edited by

Ion N. Mihailescu | Anna Paola Caricato

Pulsed Laser Ablation

Advances and Applications in Nanoparticles and Nanostructuring Thin Films

Pulsed laser–based techniques for depositing and processing materials are an important area of modern experimental and theoretical scientific research and development, with promising, challenging opportunities in the fields of nanofabrication and nanostructuring. An understanding of the interplay between deposition/processing conditions, laser parameters, and material properties and dimensionality is required for improved fundamental knowledge and novel applications.

This book discusses the basic principles of pulsed laser–matter interaction, with a focus on its peculiarities and perspectives compared to other conventional techniques and state-of-the-art applications. The book starts with an overview of growth topics, followed by a discussion of laser–matter interaction based on laser pulse duration, background conditions, materials, and combinations of materials and structures. This information outlines a foundation for introducing examples of laser nanostructuring/processing of materials, pointing out the importance of pulsed laser–based technologies in modern (nano)science.

Compared to similar texts and monographs, the book offers a comprehensive review that includes bottom-up and top-down laser-induced processes for nanoparticle and nanomicrostructure generation. Theoretical models are discussed by correlation with advanced experimental protocols in order to account for the fundamentals and underline physical mechanisms of laser–matter interaction. Reputed, internationally recognized experts in the laser-based deposition and processing field have contributed to this book. Each chapter treats a specific topic in a simple and self-explanatory way, including both fundamentals and examples from the contributors' research that introduce the reader to the field at each level (theory and practice). The book serves as an introduction to the field and as a foundation for further specific readings for graduate and postgraduate students of physics, chemistry, materials science, and engineering and researchers in laser materials processing, who will gain physical insight into and advanced knowledge of the mechanisms and processes involved in any deposition/processing experiment based on pulsed laser–matter interaction.

Ion N. Mihailescu is university professor and senior scientific researcher (1st degree) at the National Institute for Lasers, Plasma and Radiation Physics, Romania (www.inflpr.ro). He has a large experience in laser interactions, lasers and plasma physics, nanostructured thin-film technology, nanopowder generation and characterization, surface physics and engineering, laser spectroscopy, and materials processing by advanced laser technologies. He has authored 441 publications, 195 scientific papers published in proceedings of international conferences, and 20 books and monographs and holds 12 patents. He has an h-index of 36 and an i10-index of 181 (http://www.researcherid.com/rid/A-5403-2011). He is the first recipient (1994) of the Galileo Galilei award for "outstanding contribution in the field of optics" and has also received the Doctor Honoris Causa of Université Cergy-Pontoise, France (2015).

Anna Paola Caricato is a professor at the Department of Mathematics and Physics "E. De Giorgi" of the University of Salento, Italy. She received her PhD in physics from the University of Modena and Reggio Emilia, Italy, in 2000. Her research focuses on (i) laser–matter interaction for the deposition of thin films and nanoparticles by laser ablation for applications in sensors, optoelectronic devices, and solar cells and (ii) matrix-assisted pulsed laser evaporation for the deposition of organic films, polymer multilayers, nanomaterials, and composite films. She has authored more than 120 publications in peer-reviewed international journals and 6 book chapters and holds 2 patents. She has also served as a conference co-chair and committee member for international conferences in laser–matter interactions and applications.

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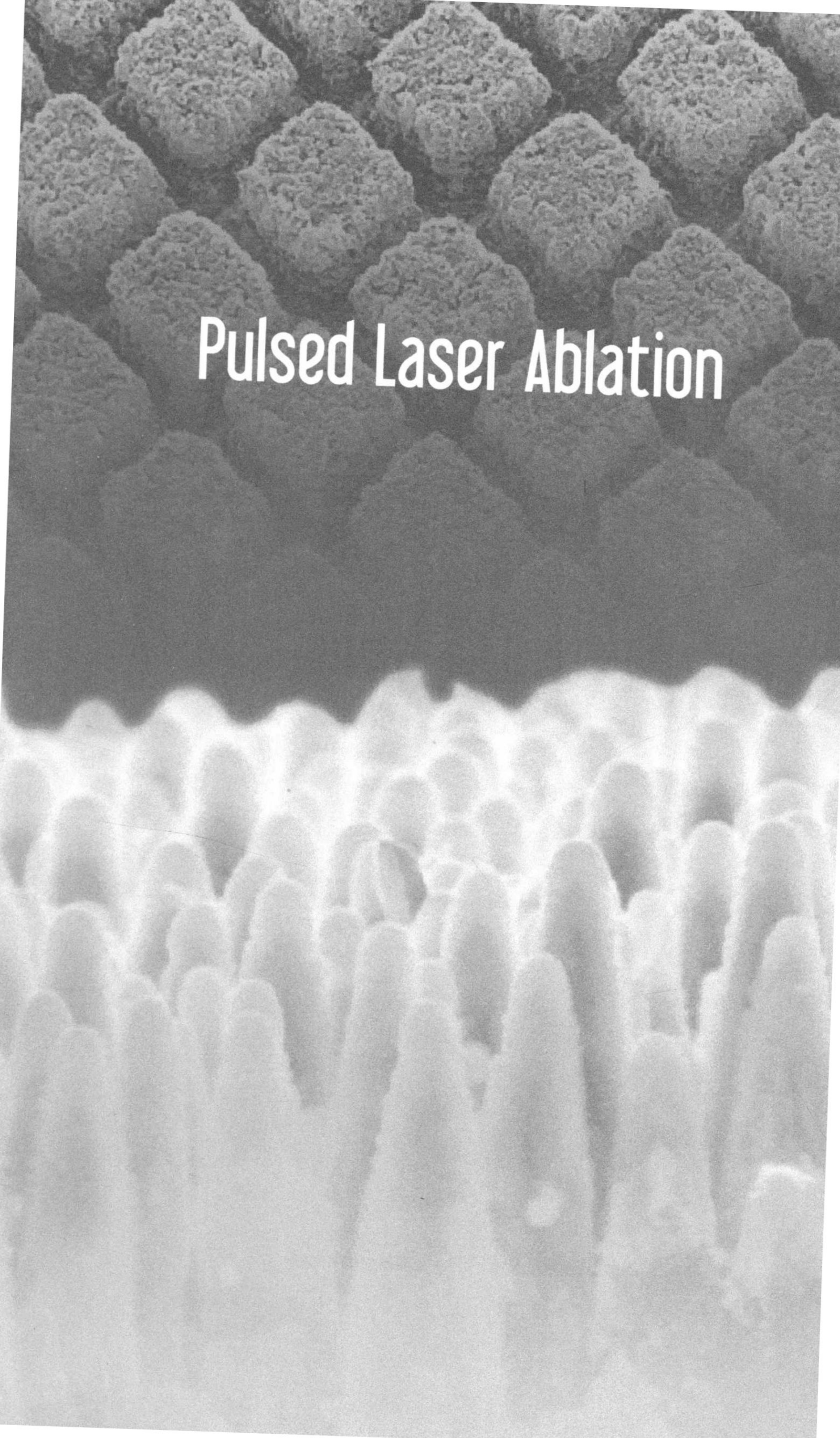

Preface

Nanotechnology and nanomaterials are at the origin of major progress, breakthroughs, and solutions to a vast number of engineering, biology, and medicine challenges. In fact, at the nanoscale, and at a macroscopic scale as well, the onset of size-dependent phenomena occurs and matter begins to exhibit entirely new properties. The advantage connected to the small feature size of nanostructured materials is exploited in many different applications, both in ordinary life and in high-technology fields.

Obviously, the possibility to valorize the new properties of nanomaterials is strictly connected to the availability of manufacturing processes and characterization techniques.

Among manufacturing methods, pulsed laser–based techniques offer several advantages compared to "traditional" ones for the fabrication of nanomaterials and surface nanostructures, due to the possibility to tune many independent processing parameters. Laser and laser ablation proved important and prospective in various fields, spanning from a better understanding of fundamental physical mechanisms and light–matter interactions to a large range of applications in physics, chemistry, biology, medicine, materials science, manufacturing technology, and even arts and conservation.

This book consists of 14 chapters covering a broad range of topics, written by internationally recognized experts in the field, on the recent advances in the application of laser ablation for the generation of nanoparticles and surface nano- and microstructures and their applications.

It includes a comprehensive overview of the classical theory of growth, with a focus on the importance of kinetic factors and processes in far-from-equilibrium deposition techniques such as pulsed laser deposition (Chapter 1). The wetting, adherence, and nanostructuring properties of the synthesized coatings, by pulsed laser processes, are described and discussed in Chapter 7. A detailed description of the mechanisms and significance of deposition parameters on nanoparticle immobilization and production in different environments (e.g., vacuum, Chapter 2; a high-gas-pressure atmosphere, Chapter 3; liquid, Chapter 5; and matrices, Chapter 6), pulse duration (i.e., the ns regime, Chapters 2, 3, and 5; or the fs regime, Chapters 4 and 5), and use of two time-delayed laser pulses (Chapter 9) is provided. An overview of the results obtained in recent molecular dynamic simulations of laser ablation of metal targets in vacuum, a background gas, and a liquid environment (Chapter 12) is also given.

The processing of materials by fs laser pulses has attracted a great deal of attention because fs pulse energy can be precisely and rapidly delivered to the material without detectable heat perturbation of the neighboring zones. In some cases, periodic micro- and nanostructures can be generated directly (without the use of masks or chemical photoresists to relieve the environmental concerns) in almost any samples from semiconductor to dielectric materials and polymers, supplying relevant results to be used in different applications like nanofluidics, nanophotonics, and biomedical devices.

The effects of some key parameters, including multiple pulses, variable pulse shaping, and fluence, which could be useful in the laser nanostructuring of surfaces and micromachining of different materials (e.g., dielectric, Chapter 10; semiconductor, Chapter 11; and polymer, Chapter 13), are reviewed and discussed from fundamental and/or applicative points of view. The use of laser-based material processing techniques, such as pulsed laser deposition (PLD), laser-induced forward transfer (LIFT), material processing via 3D laser structuring (LS), and laser annealing (LA) techniques for energy storage applications is analyzed in Chapter 14.

Next, Chapter 8 is devoted to the importance of the use of core-shell nanoparticles when different material properties must be merged at the nanoscale to meet the requirements for smart applications.

In the opinion of the authors, the book offers a comprehensive review of the latest advances in top research and development in the laser material processing field for nanoparticles and nanomicrostructure generation and exploitation of different kinds of materials. Theoretical models are discussed by correlation with advanced experimental protocols, to explain the fundamentals and underline physical mechanisms of laser–matter interaction.

The book was conceived as a starting point and guide for students and young researchers who are beginning to initiate in the field of nanostructures and nanoparticles.

Last but not least, the two editors would like to thank all of the chapter contributors for their great efforts and kind cooperation in preparing this book.

Ion N. Mihailescu and Anna Paola Caricato

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