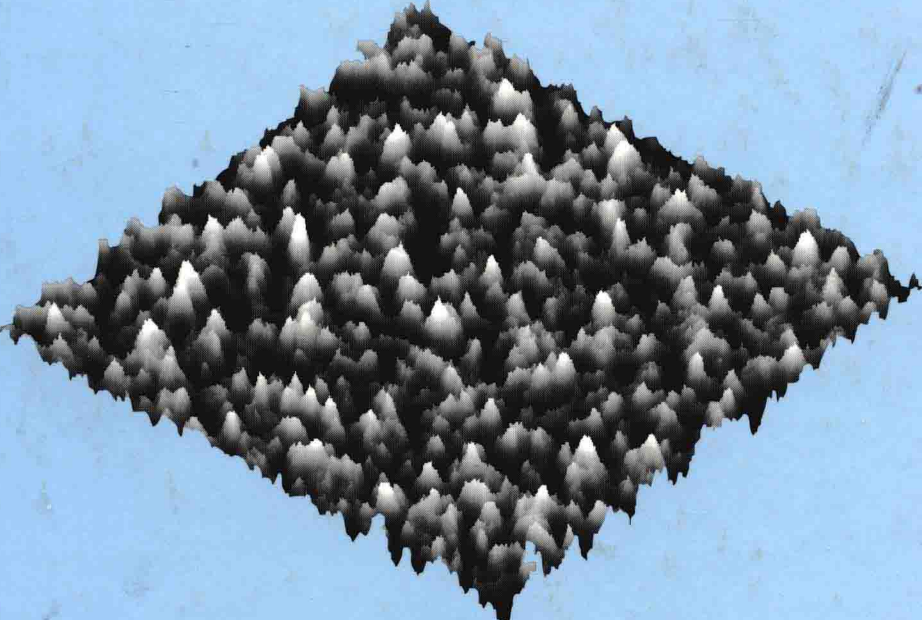
IMAGE-BASED FRACTAL DESCRIPTION OF MICROSTRUCTURES

J. M. Li, Li Lü, M. O. Lai and B. Ralph



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Fractal analysis has rapidly become an important field in materials science and engineering with broad applications to theoretical analysis and quantitative description of microstructures of materials. Fractal methods have thus far shown great potential in engineering applications in quantitative microscopic analysis of materials using commercial microscopes.

This book attempts to introduce the fundamentals and the basis methods of fractal description of microstructures in combination with digital imaging and computer technologies. Basic concepts are given in the form of mathematical expressions. Detailed algorithms in practical applications are also provided. Fractal measurement, error analysis and fractal description of cluster growth, thin films and surfaces are emphasized in this book.

Image-Based Fractal Description of Microstructures provides a comprehensive approach to materials characterization by fractal analysis from theory to application and is therefore an essential source of reference for university professors, professional engineers and research students.

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Preface

Microstructures refer essentially to a set of basic elements such as the arrangement of atoms or molecules, dislocations, grains, particles, surfaces, boundaries, etc. Many techniques such as light microscopy, scanning electron microscopy, transmission electron microscopy, atomic force microscopy, X-ray, ultrasonic, have been used in the characterization of these basic elements. Since microstructures are closely linked to the properties of solids, qualitative description from microstructures images may not be sufficient nor able to the requirements for the development of materials. Quantitative measurements of the basic elements therefore become more and more necessary. This becomes the aim of this book to introduce the science and the applications of image-based fractal to materials scientists and engineers.

To better understand material microstructures in viewpoint of fractal, we begin with classification of basic elements in microstructures. Since integer dimension in an Euclidean space is not a sufficient in describing the basic elements in microstructures, Hausdorff dimension introduced to extend the integer dimension concept. A new classification of basic elements in microstructures in terms of fractal dimension is therefore introduced together with introductions to digital image, image processing, and parameter measurement.

Measurements and processes of images are the key to accurately describe microstructures. Image processing involves the collection of information from signal processing of the 2D projections from a 3D scene including image pre-processing, object abstraction and image post-processing. The goal of image pre-processing is to suppress distortions of image and enhance features of interest for further processing. The operations include brightness and contrast transformations, image enhancement, Fourier-based spatial frequency transform, non-uniform illumination correction, and noise and filtration. Humans perform object recognition effortlessly and instantaneously whilst machine vision needs more techniques. Post-processing based on binary image is also dealt with some details. The effects of the image-processing operations on fractal measurement are also discussed in the book.

Fundamental statistics in terms of basic concepts, theorems and methods of parameter estimation are discussed to facilitate the needs for understanding fractal measurement. The topics include populations, sampling and probability; statistical measures for population, probability distribution; some useful theorems and simple linear regression analysis. Some famous examples of fractals such as Cantor set, Koch curve, Sierpinski graphics, Weierstrass-Mandelbrot curve and fractal Brownian motion (FBM) are cited. FBM and its development have been discussed emphatically, including the simulations of 2-dimensional (2D) profiles and 3D surface since they have potential applications in the description of material microstructures.

A 3D surface model called the "variation-correlation function (VCF)" is introduced. The algorithms and quantitative parameters based on this model are discussed. An approach for quantitative description of 3D surfaces is established using this model.

In addition to fundamentals of images and fractals, some applications in cluster growth, thin film deposition, semiconductor, metal solidification and fractography are also illustrated in the book. Furthermore, some new development of the analytical procedures is offered.

Fractal has changed the philosophy of measure. The fractal relations among scale, fractal parameters and conventional quantitative parameters are employed in this book to describe the fine world of fractal from nucleation to growth, from micro to macro, and from local to global.

This book is designed for materials scientists, research students and engineers. It can be used by those who are just getting into the field as well as the experienced practitioners of fractals.

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L. Lü
M.O. Lai
B. Ralph

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