PREFACE

The papers in this bound volume were presented at the first International Conference on Grain Growth in Polycrystalline Materials held from 18 to 21 June 1991 at Centro Sviluppo Materiali in Rome, Italy under the auspices of ILVA S.p.A.

The phenomena of grain growth has been utilized in material processing for many years. Today scientific and practical knowledge has reached a level which, in several cases, allows for the development of materials by suitable grain growth treatment. In the recent past, a significant development and research effort has been directed toward a better understanding of grain growth process from theoretical and experimental point of view. A wide variety of materials especially alloys of Fe, Al, Cu, Fe-Ni, superalloys as well as ceramics, in bulk or as thin films, are involved in this scientific and technological effort.

The purpose of this conference was to bring together researchers in the fields of experimental, simulation, and theoretical aspects of grain growth in order to share the currently available experimental data and to compare these data with recent theoretical results. A further goal was to focus on the application of the newly found scientific understanding to industrial observations and processes.

The leading authorities in various specialties delivered nineteen informative invited lectures, giving their comprehensive and penetrating insight into the important topics of grain growth. The regular contributions, ninety seven in total, and the keynote lectures covered experimental and theoretical investigations on grain growth phenomena and their observation in industrial practice for various materials, including metals and alloys, ceramics, sintered materials, thin films, etc.; normal and abnormal grain growth including twinning, texture, particle and other drag effects as well as analysis of topological aspects and grain size and grain orientation correlations, experimental and theoretical investigation of grain boundary structure, mobility and interaction with particles and impurity atoms.

Finally, experimental methods (e.g. ECP, HVEM, X-ray diffraction and topography, etch pitting, etc.) applicable to measurements of grain size, orientation of individual grains, etc. and combination of physical and topological parameters were highlighted by devoting several papers to this topic.

Last but not least, I wish to express my sincere appreciation and gratitude for the time and effort devoted by many authors to make this symposium a success. I am also grateful to the plenary lecturers for accepting our invitations.

Finally, my sincere thanks to the C.S.M. top management, particularly to Prof. A. Pini Prato and Dr. R. Bruno, for their assistance and encouragement in organizing the conference. Special thanks to Dr. S. Fortunati and to the various collaborators who at C.S.M. significantly contributed to different aspects of the conduct and in general to the success of the Conference.

G. Abbruzzese

Centro Sviluppo Materiali
Rome, Italy
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THE CONFERENCE OPENING SPEECH

Ladies and Gentlemen,

on behalf of the Organizing Committe, I have the privilege of opening this International Conference on Grain Growth in Polycrystalline Materials.

First of all I take pleasure in welcoming all the Professors, Scientists and Researchers who have met together here coming from more than thirty countries all over the world.

This testifies the great appeal of the Conference Programme set up by the International Scientific Committe chaired by Professor Lücke, as well as the presentation of key-notes and invited papers by so outstanding scholars of the subject, and finally, to a certain extent, the city of Rome with its famous antiquities and architectural beauties.

Secondly, I would like to tell you a few words about the grounds for holding this conference at CSM, this might be of same interest for at least a part of the present audience from the point of view of the opportunities to organize further events in the next few years.

CSM is the R&D center of the ILVA Group, the state-owned largest Italian iron and steel company. and as such it is mainly involved in applied research, aiming at the increase of the company's profit in the short and medium terms.

However, we are perfectly aware that not only a very high educational level of the research personnel, but also a continuous and direct involvement of the same in high level, fundamental or at least base-oriented research, are prerequisites for keeping abreast with the most recent advances in material science and for gathering those creative ideas which are indispensable for the success of the developmental work.

Due to the weight of the everyday commitments, we would not be able to pursue such an ambitious objective without reinforcing the links with the University world, both in Italy and abroad, as well as with the italian National Research Council, in order to stimulate cooperation and exploit synergies.

Briefly, our wish is to become a really active junction of a network including the largest possible number of academic institutions and specialized research laboratories.

Of course, meetings such as that being held here offer to everybody an admirable opportunity to summarize the results achieved up to now, to clarify the ideas for further cooperation, to establish new connections and to strengthen the old ones.

This is the reason why CSM has a mind to organize a series of conferences, with a two or three years periodicity, on important and topical subjects of Material Science. The present conference on Grain Growth in Polycrystalline Materials is considered by us to be the first one of that series, and we strongly wish that its final results and hopefully success will stimulate in the audience the desire of meeting again here and the resolution to make proselytes for this good cause.

It is time now to enter into the heart of the matter wishing to all the attendees a fruitful and successful Scientific meeting.

Rome, 18 june 1991

Prof. P. Brozzo

Chairman of the Organizing Committee

DEDICATED TO

CYRIL STANLEY SMITH

Quite early in the conference, it became apparent that most of the concepts that form the basis of our present day understanding of grain growth were first enunciated by one individual, Cyril Stanley Smith, in papers that were published between 1948 and 1954. {C.S. Smith, TAIME 175, 15-51 (1948); ibid. 185, 312-313 (1949); ibid 194, 755-765 (1952) with W.M. Williams; ibid. 197, 81-87 (1953) with L. Guttman; in "Metal Interfaces", ASM Seminar Report, (ASM, Cleveland 1952) pp. 65-108; in "L'Etat Solide" (19th Solvay Conference in Physics, Brussels 1952), pp. 11-53; in "Imperfections in Nearly Perfect Crystals", W. Shockley, Ed. (John Wiley 1952), pp. 377-401; Acta Met. 1, 295-300 (1953); Trans. ASM 45, 533-575 (1953); Trans. Chalmers Univ. of Techn. 152, 1-49 (1954), and "The Shape of Things", Scientific American 190, 58-64 (1954).} It is fitting and gratifying that, as a result of a vote of all the participants and of the Organizing Committee, we gratefully acknowledge our debt, and dedicate this symposium volume to him.

From these papers of Cyril Smith we learned of the importance of grain boundary area reduction and the relationship of area reduction to motion by curvature; the importance of dihedral angles; the remarkable result in two dimensions with 120 degree trijunction angles, that the rate of growth or shrinking of a grain depends only on the number of its corners and not on its size or shape, and the importance of particles in slowing or stopping grain growth. The evolution of soap froths were examined in three dimensions and between closely spaced parallel plates to simulated two dimensions. Grain shapes in opaque metals were revealed by fracturing embrittled specimens or in stereoscopic radiography that revealed grain boundaries coated by thin films. The paper with Guttman on quantitative microscopy, incidental to grain growth because it gave methods for measuring grain boundary areas, as well as line lengths and volume fractions, on random sections of opaque specimens, was influential in launching yet another active field.

What is all the more remarkable is that this body of work came at a time when Cyril Smith was in the middle of his long and productive career and was extremely busy. He was the founding Director of the Institute for the Study of Metals at the University of Chicago, and had assembled its remarkable staff from many disciplines. He also was active in many high-level government advisory committees.

It has been sixty-five years since Cyril Smith received his Sc. D. from MIT in 1926 at the age of twenty-one. In the twenty years that followed his studies, he established himself as on of the leading and most creative metallurgists in the world, first at the American Brass Company, and then during the war as metallurgy division chief at Los Alamos. The associations with the best minds in other disciplines, that began in Los Alamos, continued at Chicago and to this day at MIT. These provided unique opportunities, for in his long experience with metallurgical phenomena, Cyril Smith had developed a strong sense of "what was what", but now he had access to people who could provide the appropriate mathematics for deriving and expressing these concepts in more elegant and permanent forms. Among the people he contacted about his grain growth ideas were John von Neumann, Clarence Zener, Saunders MacLane, and his doctoral student at the time, William Mullins.

The grain growth papers were not only highly original, but at a new level of sophistication for metallurgy. As this conference showed, after forty years they have stood the test of time. I thought I knew them well. My own paper with E. Holm and D. Srolovitz is based on them. Imagine my surprise on rereading these papers for this dedication when I encountered in the 1952 AIME paper the following sentence, "Quite contrary to Harker and Parker, the writer predicts that grain growth will slow and stop (in the absence of inclusions) only when grain corner angles can depart from 120 degrees instead of when they approach it, as they suggest." Had we remembered this line, we would have understood our computer results much sooner.

Grain growth was only one field Cyril Smith has blessed us with his insight. In his long career he has made a habit of launching new fields and new directions of inquiry, not only in science, but in history and philosophy as well. He is a true renaissance man, still active, with many ideas in many fields to share with his many colleagues, myself included, who have valued being associated with him.

John W. Cahn

October 4, 1991;
the 87th birthday of Cyril Stanley Smith.