Journal of Statistical Physics, Vol. 94, Nos. 5/6, 1999

Book Review: *Statistical Physics of Fracture and Breakdown in Disordered Systems*

Statistical Physics of Fracture and Breakdown in Disordered Systems. B. K. Chakrabarti and L. G. Benguigui, 161 pp., Oxford University Press, Oxford, 1998.

Failure processes in disordered materials and media, ranging from brittle fracture and ductile yielding to dialectric breakdown, constitute a set of complex phenomena that have been studied for a long time. Their practical significance cannot be overemphasized as they occur in a wide variety of systems, ranging from natural rock to aircrafts' fuselages. The traditional work on these phenomena has been based on the important work of Griffith, which by itself makes an extensive literature. However, Griffith's work is presumably valid for solids that are essentially homogeneous, and its extension to heterogeneous materials, even as simple as polycrystalline ceramics with various crystalline orientations and/or grain boundary energies, it not obvious. This has inspired development of many discrete (lattice) models of fracture and failure in which disorder is explicitly included in the model at certain length scales. This activity began with a paper of this reviewer (*Phys. Rev. B* **33**:7848 (1986)), and has become a very active research field. With the advent of more powerful computers Molecular Dynamics simulation of mechanical fracture of solids has also become feasible, and the literature on this subject is also growing rapidly.

Chakrabarti and Benguigui's monograph represents a review of some of the recent progress that has been made using such lattice models. It consists of four chapters which discuss three classes of failure phenomena, namely, electric and dielectric breakdown, meachanical fracture, and earthquakes. Chapter 1 is an introduction to the general problem of failure of materials and introduces some of the basic concepts that are used in the rest of the book, such as the percolation models of disordered media, statistics of extremes, and stress concentration.

Chapter 2 discusses electric and dielectric breakdown in disordered solids. First, the fuse problem for electric breakdown is introduced and a

0022-4715/99/0300-1057$16.00/0

qualitative analysis of the problem is given. Next, concepts such as the most probable failure paths and the current distribution in disordered solids, are discussed. Then, recent lattice models of electric breakdown are briefly described and their predictions are discussed. Also discussed is the problem of electromigration failure in polycrystalline metal films, an important practical phenomenon. The effect of several relevant factors, such the temperature of the sytstem and AC fields, are also discussed. The authors then dicuss the dielectric breakdown problem, and after a brief analysis in terms of the relevant continuum equations, they take up the lattice models. The emphasis in this chapter is on the universal aspects of these phenomena. Whenever possible, the authors also discuss laboratory and table-top experiments.

Chapter 3 discusses fracture strength of disordered solids. First, the standard concepts, such as modes of loading a solid, stress concentration, and Griffith's law are discussed. Next, the authors discuss briefly Molecular Dynamics simulations of fracture, after which fracture in solids with percolation disorder is discussed, and several useful scaling laws for the fracture properties near the percolation threshold are presented. Lattice models of quasi-static fracture are discussed next. Interesting results that emerge from such models, such as the distribution of fracture strength, and whether this is distribution is a Weibull or a Gumbel distribution, are also discussed and compared with the results of simple experiments. Finally, a brief discussion is given of dynamic fracture and the speed of fracture propagation, subjects of considerable recent research activity.

Chapter 4 is essentially a brief discussion of models of earthquakes. After a short discussion of the classical Guttenberg–Richter power law for the frequency distribution of the elastic energy released during an earthquake, the authors discuss another classical model, namely, the Burridge–Knoppoff stick-slip model of earthquakes, and its recent computer simulations. Then, self-organized critical states and their possible relation to earthquakes are discussed.

This book has several considerable strengths and a few weaknesses. It covers most of the recent statistical and lattice models of failure phenomena and earthquakes. Most of the concepts and models are explained in simple terms. The effect of strong heterogeneities, represented by a system near its percolation threshold, is discussed well. Interesting experiments, most of which were designed explicitly for checking a particular prediction, are discussed. One weakness of this book is that, some of the phenomena and their models are discussed too briefly, and therefore the reader has to go back to the original source for more details. For example, I found the chapter on earthquakes to be too short, and the discussion of the Molecular Dynamics methods to be too brief. Some of the important continuum and lattice models are not discussed at all. This is particularly true about electric and dielectric phenomena, and the fiber-bundle model of fracture of fibrous materials. Finally, each class of materials has its own distinct fracture characteristics which may not be common among all materials. For example, fracture of polymers is very different from that of rock or rock-like materials, such as concrete, but this book does not attempt to distinguish between different materials, and instead discusses failure phenomena from an essentially generic point of view. This can of course be viewed as a strength of the book.

Overall, I find this book to be useful and timely. It can serve as a convenient starting point for people who would like to begin doing research on failure phenomena and wish to learn about recent advances on statistical modeling of such phenomena. It can also be used as part of the required reading for a course on failure of materials. Finally, some of the discrete models that are discussed are simple enough that they can be taught in a course on computer simulation of disordered media, and hence the book can also be useful to such a class.

Muhammad Sahimi
Department of Chemical Engineering
University of Southern California
Los Angeles, California 90089-1211