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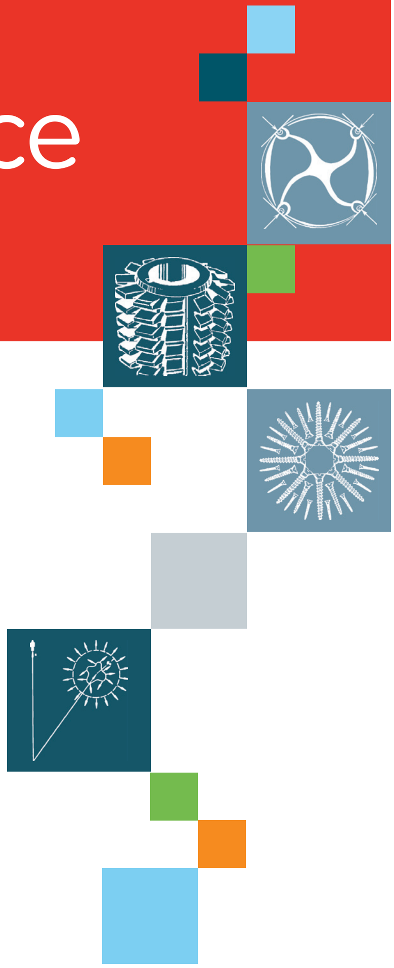

Contents:

Special Issue on Laser Processing of Materials

Guest Editors: Leszek A. Dobrzański and Anna D. Dobrzańska-Danikiewicz

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Georgia Institute of Technology
Atlanta, GA, USA

Dr. George E. Totten
G. E. Totten Associates, LLC
Seattle, WA, USA

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EDITORIAL SERVICES

Sara Welliver
Supervisor, Peer Review Services
J&J Editorial Services
201 Shannon Oaks Cir #124
Cary, NC 27511, USA
tel +1.919.650.1459, ext. 210
astm@jjeditorial.com

POSTMASTER send address change to:
ASTM International—MPC
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West Conshohocken, PA 19428-2959

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IN APPRECIATION OF THE REVIEWERS

The high quality of the papers that appear in this publication is a tribute not only to the obvious efforts of the authors represented but to the unheralded, though essential, efforts of their reviewers. It is to the reviewers' dedication to upholding the high standards of their profession that this note pays tribute. On behalf of ASTM International and the authors as well, we acknowledge with appreciation their important contribution to the success of this journal.

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Overview

The history of lasers is relatively short. It was preceded by fundamental theoretical work by Max Planck in 1900; Albert Einstein in 1917; the achievements of the team of Charles H. Townes, Arthur L. Schawlow, James P. Gordon, and Herbert J. Zeiger in 1954; and Nikolai Basov in 1955, but it was not until 1960 that Theodore H. Maiman constructed the first laser. Undoubtedly, it is impossible not to mention the thirty-year patent's war initiated by Gordon Gould, which proved to be effective, and in this way he is the author of the first patent in history that concerns lasers. During the past almost 60 years, lasers have gained numerous applications, from medicine to numerous industrial applications. This special issue on *Laser Processing of Materials* presents numerous examples of detailed research on various aspects of such laser applications.

The inaugural opening paper of this special issue is on "Applications of Laser Processing of Materials in Surface Engineering in the Industry 4.0 Stage of the Industrial Revolution," and it is prepared by the guest editors of this issue, Leszek A. Dobrzański and Anna D. Dobrzańska-Danikiewicz from Medical and Dental Engineering Center for Research, Design and Production ASKLEPIOS, in Gliwice, Poland, and the Faculty of Mechanical Engineering of the University of Zielona Góra, in Zielona Góra, Poland, respectively. The paper presents a comprehensive literature study showing the contemporary industrial applications of laser processing of materials in the area of surface engineering. The considerations were preceded by a detailed presentation of knowledge development that enabled the invention and production of the laser, as well as the development of its numerous industrial applications and examples of applications in other fields. The authors' research results present the application of laser technologies for remelting, alloying, feathering, and cladding—including hot work tool alloy steels, high-speed steels, magnesium, and aluminum alloys—for the production of porous titanium micro skeletons prepared using the additive selective laser sintering SLS method, for the laser texturing of polycrystalline silicon and for the use of selective laser sintering for the producing of electrical contacts on photovoltaic cells. An important part of this paper is the analysis of 21 surface engineering technologies included in the group of laser processing of materials, using its own methodology of technological foresight and determining the strategic position of individual technologies in a twenty-year timespan. It has been shown that the analyzed technologies of laser processing of materials are increasingly used in modern technology, and due to their high development potential, they are one of the most important elements in the development of the idea of Industry 4.0.

Additional papers contained in this special issue also confirm this thesis. They concern various aspects of the use of laser processing of materials, including in particular marking; texturing and shaping the surface roughness of various materials; surface hardening of steels; cladding; butt welding of steel sheets and plates; and the additive technologies of nickel alloys and corrosion-resistant steels.

The laser marking applies to the paper developed by the team of Anish Shivaram from Arlington, TN, on the subject of "Effects of Laser Marking on Fatigue Strength of Titanium Alloys." Laser marking is a requirement for all medical implants in the biomedical industry. The purpose is to provide permanent identification in the form of laser engraving the details of the implant applied in medicine. However, improper choice of laser marking parameters can induce high residual stresses on the implant and can result in fracture at the marking region. The objective of this study was to evaluate the effect of various laser marking parameters on the residual stresses and fatigue strength of titanium alloy. Laser marked samples showed a reduction in fatigue strength as compared to non-laser marked samples.

The first paper on texture and surface roughness formation using lasers was developed by Leszek A. Dobrzański and Aleksandra Drygała from Gliwice, Poland, and the Institute of Engineering Materials and Biomaterials of the

Silesian University of Technology in Gliwice, Poland. In this paper, entitled "Laser Application in Photovoltaics for Surface Texturization of Silicon and Front Electrode Deposition," the authors initiated the research because most conventional methods used for texturization of monocrystalline silicon are ineffective when applied for texturing polycrystalline silicon. It is related to the random distribution of grains of different crystallographic orientations on the surface of polycrystalline silicon. The texturing of polycrystalline silicon surface using Nd:YAG lasers makes it possible to increase absorption of the incident solar radiation when the additional etching in KOH solution is used. Moreover, the paper advocates using the selective laser sintering SLS for front contacts formed on monocrystalline silicon solar cells.

The paper on "Tribological Behavior of Surface Textured Gray Cast Iron at Different Texture Density by Ultrafast Laser" was prepared by D. Nazeer Basha and coauthors from India. In this study, the surface modification of Gray Cast Iron, using femtosecond Laser irradiation, is adopted in order to establish an optimal geometric pattern with dimple features and dimensions, to improve wear and friction behavior. The textured surfaces cause a significant reduction in friction coefficient (by 72%) and wear (by 19%) over the untextured surfaces. The wear track of textured surface exhibited a significant reduction of wear debris and was found to be smoother than the un-textured surface. Among various patterns tried, the pattern with 55 % texture density gave the best results.

K. S. Srin and coauthors from India prepared the paper entitled "Controllable Superhydrophobic Stainless Steel Surfaces Fabrication by Femtosecond Laser." The authors created hydrophobic surfaces on stainless steel AISI 304 surfaces by producing a hierarchical nano/microstructures with ultrafast laser ablation. The authors demonstrated a simple way to tune hydrophobicity using femtosecond laser surface modification in a single step with no subsequent post-treatment. The results revealed that the average pulse energy range of 0.035–0.05 mJ at 10000 Hz with scanning speed 10–100 mm/s and line separation 10–30 μm produced hydrophobic surfaces with the apparent contact angle of 110–135°.

"Effect of Surface Roughness on CO_2 Laser Absorption by 316L Stainless Steel and Aluminum" is the title of a paper developed by M. Ahmed Obeidi with coauthors from Dublin City University, Ireland. This study investigates a comparison of the effect of the surface roughness of flat 316L stainless steel and aluminum samples on the thermal energy absorbed in laser processing. The aim was to characterize the effect and identify the potential energy savings. The expected outcome of the study was confirmed, finding a noticeable improvement in the absorbed energy on the rougher surfaces for both materials, with a saving of ~62% in the laser power applied when the aluminum surface roughness increases from 2.4 μm to 7.03 μm.

The paper on "Adaptive Process Control for Uniform Laser Hardening of Complex Geometries Using Iterative Numerical Simulation" is presented by V. R. Barath and coauthors from India, and it is the first regarding laser surface hardening. In this work, an iterative numerical approach was used to estimate the required modulation in laser power to achieve a uniform surface temperature throughout the process zone. The numerical model was validated by carrying out laser hardening experiments using 6 kW diode laser. The developed iterative approach can be effectively used on any geometry with the variable heat sink to obtain constant surface temperature throughout the process zone.

Jacek Górka and Marek Opiela from the Silesian University of Technology in Gliwice, Poland, prepared the paper entitled "Structure and Properties of HSLA Steel Melted by the Laser Beam." This paper presents an examination of laser beam remelting of microalloyed HSLA-type steel, 28MnTiNbVB. The remelted zone is martensitic with lath structure possessing a hardness of up to 600 HV10. Laths are smaller; additionally, smaller precipitations are more tightly packed compared to the parent material. Examination results show that steel 28MnTiNbVB exhibits limited weldability.

The group of Aleksander Lisiecki prepared the paper on "Robotic Fiber Laser Cladding of Steel Substrate with Fe-Based Metallic Powder," which is the first regarding laser cladding. The paper describes the investigations of robotized laser cladding of mild steel by Fe-based powder and the study of process parameters on quality and properties of the test surface layers. As the substrate for cladding the mild steel was chosen, the experimental powder was composed of 7.0 wt.% of Mo, 4.0 wt.% of Cr, 2.0 wt.% of W and V, and also 0.8 ÷ 1.0 wt.% of C. The area of melt pool and surrounding regions were protected by Ar flow. The results of the investigations show that the microstructure of surface layers is homogeneous and fine-grained with dispersive precipitation of very fine carbides. The hardness of the mild steel substrate ranges from 120 to 150 HV1, while the hardness in the surface layer is significantly increased to 800 HV1.

The same group of authors prepared the next paper on "Robotized Fiber Laser Cladding of Steel Substrate by Metal Matrix Composite Powder at Cryogenic Conditions." The paper presents the results of investigations on laser cladding of mild steel plates (0.17 wt.% C and 1.4 wt.% Mn) by nickel powder with an additional 60 wt.% of tungsten carbides at conditions of forced cooling by liquid nitrogen at approximately −190°C. The results show that the conditions of cooling have a strong influence on the cladding process, mechanism of a bead formation, quality, microstructure, and geometry of the beads. Laser cladding at forced cooling leads to a favorable fine-grained microstructure and increased micro-hardness of the metal matrix, as well as lower dilution. In the case of stringer beads produced at cryogenic conditions, the heat-affected zone in the substrate of the mild steel is hardened with evident traces of bainitic microstructure.

Agnieszka Kurc-Lisiecka and Aleksander Lisiecki from WSB University, Poznań, and the Silesian University of Technology in Gliwice, Poland, prepared the unique paper on the butt joints welding entitled "Weld Metal Toughness of Autogenous Laser-Welded Joints of High-Strength Steel Domex 960." It found that the energy input has a clear influence on the microstructure and the impact toughness of the weld metal. The weld metal of the test butt joint welded at the energy input of 198 J/mm showed the average impact toughness at approximately 80% of the parent metal, however, while the weld metal of the test butt joint welded at the lower energy input of 132 J/mm showed the average impact toughness at the level of just 60% of the parent metal.

The last two papers address additive manufacturing using lasers. The first of these, titled "On the Spatial Variation of the Microstructure and Microhardness Properties of Nickel-Based Superalloy René 142 Fabricated via Scanning Laser Epitaxy (SLE)," was prepared by Amrita Basak and colleagues from Atlanta, GA. This paper seeks to investigate and characterize the spatial variation of the microstructure and microhardness properties of René 142, a high-nickel-based superalloy fabricated through single-pass depositions using SLE, a laser powder bed fusion based additive manufacturing (AM) process. Through this study, it is demonstrated that the microstructure and the microhardness properties of the AM-fabricated René 142 deposits are strong functions of the spatial location.

Alexander Schwarz leads the team from Germany and South Africa that prepared the paper on "New Welding Joint Geometries Manufactured by Powder Bed Fusion from 316L." This paper presents new designs for welding joints and shows how the different welding behavior can be used to improve the additively manufactured parts for hybrid welding processes. In metal additive manufacturing, there is an increasing demand for large-size parts. Instead of directly building parts, technologies like hybrid building are used. To avoid extensive clamping devices for welding, additive manufacturing can be used to design new gap geometries. The powder bed fusion process leads to a different microstructure that needs to be taken into account for the welding process. The new microstructure leads to an extensive shrinkage during welding that exceeds the shrinkage of conventionally produced parts. If additively manufactured parts should be laser welded, this can be avoided by combining different welding processes. If the backside of a part is first welded by conventional welding, the resulting shrinkage will close the gap on the structured surface. If laser welding is then applied to a structured surface, it is nearly impossible to see the weld.

We began this editorial Overview by recalling the fundamental theoretical works of the German physicist Max Planck, the Nobel Prize winner in Physics from 1918. In conclusion, fastening the whole of information with a kind of buckle, we would like to quote one of his thoughts:

> "Experiments are the only means of knowledge at our disposal. The rest is poetry, imagination."

We believe the experiments reported in this special issue are reliable and the studies presented are valuable and provide significant, detailed information on the possibility of using lasers in various technological processes used in relation to various engineering materials. We hope that you will accept our conviction and that reading this special issue will bring you satisfaction and increase your knowledge. Have a nice reading.

Leszek A. Dobrzański
ASKLEPIOS
Gliwice, Poland

Anna D. Dobrzańska-Danikiewicz
University of Zielona Góra
Góra, Poland