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CERAMIC MICROSTRUCTURES '86
Role of Interfaces

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PREFACE

The Proceedings of the International Materials Symposium on Ceramic Microstructures '86: Role of Interfaces presents a comprehensive coverage of the past decade's advances in ceramic science and technology related to microstructures. The term microstructure is used in the broad sense and is synonymous with character. Character is defined as a complete detailed description of chemical and physical characteristics of a material.

This symposium is the third in a series, held every ten years, on ceramic microstructures. The first symposium, in 1966, had as a subtitle "Their Analysis, Significance and Production" and emphasized the need and importance of characterization in order to fully understand the chemical and physical properties of materials. The second Symposium, in 1976, placed emphasis on the exploration of characters most suited and needed for "Energy-Related Applications." By the time of that conference, the sequence of processing--characterization--properties was fully accepted. It was recognized that characterization was the basis of materials science; the objective of processing was to produce a desired character that was considered necessary to realize a given property or behavior. To further emphasize the importance of character, the symposium dealt primarily with the property/character coupling.

This third Microstructures Symposium emphasizes the "Role of Interfaces," which falls within the coverage of the processing/character coupling. New analytical tools and procedures, and development of greater sophistication in research approaches, have emphasized the importance and provided the impetus for exploring the nature and role of grain boundaries and interphase interfaces. In addition, this development has also sparked the initiation of studies in processing or microstructure production, with emphasis on uniformity and homogeneity, which are controlling factors in the realization of reliability.

Much progress has been made during the past ten years toward an understanding of all aspects of ceramic microstructures. The objectives of this Symposium were to explore this progress as well as to assess current activities and understanding. Major areas of discussion were the nature of interfaces and the role that they play in the production of ceramic microstructures, their characterization, and the correlation and relationship of their character with electrical and mechanical properties and behavior. Also, a group of papers dealt with reactions and adherence of dissimilar materials at interfaces that are important in designing and developing composites.

The editors have benefited from the cheerful help and assistance of many people. Special thanks are extended to David A. Shirley, Director of Lawrence Berkeley Laboratory, for his welcoming remarks; Peggy Little, for her invaluable assistance as Conference Coordinator; Tony Tomsia, for his general assistance particularly in organizing the Poster Session; and Rich Albert, for his assistance with the editing of the manuscripts.

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The editors also extend their thanks to the speakers and authors. This volume would not have materialized without their participation. Because of the indicated advances that have occurred in the past twenty years, it is anticipated that the next ten years will be most productive and that the Ceramic Microstructures '96 Symposium will bring forth interesting and productive results.

Joseph A. Pask
Anthony G. Evans

Berkeley, California
December, 1986

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PROGRESS IN THE UNDERSTANDING OF CERAMIC MICROSTRUCTURES AND INTERFACES SINCE 1976

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INTRODUCTION: THE SCENE IN 1976

In reviewing this decade's progress, our base line will be the proceedings of the previous "Microstructures" conference [1]; in addition, Kingery's papers [2] on "Concepts Plausible and Necessary for Interpretation of Grain Boundary Phenomena" of 1974, and Johnson's Review [3] on "Grain Boundary Segregation in Ceramics" of 1977 will mark the position around the mid-seventies.

Firmly established at the time was the importance of grain boundaries for the elimination of pores during sintering [4-7]. The segregation of impurities to grain boundaries had been inferred from indirect evidence [2], and Auger spectroscopy (AES) had recently begun to provide direct quantitative data [3]. However, it had not been possible to prove the segregation of Mg in alumina which had been invoked to explain the rapid and complete densification of this material [3], and the mechanism of this important dopant effect remained unexplained.

Beside AES, Transmission Electron Microscopy (TEM) and analytical Scanning Transmission Microscopy (STEM) were just beginning to make their impact on ceramics research. Their increasing application has been instrumental for the rapid progress during of the following decade. Glassy interlayers between the crystal grains in ceramics, previously inferred from high temperature behaviour, were demonstrated in TEM shortly after the '76 conference [8].

In the mid-seventies, grain boundary structures were directly accessible only to the field ion microscope [9]. Despite the great effort needed for each specimen tip containing a grain boundary, a large volume of evidence had accumulated [10] from such studies by 1976. Several speculative models of grain boundary structure had been developed. They stressed the importance of lattice site coincidences across the boundary and throughout both crystals ("CSL-model") [11], or the presence of energetically favourable configurations ("structural units") at the boundary itself [12], or matching of lattice plane spacings at the boundary ("plane matching model") [13]. TEM had revealed the existence of grain boundary dislocations in specific patterns, confirming that large angle boundaries have regular structure. Computer modelling had been recognized as a promising method of developing detailed ideas of the atomistic