

Special Section on Applications of Laser Ablation and Micromachining

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Welcome to this special section on laser ablation. Advances in ultrafast pulsed laser technologies have made it possible to investigate physical processes on the shortest time scale and structure the materials with optical resolution. The technological potential of ultrashort laser pulses is based primarily on localization of energy, minimizing thermal damage to the materials, and ability to form three-dimensional structures. All three features are extremely attractive for various applications, ranging from microfabrication of polymeric materials and optical thin-film deposition, through structuring the dielectric and metallic surfaces and optical-device integration, to life sciences and laser treatment of biological issues. Some aspects of the interdisciplinary science and technology of laser ablation are discussed in eight papers that we offer to your attention. As a set, the manuscripts illustrate the international diversity of research efforts dedicated to advancing this technology.

Pulsed laser thin-film deposition technologies, targeting deposition of films suitable for optical waveguide fabrication, have been under development in recent years. The application of pulsed laser deposition was known to be limited by the unsatisfactory quality and the above-threshold degree of contamination of thin films with large particles of the material. This partly relates to the regime of ablation and the mass of dielectric material evaporated with each laser pulse: the larger the evaporated volume, the higher the chances of droplet formation on the thin-film substrate during the condensation process, leading to the poor quality of films. The results of the research of Luther-Davies et al. in picosecond high-repetition pulsed laser ablation of dielectrics advances the understanding of light-matter interaction physics in an attempt to define laser regimes that allow complete elimination of macroscopic particles from the thin-film surface.

In the following article Koch et al. present a substantive discussion of laser-ablation-based material structuring on a subwavelength scale. The interest in this application is driven by the fact that laser ablation offers one very

appealing application in interdisciplinary technologies, namely the possibility to use the femtosecond beam for direct writing and nanostructuring of multifunctional devices. This technological application has a real potential of pushing the resolution limit achievable with conventional lithography: Although optical lithography is predicted to be useful for the creation of elements with critical dimension even beyond 100 nm, it is limited in application to a small set of materials and on plane surfaces. Using the tightly focused femtosecond laser beam, however, presents an alternative way of optical structuring below the diffraction limit, since for the ultrashort pulses the limit of resolution also depends on the fluence parameters of the system.

The following study by Yang et al. addresses direct fabrication of integrated optics in transparent materials, and focuses on the local refractive index changes induced by laser pulses that control the written waveguide quality and affect the flexibility of this direct-write approach. Another practical application of laser-based material microstructuring is addressed by Gomez et al., who demonstrate the fabrication of passive microfluidic devices in polymers and glasses. These devices, known as “lab-on-a-chip,” emerged to satisfy the needs of life sciences (such as genetic analysis, clinical diagnostics, and analytical chemistry). Fabrication of these devices with laser ablation offers an interesting alternative to planar clean-room technologies, which are conventionally limited in creating three-dimensional structures.

It would not be straightforward to realize the possibilities offered by laser ablation and micromachining in material processing without reliable control and optimization of the laser systems. The optimization issue becomes particularly acute for processing brittle materials. As Stoian et al. present in their elegant work, the concept of optimizing laser interaction is based on the regulation of energy delivery to achieve control of laser-induced material interactions, and can potentially lead to a feedback-regulated material processing. A topically close physical

investigation of reducing the threshold of oxide-dielectric-film damage during femtosecond pulsed laser ablation is considered by Mero et al. Their results present the dependence of the damage thresholds, the energy deposition into material, and the luminescence following the excitation as a function of pulse fluence, and demonstrate the evidence of excitation of laser-induced material defect states, such as self-trapped excitons. A short overview of the state of the art in oxide film patterning with deep-UV laser ablation is offered by Ihlemann.

The special section concludes with a discussion by Itina et al. of numerical exploration of laser fluences and their influence on the laser ablation regimes of metals and dielectrics. The researchers present very interesting numerical models of light-matter interaction that incorporate both material ionization and laser light absorption processes.

Interest in the development of laser ablation technology continues to grow, which is emphasized by a biannual SPIE conference on high-power laser ablation that has been successfully attracting participants for several years. Based on the broad interest from the potential contributors who were unable to complete papers in time for this issue,

I believe this special section could be repeated in the future. I thank all the contributing authors and the reviewers for their timely help with the selected papers, and appreciate the efforts of the *Optical Engineering* staff, in particular Peer Review Coordinator Anne Munger, Managing Editor Karolyn Labes, and Editor Donald O'Shea for their patient guidance and support.



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