Laser Induced Damage in Optical Materials

Twenty-First ASTM Symposium
November 1-3, 1989

The Twenty-First Annual Symposium on Optical Materials for High-Power Lasers (Boulder Damage Symposium) was held at the National Institute of Standards and Technology in Boulder, Colorado, November 1-3, 1989. The Symposium was sponsored jointly by the National Institute of Standards and Technology, the American Society for Testing and Materials, the International Society for Optical Engineering, the Defense Advanced Research Project Agency, and the Department of Energy. Approximately 200 scientists, including representatives of the United Kingdom, France, Japan, Canada, and the Federal Republic of Germany, attended the Symposium. The Symposium was divided into sessions concerning Materials and Measurements, Mirrors and Surfaces, Thin Films, and, finally, Fundamental Mechanisms. As in previous years, the emphasis of the papers presented at the Symposium was directed toward new frontiers and new developments. Particular emphasis was given to materials for high power apparatus. The wavelength range of the prime interest was from 10.6 μm to the uv region. Highlights included surface characterization, thin film substrate boundaries, and advances in fundamental laser-matter threshold interactions and mechanisms. The scaling of damage thresholds with pulse duration, focal area, and wavelength was discussed in detail. Harold E. Bennett of the Naval Weapons Center, Arthur H. Guenther of the Los Alamos National Laboratory, Lloyd L. Chase of the Lawrence Livermore National Laboratory, Brian E. Newnam of the Los Alamos National Laboratory, and M.J. Soileau of the University of Central Florida were co-chairmen of the Symposium. The Twenty-Second Annual Symposium is scheduled for October 24-26, 1990, at the National Institute of Standards and Technology, Boulder, Colorado.

Key words: laser damage; laser interaction; optical components; optical fabrication; optical materials and properties; thin film coatings.

1. Introduction

The Twenty-First Annual Symposium on Optical Materials for High-Power Lasers (Boulder Damage Symposium) was held, as in previous years, at the National Institute of Standards and Technology in Boulder, Colorado, November 1-3, 1989. The Symposium was held under the auspices of the ASTM with the joint sponsorship of NIST, and the Department of Energy. Approximately 200 scientists, including representatives of the United Kingdom, France, Japan, Canada, and the Federal Republic of Germany, attended the symposium. The Symposium was divided into sessions concerning Materials and Measurements, Mirrors and Surfaces, Thin Films, and, finally, Fundamental Mechanisms. In all, approximately 70 technical presentations were made. Harold E. Bennett of the Naval Weapons Center, Arthur H. Guenther, and Brian E. Newnam of the Los Alamos National Laboratory, Lloyd L. Chase of the Lawrence Livermore National Laboratory, and M. J. Soileau of the University of Central Florida were co-chairmen of the Symposium. Aaron A. Sanders of the National Institute of Standards and Technology acts as conference Coordinator.

The purpose of these symposia is to exchange information about optical materials for high power lasers. The authors welcome comments and criticism from all interested readers relevant to this purpose and particularly relative to our plans for the Twenty-second Annual Symposium, scheduled for October 24-26, 1990, at the National Institute of Standards and Technology, Boulder, Colorado.

2. Overview

The following comments by the Symposium co-chairmen represent their impression of significant advances that were discussed immediately after the close of the meeting. This is not meant to be a thorough review of the conference, but only a brief glimpse of some of the highlights.

The largest single group of papers in the Fundamental Mechanisms session dealt with the effects of high photon energies on laser-induced damage (LID) at lower photon energies. As one example, short-wavelength harmonic radiation generated within free-electron lasers can potentially reduce the LID at the fundamental lasing wavelength. Another case involved the effect of ultraviolet radiation on the damage resistance at 10.6 μm. Yet another paper dealt with the use of photoconductivity as a diagnostic to identify defects within the bandgap and to monitor the onset of LID.

One area covered at this meeting for the first time was the nonlinear properties of inorganic polymers as well as those of organic polymers. In addition, a theoretical paper described the contribution of conjugated electronic systems to the nonlinear polarizability of such materials which have potential use as photoelectronic devices.

Always of interest to theoreticians are the possible relationships of apparently different classes of materials properties. This year, one group studied the relationship between the nonlinear refractive index and two-photon absorption coefficient using a model that assumed that a Kramers-Kronig relationship exists between the two.

One paper provoked a great deal of discussion and controversy, and suggested that avalanche breakdown is not a fundamental mechanism even for intrinsically pure materials, as generally accepted. Data which they believed supported their claim that damage occurs first by multiphoton absorption followed by nonlinear free-carrier absorption and heating that then leads to damage were presented. To account for earlier observation by other experimenters, it was asserted that avalanche processes do take place after breakdown is initiated. Nevertheless, indications of avalanche before breakdown were ascribed to extrinsic processes and/or impure materials. These conclusion challenge the laser damage community to propose a set of independent experiments that can confirm or discount their proposed model.

Concerning surfaces and mirrors, perhaps one of the most encouraging developments, after many years of continuous effort, was the progress reported for the polishing of silicon carbide. SiC and Be are among the most attractive mirror materials now being considered for use in space missions. One study reported on two different techniques for producing SiC mirrors which could be finished to varying degrees of surface polish and which were stable. The most attractive technique was physical-vapor deposition finishing of SiC by ion-beam sputtering very smooth coatings with a low level of stress. The rms surface roughness on these elements was less than 0.5 nm(5 Å), and stable with time.

Another exciting development was that ultra-precise grinding of glass surfaces with diamond had attained 0.5 nm(5 Å) roughness, which is remarkable. A number of papers concentrated on mirrors for the vacuum ultraviolet, a new thrust this year. There was some concentration on production problems of working with a system with 1 m diameter mirrors subjected to very high laser fluences. Systematic errors in surface topography using noncontact interferometers were discussed. We also heard a novel suggestion for laser protection of surfaces by developing small spherical particles that would diffusely reflect incoming laser beans. The particles must have absorption levels of $\sim 10^{-5}$ to 10^{-6} cm^{-1}. If this becomes possible, then mirrors with very high reflectance of 99.999% or better could result.

In the area of thin film coatings, degradation by ultraviolet and vacuum-ultraviolet wavelengths was emphasized. One parametric study concerned degradation to ZrO_2 films caused by 25-eV synchrotron radiation. Surprisingly, after a short period, the initial damage apparently healed, possibly by the material evolving to a different crystal structure. Another paper described the much higher resistance of HfO_2 films to color-center formation caused by a 248-nm KrF laser when the usual 3% ZrO_2 impurity content was reduced to a few tenths of a percent. We also heard a report on much higher damage thresholds being attained for multilayer reflectors prepared by the sol-gel process as a result of altering the coating process to decrease the concentration of absorbing impurities.

3. Acknowledgments

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