Fractal Geometry: A Key to Understanding the Nature of Glass Fracture

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Abstract

Failure of materials affects every aspect of research, material development and production. Fracture surface features contain quantitative information about the stress and energy associated with a specific fracture event. Fracture surfaces of all materials examined can be characterized using fractal geometry. Fractal geometry is a mathematical tool that quantitatively describes irregular surfaces. Fractal objects, such as fracture surfaces, are characterized by their fractal dimension, D, which is the dimension in which the proper measurement of a fractal object is made. D* is the fractional part of the fractal dimension and represents the amount of tortuosity out of the plane. The fractal dimensional increment, D*, is directly related to the fracture energy, g, during fracture for many materials, i.e., g = E a0 D* where E is the elastic modulus and a0 is a material structural parameter. Of course, this means that D* can be related to the fracture toughness, KC = E a01/2 D*1/2, as well. These equations then provide a link to fracture mechanics and quantitative fractography. The combination of atomistic modeling, experimental measurements and the application of fracture mechanics and fractal geometry leads to a suggested sequence and organization of the brittle fracture process. By applying fractographic principles combined with fractal analysis and fracture mechanics, several different types of problems can be solved. The combined analyses can be used to determine whether a product has been manufactured properly, to identify toughening mechanisms in composites and to identify the type of loading during fracture. Examples of each application will be discussed in terms of fracture surface analysis and microstructural characterization.

Keywords: Fracture, fractal geometry, fractography, fracture mechanics

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