Summary

This volume is divided into four sections, dealing with the following areas in fractography and materials science: environment, microstructure and fatigue, nonmetallics and composites, and techniques.

The papers in the environment section illustrate that the fracture topography of the specimen is a synergistic combination of the microstructure, the chemical environment, and the loading condition. The paper by Ruppen and McEvily shows how the fracture topography of one alloy changes when different processing produces different microstructures. These authors also show that not only could the environment have an effect on fatigue fracture topography but different crack growth rates could change fracture mechanisms, which would result in different fracture topography. Meyn and Brooks, in their paper, present important evidence about a characteristic structure called a "flute," normally found in planar slip alloys. They report that in some titanium alloys greater numbers of "flutes" are associated with cleavage due to stress corrosion than are found with the "cleavage-like" structures that can result from fatigue. Fraser and Metzbower cover a broad range of treatments and alloys in high-strength steel, illustrating the interactions of microstructure with the mechanical and chemical environment. And Provenzano et al bring out the importance of microstructural contaminants in pressure vessel steels and their importance in stress-corrosion cracking.

Caskey, in his paper, uses yet another tool, X-ray diffraction, to bring out the importance of the crystal structure relationships in hydrogen-assisted fracture (HAF) of austenitic stainless steel. One of the most important parts of his paper is the evidence that the presence of martensite is not a prerequisite for cleavage in HAF of austenitic stainless steels. It was previously thought that only martensite lath structures were responsible for cleavage in HAF and stress-corrosion cracking of austenitic stainless steels.

The last paper in this section, by Mills, displays another important trend in evaluation of microstructures and fracture surfaces. Some of the significant microstructural features, particularly at grain boundaries, were too small to be resolved with conventional optical metallographic techniques. This work illustrates the trend toward using the scanning electron microscope and the transmission electron microscope (TEM) for examination of conventional

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metallographic structures. Mills also uses the TEM to examine dislocation structures and relates the fracture topography to the dislocation structures.

In the microstructure and fatigue section, four papers are primarily concerned with the effect of microstructural variables on the fracture surface topography, and two papers deal with fatigue crack growth rate studies in aluminum and steel. Steele demonstrates the importance of understanding the relationship between fracture morphology and the underlying microstructure by studying crack initiation and propagation mechanisms in several ferrous alloys. The fractographic importance of microstructural parameters, such as prior austenitic grain size, microstructural phases, and mechanical twins, is demonstrated using examples.

The paper by Wilson investigates the influence of nonmetallic inclusions on fatigue crack propagation in three different plate steel grades. Fatigue studies were performed comparing steels with conventional steel-making inclusions to calcium-treated steels with controlled morphology inclusions. The results show that the calcium treatment of inclusions improves fatigue crack propagation resistance and minimizes anisotropy for all steel grades.

Metzbower and Moon reveal the fractographic features associated with single overload fractures in laser-welded steels and a titanium alloy. The significance of the microstructure in the base plate, heat-affected zone, and fusion area on the fracture topographs is clearly demonstrated by using examples.

The paper by Datta and Wood compare fractographic features of toughness specimens tested using different strain rates. The results show that Type 4340 steel, quenched and tempered to different strength levels, was characterized by the same fracture mechanism in the origin area for each strength level evaluated, regardless of the toughness test employed.

Albertin and Hudak have determined the effect of a negative R-ratio ($R = -1$) on the fatigue crack growth rate in Type 2219-T851 aluminum alloy and correlated the macroscopic growth rate with microfractographic observations. They conclude that fatigue striation spacings for negative R-ratios were a function of ΔK and that their measurement on fracture surfaces should be an extremely useful tool for failure analysis.

Au and Ke have studied the effect of R-ratio, frequency, environment, and carbon content on the fatigue crack growth rate in Type 9310 carburized steel and observed the microscopic features as a function of the macroscopic growth rate. They found that good correlation existed between fatigue striation spacings and the macroscopic growth rate in the intermediate growth range (10^{-4} to 10^{-3} mm/cycle).

The nonmetallics and composites section represents a more recent area of investigation using fractographic techniques. With increasing use of ceramics, composites, and plastics in structural applications, the understanding of the fracture behavior of these materials has grown in importance. Because of the greater difficulty in obtaining the equivalent of conventional metallographic microstructures with these materials, fracture surface evaluation is important in helping to illuminate the actual structures of these materials. With ceramics in particular, fractography is a vital part of the evaluation of the fracture mechanics properties of ceramics.

The paper by Govila et al illustrates the use of fractography in interpreting mechanical test results of ceramics at high temperatures. These authors show that ceramics can also change in fracture mode with changing temperatures. Mecholsky and Freiman reveal how some fracture features are similar in several different polycrystalline ceramics. The paper by Abdel-Latif et al presents one point of view about the dynamic fracture of brittle materials. The authors try to relate current empirical brittle fracture equations to the multiple-mist phenomenon found in high-strength glass fractures. Adler and James, in their paper, present an interesting technique for the evaluation of impact damage to transparent materials.

Rimnac et al show the effect of molecular weight, plasticizer content, and residual orientation on the fatigue fracture topography of one particular polymer (polyvinyl chloride). These factors seem to affect the morphology and spacing of the discontinuous growth bands that are characteristic of fatigue fracture, although fatigue striations were sometimes seen at high ΔK levels.

The paper by Kim et al, dealing with an exotic metal matrix composite, introduces another useful tool in fracture analysis, Auger electron spectroscopy (AES). In these composites, subtle diffusion interactions detected by AES were shown to be responsible for brittle fracture of the tungsten fibers.

In the techniques section, many innovative techniques associated with fractography are presented by a variety of authors. Underwood and Chakrabortty show how fatigue fracture mechanisms in titanium alloys are being studied using quantitative stereological analysis of the fracture surfaces. They demonstrate that the topographics associated with the fracture surfaces can be characterized in terms of different crack roughness parameters.

Passoja and Psioda apply Fourier transform analysis to crack profiles in Type 7075-T6 aluminum specimens, which were generated using cyclic loading conditions. They show that Fourier transform analysis reveals inherent periodicities in the fracture profile. These same statistical spacings were found in the microstructure of the aluminum alloy. This paper presents a new tool that may lead to a more quantitative evaluation of fracture surfaces.

The paper by Hahn et al reveals how the position of a stable propagating stress-corrosion crack in a stainless steel (and also in admiralty metal) can be monitored by applying a small load pulse to cause limited plastic blunting at the crack tip. The authors indicate that the markings associated with the blunting can be used to determine crack velocities or to investigate whether cracking is discontinuous or continuous.

In the electronic area, Zakraysek has developed a test method for determining the quality of electrodeposited copper used in printed circuit boards. He used a mini-cup ductility test to evaluate the intergranular embrittlement of copper in the temperature range of 22 to 300°C.

Two papers involve precision sectioning techniques, which allow direct correlation between the fracture surface topography and the underlying microstructure. Nenonen et al evaluate different steels that are characterized by a bainitic microstructure and have found that the bainite packet size and orientation are very influential in the fracture process. They also indicate that tear lines and holes on the fracture surface are due to the crack changing direction at high-angle packet boundaries. Krishnadev et al apply precision sectioning techniques to evaluate high-strength low-alloy steels and iron-base alloys with different microstructures under a variety of testing conditions to gain an understanding of fracture mechanisms. In their fatigue studies at various test temperatures, the results indicate enhanced fatigue lives at low temperatures. In their single-overload studies, the results show that chemical composition, temperature, strain rate, and mode of loading affect the fracture surface topography.

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