

Preface

Technologies based on nanostructured materials are present and has become increasingly important in our daily lives. Nanomaterials can be found in many applications, such as catalytic processes, ultra-violet filters, pigments, electronics, etc. It has long been recognized that nanostructured materials can have significantly altered properties when compared to their larger scale counterparts. A high level of control over the microstructure evolution of such materials is necessary during processing to ensure the development and synthesis of more stable high performance nanomaterials. Studies of stability and processing of nanomaterials typically involve concepts of sintering. That is, due to the large interface areas, nanomaterials tend to transform into their microscale counterparts if enough diffusion is provided. Therefore, a fundamental understanding of the sintering process is of critical importance to maintain reasonable control over the evolution nano- and microstructures. This understanding is provided through sintering theories, developed many years ago for the processing of powders in both metallurgy and ceramic industries. However, stability concepts are not the only connections between nanomaterials and sintering. Nanograined structures, that show outstanding mechanical and electrical properties, can only be obtained using either a refined control of sintering parameters, or assisted processing, such as field-assisted sintering. In this book, we present an organized collection of contributions from outstanding leading researchers in the field of (assisted) sintering technologies. The objective is to provide the reader with a useful overview of sintering concepts, followed by a detailed description of the particularities of nanosintering, and an up-to-date description and review of the current understanding of densification mechanisms that occur during electric field assisted sintering.

This book is intended to be both a teaching and consulting text. Although the individual chapters represent independent contributions from the respective authors, the editors made a great effort to communicate with all of the authors during the preparation of the texts to assure a logical order in the book. The final editorial review was conducted in a way to generate a text suitable for graduate level courses in field assisted-sintering. Some redundancies between individual

chapters are by intention to improve the book's educational value and make it appealing as a compendium for researchers and industrial users throughout their career.

As an experimental approach, this book has been used during the editing process as the textbook for a Field-Assisted Sintering graduate course offered in Fall of 2011 at the University of California, Davis. The course was taught by the Editors to a class of seven Materials Science and Chemical Engineering graduate and undergraduate students in a reading and discussion format. The students' comments were used as guidelines to improve the educational value during the editing of the individual chapters. With the assistance of the authors, this process helped this book to become a clear and didactic introduction to the field of assisted sintering. The following students are therefore greatly acknowledged as contributing reviewers to this book: Chi-Hsiu Chang, Hasan Ghadialy, Tammy Harrell, Seong Kim, Binzhi Li, Eskin Murat, and Jorgen F. Rufner.

The first chapter of this book provides a short overview of sintering and competitive processes, such as grain growth and coalescence. The driving forces are described in detail, as well as the relevant kinetic mechanisms. The following chapter, by Li and Pan (University of Leicester, UK) introduces nanoeffects in sintering and describes that nanoparticles should have different sintering behavior than their larger counterparts. This chapter also addresses simulations of two-particle sintering by molecular dynamics, and discusses how the simulated results relate to the classical models for sintering. The third chapter, by Liu and Gong (Northwestern Polytechnical University, China) presents nanoscale effects related to grain growth. As retaining grain growth is a common goal during sintering, the chapter addresses the problem from both the kinetics and thermodynamics points of view. Available models to control the grain growth using dopants are presented and discussed.

In the following topic, Kelly and Graeve (Alfred University, USA) add a more realistic perspective to sintering considering agglomerations and aggregations of nanoparticles as precursors. In addition, the authors discuss influences of processing parameters during nanoparticle synthesis. In a more "simulation" perspective, the Chapter by Wonisch, Rasp, Kraft, and Riedel (Fraunhofer Institute for Mechanics of Materials, Germany) provides a different perspective through simulations of sintering when exploiting to manufacture parts. The authors use finite element approaches to simulate sintering of large bodies and investigate effects of particle rearrangement during densification.

In another experimental oriented chapter, Lu, Li, and Chen (Virginia Polytechnic Institute and State University, USA) discuss the synthesis of porous materials, where sintering concepts are used to achieve porosity control. Several different methods of achieving and controlling such microstructures are described with the aid of examples.

From the second half on, this book turns its focus toward field assisted sintering processes and a review of heavily debated mechanisms. Munir and Quach (University of California, Davis, USA) and Ohyanagi (Ryukoku University, Japan) introduce electrical field assisted sintering concepts to set the bases for the

following chapters, and show concrete examples of products that can be obtained using this technique. The authors briefly introduce some of the relevant mechanisms and focus particularly on Spark Plasma Sintering. In the following chapter, Anselmi-Tamburini, Holland, Spinolo, Maglia, Tredici, and Mukherjee (University of Pavia, Italy and University of California, Davis, USA) present a more quantitative description of the effects of currents and fields on mass transport phenomena during sintering.

With a different point of view, Guillon (Friedrich-Schiller-Universität Jena, Germany) describes the role of pressure and heating rates during the SPS process in the next chapter. That is, most of the advantageous effects related to the SPS process can be attributed to the applied pressure and high heating rates. Guillon shows this by using model systems and comparing hot pressing sintering with the field assisted process. Finally, the final chapter of the book by van Benthem (University of California, Davis, USA) reviews characterization techniques suitable to obtain a deeper understanding of the relevant mechanisms during sintering. The chapter concentrates on electron microscopy methods for the atomic resolution characterization of as-sintered microstructures, and discusses new avenues for in situ investigations that will shed light on defect evolutions during densification.

Davis, CA, USA

Ricardo H. R. Castro
Klaus van Benthem

Sintering

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Castro, R.; van Benthem, K. (Eds.)

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