Springer Series in Materials Science 161

Laser-Assisted Fabrication of Materials

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1. Auflage 2012. Buch. xxxii, 488 S. Hardcover
ISBN 978 3 642 28358 1
Format (B x L): 15,5 x 23,5 cm
Gewicht: 937 g

Weitere Fachgebiete > Technik > Technik Allgemein > Technische Optik, Lasertechnologie

Preface

Due to its ability to deliver coherent beam with negligible divergence, laser as a source of heat enjoys immense importance in the field of maco and micro-processing of materials. Fabrication may be achieved by removal of materials (laser assisted cutting, drilling, etc.), deformation (bending, extrusion), joining (welding, soldering), and addition of materials (surface cladding or direct laser cladding). A faster processing speed, conservation of strategic alloying elements, a large heating/cooling rate associated with the processing and retention of metastability in the microstructure are the notable advantages associated with laser assisted fabrication of materials. However, in spite of the unique advantages associated with the technique, large-scale application of the technology needs to be ensured. Acceptance of the technology in industry scale is yet to be popular, predominantly due to lack of widespread knowledge on the different materials phenomena and the influence of laser parameters on it. However, extensive research efforts are undertaken and the significant contribution in this direction encompasses various fields like interaction of laser with materials, role of process parameters on the different materials processing and process optimization, solidification behavior of materials under non-equilibrium processing conditions, development of metastable microstructures/novel materials, and modeling/process control. A complete knowledge in this direction demands blending of the existing theory with the advanced research in this direction. The compilation on 'Laser assisted fabrication' is aimed at (a) Developing in-depth engineering concepts on various laser assisted macro and micro-fabrication techniques; (b) Engineering background-a review of engineering background of different micro/macro-fabrication techniques; thermal history of the treated zone; microstructural development and evolution of properties of the treated zone; (c) Application of laser assisted fabrication including laser cutting and drilling, welding, surface modification, laser forming, and rapid prototyping; (d) An in-depth understanding of laser assisted microfabrication of metallic, polymeric materials, and thin film and (e) finally introducing an industrially acceptable optical monitoring tool for control of laser processing. It consists of 11 chapters. The contributions from the authors who have expertise in different areas of laser materials processing are gratefully acknowledged. Needless to mention, without the time and efforts spent by the reviewers this special issue would not have been presented in this form. The invitation, cooperation, and encouragement from Dr. Claus Ascheron and necessary help from Dr. Elke Sauer from Springer Verlag were of immense help to nucleate and expand the contribution in the present form.

Laser parameters play an important role in determining the properties of the processed zone. Chapter 1 presents a brief introduction to different types of lasers and their general application, fundamentals of laser–matter interaction, and classification of laser material processing. The materials processing techniques covered have been broadly divided into four major categories; namely, laser assisted forming, joining, machining, and surface engineering. Besides discussing the scope and principle of these processes, each section enumerates a detailed update of the literature, scientific issues, and technological innovations. The entire discussion primarily focuses on correlating the properties with processing parameters and microstructure and composition.

Recently, a large numbers of lasers have been developed aimed at application for different purposes, especially, fabrication of miniature components. Chapter 2 presents a brief overview of recent developments of lasers and its application in materials processing. The applications of excimer lasers (operating in short wavelengths in ultraviolet spectrum) and Ti-sapphire on micro-machining like MEMS, microelectronics, telecommunication, optoelectronics, and biomedical devices have been discussed in detail.

Laser cutting is a popular manufacturing technique which has a potential scope of applications in cutting of different materials, especially, difficult to cut materials. Chapter 3 summarizes the up-to-date progress of laser assisted machining of metals, ceramics, and metal matrix composites. It also discusses the analysis of temperature distribution around the cutting region, material removal mechanisms, tool wear mechanisms, and the improvement in machined surface integrity of various engineering materials by the assistance of laser beam.

Laser as a source of heat can be effectively used for joining of materials by fusion welding and brazing in autogenous (without filler material) or with a filler or in hybrid modes. However, to overcome certain limitations associated with laser welding, modifications in process designing have been undertaken like laser-arc hybrid welding, remote welding, induction assisted welding, laser weld brazing, and SHADOW welding. The process may be extended to join plastics and ceramics. Chapter 4 describes the basic principles of various laser-based joining processes, laser system technology, process parameters, metallurgical effects on different base materials, joint performance, and applications.

Direct laser cladding (DLD) is the emerging manufacturing technique for development of near net shape components. A rapid processing speed, one-step processing, possibility in retention of metastability in the microstructure and development of components with improved properties are the advantages associated with the technique. Chapter 5 describes the additive manufacturing techniques by direct laser cladding along with its practical applications examples.

Processing of materials on the micro scale requires pulsed and/or short wavelength laser systems with moderate average powers in the range of a few watts or below along with good beam qualities. Chapter 6 provides an overview of pulsed laser assisted micromachining with a focus on structuring by laser ablation, laser generative processes, and finally nanomachining.

Polymers have numerous engineering applications where they need to be shaped. One of the important applications of polymeric materials is bio-implant materials, however, it is known that they offer excellent bulk properties for biological applications; however, their surface properties need to be tailored to improve their performance. Chapter 7 presents the detailed investigations on CO_2 laser surface processing of nylon 6,6 and its effect on surface characteristics and properties of modified surface.

Laser assisted fabrication of materials on micro and nanoscale offers a cost-effective solution for advanced material research and application. Laser ablation and surface modification are suitable for direct patterning of materials and their surface properties. Chapter 8 presents the application of lasers in patterning, rapid prototyping, and small-batch manufacturing. Especially, the applications of ultraviolet, NIR and IR laser radiation for precise and debris-free pattern generation, machining, and rapid manufacturing are discussed.

The thermal history of the processed zone plays an important role to determine the microstructure, thermal stress distribution, and properties of the fabricated components. However, due to very short laser–material interaction time during processing, measurement of temperatures by conventional techniques is difficult leading to the development of heat and mass-transfer model for prediction of performance of fabricated components. Recent developments in optical sensors led to invention of tools for precise measurement of temperature during laser processing. Chapter 9 discusses different optical-based techniques for monitoring of temperatures during laser materials processing.

The stumbling block for industrialization of laser is due to the following facts: high installation cost, lack of understanding on the microstructures and properties in the fabricated component due to non-equilibrium processing by laser, optimum fabrication quality under narrow process parameters, and unavailability of data points on optimum process parameters. However, laser assisted cutting, surface hardening and similar material welding are the three important fabrications where laser as a source of heat are gradually getting popular. Chapter 10 critically reviews the scope for the industrial acceptability and adaptability of high power lasers to assess the real potential of these research areas.

In conclusion, it may be stated that all the articles in the present issue present the details of laser assisted macro and micro-processing of materials, principle of individual technique and original research efforts on advanced field of laser materials processing. We sincerely acknowledge the secretarial help by Mr. Prashant Sharma and Subhasisa Nath, research scholars working with us for

helping us during the preparation of the volume. The cooperation and help from our family members are gratefully acknowledged. Finally, we wish the issue to be a successful, popular, and useful one to engineers, scientists, and researchers in the field of materials science and manufacturing technology.

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