Fabrication Of Complex Optical Components From Mold Design To Product Lecture Notes In Production Engineering

SU-8 is a very promising material for micro-optics. It is mechanically robust with high thermal and chemical resistance, has high transmission at visible and near-infrared wavelengths, and has relatively high refractive index after curing. While lithographic processing of SU-8 is relatively common, molding of SU-8 requires different processing parameters due to challenges with solvent removal and cross linking. Understanding the effects of the molding process on SU-8 is necessary to optimize performance of molded micro-optical components, and also to enable fabrication of more complex micro-optics through subsequent lithographic processing of molded structures. In this thesis, we explore techniques for micromolding of micro- and nano-optics in SU-8 and examine properties of SU-8 as it undergoes the molding process. Elastomeric mold templates are first cast from master structures fabricated using standard techniques. The elastomeric templates are then used in low pressure molding processes to produce high-fidelity refractive and diffractive micro-optics in SU-8. The use of the elastomeric mold templates enables realization of a wider variety of optical surfaces than can be achieved with conventional lithographic patterning in SU-8, and further enables conformal fabrication of SU-8 micro-optics on non-planar surfaces. Molding processes and experimental results for both thin (diffractive) and thick (refractive) elements are presented. Replication of SU-8 micro-optics on both planar and non-planar surfaces, and hybrid processes combining molding and lithographic exposure are demonstrated. SU-8 dimensional changes during processing are characterized, and minimum moldable feature sizes are explored. Solvent content and refractive index as functions of processing parameters are also examined, along with analysis of the SU-8's lithographic properties after undergoing the molding process. The intermediary molds are characterized for shrinkage, and mold lifespan is explored. These characterizations further enable hybrid combinations of micro-molding and lithographic processing to fabricate complex micro-optics that are difficult or impossible to realize using conventional techniques.

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Configurations based on both wave-guide and free-space optics are covered. Novel directions in the area of nanooptics and photonic crystals are included. The reader can expect up-to-date information with many new results. The book is intended for graduate students, teachers, and researchers in industry."--Jacket.

The main focus of this dissertation is to seek scientific and fundamental knowledge of nonconventional optical components including its optical design, ultraprecision prototyping, precision molds making, transition into industrial production and efficient evaluation. A nonconventional component in this dissertation is loosely defined as an optical component either that is not symmetric around its optical axis or that is aspherical surface with three or higher order coefficient. Nonconventional optics have broadened the vision of optical designers and enhanced the design flexibility and thus are becoming increasingly important as a core next-generation optical component.

These optical components have gradually been implemented to replace conventional spherical and aspherical counterparts in the fields of imaging (Plummer, 1982), illumination (Fournier & Rolland, 2008), aviation (Spano, 2008) , and energy (Zamora, et al., 2009) where freeform optics have demonstrated excellent optical performance and high degree of system integration. However, design, fabrication and metrology of nonconventional optics have not been developed at the same pace. Due to the complex nature of nonconventional optics manufacturing processes, the production efficiency and finished quality of nonconventional optical components are difficult to be improved. To validate optical performance, in this dissertation ultraprecision diamond tooling is applied to prototype the optical design, which is capable of generating precision optical features both on polymer blank and metal mold without post grinding and polishing process. In addition, the prototyping process also paves the way to mold fabrication. To produce low cost high volume high quality nonconventional optical components, precision compression/microinjection molding has been combined with ultraprecision diamond machining and cleanroom manufacturing respectively for different size scale and application. Once the low cost molded nonconventional optical components and assembly are fabricated, their optical performance needs to be characterized to ensure quality in industrial production. The geometric feature and principle optical parameter, such as focal length, are two important aspects that influence the final optical performance considerably. In order to solve the major problems in manufacturing affordable high quality nonconventional optical components, this dissertation will include several key steps: 1) Investigate nonconventional optics design that could be functionally and economically applied in various optical components or systems to further improve their performance; 2) Validate and evaluate nonconventional optics design by ultraprecision prototyping; 3) Develop the precision molds manufacturing process and the corresponding molding process both for miniaturized lens profile and micro scale diffraction structure; 4) Investigate the products quality by crucial optical parameters measurement and surface profiling. Overall, this dissertation describes a comprehensive understanding of low cost high volume nonconventional optics manufacturing.

Introduction to Fiber-Optic Communications provides students with the most up-to-date, comprehensive coverage of modern optical fiber communications and applications, striking a fine balance between theory and practice that avoids excessive mathematics and derivations. Unlike other textbooks currently available, this book covers all of the important recent technologies and developments in the field, including electro-optic modulators, coherent optical systems, and silicon integrated photonic circuits. Filled with practical, relevant worked examples and exercise problems, the book presents complete coverage of the topics that optical and communications engineering students need to be successful. From principles of optical and optoelectronic components, to optical transmission system design, and from conventional optical fiber links, to more useful optical communication systems with advanced modulation formats and high-speed DSP, this book covers the necessities on the topic, even including today's important application areas of passive optical networks, datacenters and optical interconnections. Covers fiber-optic communication system fundamentals, design rules and terminologies Provides students with an understanding of the physical principles and characteristics of passive and active fiber-optic components Teaches students how to perform fiber-optic system design, performance evaluation and troubleshooting Includes modern advances in modulation and decoding strategies

Laser materials interaction and processing is an established and growing field within the materials science community. By taking a detailed look at the fundamentals of laser matter interaction, Recent Advances in Laser Processing of Materials charts the recent progress of laser materials interaction and processing in various emerging materials science domains. With special emphasis placed on nanostructures and future developments, this book provides an interdisciplinary support for basic and applied photo-assisted processing research. Coverage includes: laser assisted synthesis of new materials (nanoparticles, nanotubes, active molecules, new phases...) laser assisted surface transformation (nanostructuring, lithography, etching...) laser assisted bulk material transformation (doping, marking, crystallisation...) Laser assisted synthesis of new materials (nanoparticles, nanotubes, active molecules, new phases...) Laser assisted surface transformation (nanostructuring, lithography, etching...) Laser assisted bulk material transformation (doping, marking, crystallisation...)

Three-Dimensional Microfabrication Using Two-Photon Polymerization, Second Edition offers a comprehensive guide to TPP microfabrication and a unified description of TPP microfabrication across disciplines. It offers in-depth discussion and analysis of all aspects of TPP, including the necessary background, pros and cons of TPP microfabrication, material selection, equipment, processes and characterization. Current and future applications are covered, along with case studies that illustrate the book's concepts. This new edition includes updated chapters on metrology, synthesis and the characterization of photoinitiators used in TPP, negative- and positive-tone photoresists, and nonlinear optical characterization of polymers. This is an important resource that will be useful for scientists involved in microfabrication, generation of micro- and nano-patterns and micromachining. Discusses the major types of nanomaterials used in the agriculture and forestry sectors, exploring how their properties make them effective for specific applications Explores the design, fabrication, characterization and applications of nanomaterials for new Agri-products Offers an overview of regulatory aspects regarding the use of nanomaterials for agriculture and forestry

This book provides details on various micro and precision manufacturing and finishing operations performed by conventional and advanced processes, including micro-manufacturing of micro-tools and precision finishing of engineered components. It describes the process mechanism, principles and parameters while performing micro-fabrication and precision finishing operations. The text provides the readers with knowledge of micro and precision manufacturing and encourages them to explore the future venues in this field.

MEMS technology is increasingly penetrating into our lives and improving our quality of life. In parallel to this, advances in nanotechnology and nanomaterials have been catalyzing the rise of NEMS. Consisting of nine chapters reviewing state-of-the-art technologies and their future trends, this book focuses on the latest development of devices and fabrication processes in the field of these extremely miniaturized electromechanical systems. The book offers new knowledge and insight into design, fabrication, and packaging, as well as solutions in these aspects for targeted applications, aiming to support scientists, engineers and academic trainees who are engaged in relevant research. In the chapters, practical issues and advances are discussed for flexible microdevices, bioMEMS, intelligent implants, optical MEMS, nanomachined structures and NEMS, and others. Most of the chapters also focus on novel fabrication/packaging processes, including silicon bulk micromachining, laser micromachining, nanolithography, and packaging for implantable microelectronics enabled by nanomaterials.

This collection of papers, presented at the 11th International Conference on Precision Engineering, offers a broader global perspective on the challenges and opportunities ahead.

The discussion encompasses leading-edge technologies and forecasts future trends. Coverage includes advanced manufacturing systems; ultra-precision- and micro-machining; nanotechnology for fabrication and measurement; rapid prototyping and production technology; new materials and advanced processes; computer-aided production engineering; manufacturing process control; production planning and scheduling, and much more.

The continuous miniaturization of products and the growing complexity of their embedded multifunctionalities necessitates continuous research and development efforts regarding micro components and related micro manufacturing technologies. Highly miniaturized systems, manufactured using a wide variety of materials, have found application in key technological fields, such as healthcare devices, micro implants, mobility, communications, optics, and micro electromechanical systems. Innovations required for the high-precision manufacturing of micro components can specifically be achieved through optimizations using post-process (i.e., offline) and in-process (i.e., online) metrology of both process input and output parameters, as well as geometrical features of the produced micro parts. However, it is of critical importance to reduce the metrology and optimization efforts, since process and product quality control can represent a significant portion of the total production time in micro manufacturing. To solve this fundamental challenge, research efforts have been undertaken in order to define, investigate, implement, and validate the so-called "product/process manufacturing fingerprint" concept. The "product manufacturing fingerprint" concept refers to those unique dimensional outcomes (e.g., surface topography, form error, critical dimensions, etc.) on the produced component that, if kept under control and within specifications, ensure that the entire micro component complies to its specifications. The "process manufacturing fingerprint" is a specific process parameter or feature to be monitored and controlled, in order to maintain the manufacture of products within the specified tolerances. By integrating both product and process manufacturing fingerprint concepts, the metrology and optimization efforts are highly reduced. Therefore, the quality of the micro products increases, with an obvious improvement in production yield. Accordingly, this Special Issue seeks to showcase research papers, short communications, and review articles that focus on novel methodological developments and applications in micro- and sub-micro-scale manufacturing, process monitoring and control, as well as micro and sub-micro product quality assurance. Focus will be on micro manufacturing process chains and their micro product/process fingerprint, towards full process optimization and zero-defect micro manufacturing.

Good optical design is not in itself adequate for optimum performance of optical systems. The mechanical design of the optics and associated support structures is every bit as important as the optics themselves. Optomechanical engineering plays an increasingly important role in the success of new laser systems, space telescopes and instruments, biomedical and optical communication equipment, imaging entertainment systems, and more. This is the first handbook on the subject of optomechanical engineering, a subject that has become very important in the area of optics during the last decade. Covering all major aspects of optomechanical engineering - from conceptual design to fabrication and integration of complex optical systems - this handbook is comprehensive. The practical information within is ideal for optical and optomechanical engineers and scientists involved in the design, development and integration of modern optical systems for commercial, space, and military applications. Charts, tables, figures, and photos augment this already impressive handbook. The text consists of ten chapters, each authored by a world-renowned expert. This unique collaboration makes the Handbook a comprehensive source of cutting edge information and research in the important field of optomechanical engineering. Some of the current research trends that are covered include:

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High quality optical components for consumer products made of glass and plastic are mostly fabricated by replication. This highly developed production technology requires several consecutive, well-matched processing steps called a "process chain" covering all steps from mold design, advanced machining and coating of molds, up to the actual replication and final precision measurement of the quality of the optical components. Current market demands for leading edge optical applications require high precision and cost effective parts in large volumes. For meeting these demands it is necessary to develop high quality process chains and moreover, to crosslink all demands and interdependencies within these process chains. The Transregional Collaborative Research Center "Process chains for the replication of complex optical elements" at Bremen, Aachen and Stillwater worked extensively and thoroughly in this field from 2001 to 2012. This volume will present the latest scientific results for the complete process chain giving a profound insight into present-day high-tech production.

"Given the many different applications and uses of diffractive optics, the importance of this field cannot be underestimated. This book supplements the available literature on diffractive optic elements (DOEs) by equipping readers with the skills to begin designing, simulating, and fabricating diffractive optics. The design of DOEs is presented with simple equations and step-by-step procedures for simulation--from the simplest 1D grating to the more complex multifunctional DOEs--and analyzing their diffraction patterns using MATLAB. The fundamentals of fabrication techniques such as photolithography, electron beam lithography, and focused ion beam lithography with basic instructions for the beginner are presented. Basic error analysis and error-correction techniques for a few cases are also discussed. The contents of all the chapters are supported throughout by practical exercises and clearly commented MATLAB® codes (the codes are also on an accompanying CD), making this book useful even to a novice programmer"--

Mechanics of Microsystems Alberto Corigliano, Raffaele Ardito, Claudia Comi, Attilio Frangi, Aldo Ghisi and Stefano Mariani, Politecnico di Milano, Italy A mechanical approach to microsystems, covering fundamental concepts including MEMS design, modelling and reliability Mechanics of Microsystems takes a mechanical approach to microsystems and covers fundamental concepts including MEMS design, modelling and reliability. The book examines the mechanical behaviour of microsystems from a ‘design for reliability’ point of view and includes examples of applications in industry. Mechanics of Microsystems is divided into two main parts. The first part recalls basic knowledge related to the microsystems behaviour and offers an overview on microsystems and fundamental design and modelling tools from a mechanical point of view, together with many practical examples of real microsystems. The second part covers the mechanical characterization of materials at the micro-scale and considers the most important reliability issues (fracture, fatigue, stiction, damping phenomena, etc) which are fundamental to fabricate a real working device. Key features: Provides an overview of MEMS, with special focus on mechanical-based Microsystems and reliability issues. Includes examples of applications in industry. Accompanied by a website hosting supplementary material. The book provides essential reading for researchers and practitioners working with MEMS, as well as graduate students in mechanical, materials and electrical engineering.

This book provides the reader with the broad range of materials that were discussed in a series of short courses presented at Georgia Tech on the design, fabrication, and testing of diffractive optical elements (DOEs). Although there are not long derivations or detailed methods for specific engineering calculations, the reader should be familiar and comfortable with basic computational techniques. This text is not a 'cookbook' for producing DOEs, but it should provide readers with sufficient information to assess whether this technology would benefit their work, and to understand the requirements for using the concepts and techniques presented by the authors.

4M 2006 - Second International Conference on Multi-Material Micro Manufacture covers the latest state-of-the-art research results from leading European researchers in advanced micro technologies for batch processing of metals, polymers, and ceramics, and the development of new production platforms for micro systems-based products. These contributions are from leading authors at a platform endorsed and funded by the European Union R&D community, as well as leading universities, and independent research and corporate organizations. Contains authoritative papers that reflect the latest developments in micro technologies and micro systems-based products

This edited volume reviews the current state of the art in the additive manufacturing of optical componentry, exploring key principles, materials, processes and applications. A short introduction lets readers familiarize themselves with the fundamental principles of the 3D printing method. This is followed by a chapter on commonly-used and emerging materials for printing of optical components, and subsequent chapters are dedicated to specific topics and case studies. The high potential of additive manufactured optical components is presented based on different manufacturing techniques and accompanied with extensive examples – from nanooptics to large scale optics – and taking research and industrial perspectives. Readers are provided with an extensive overview of the new possibilities brought about by this alternative method for optical components manufacture. Finally, the limitations of the method with respect to manufacturing techniques, materials and optical properties of the generated objects are discussed. With contributions from experts in academia and industry, this work will appeal to a wide readership, from undergraduate students through engineers to researchers interested in modern methods of manufacturing optical components.

Eight contributions address: GaAs on Si, ion beam synthesis in silicon, ion beam processing of chemical vapor deposited silicon layers, technology and devices for silicon based three-dimensional circuits, integrated fabrication of micromechanical structures on silicon, micromachining of silicon for

Optical science and engineering affect almost every aspect of our lives. Millions of miles of optical fiber carry voice and data signals around the world. Lasers are used in surgery of the retina, kidneys, and heart. New high-efficiency light sources promise dramatic reductions in electricity consumption. Night-vision equipment and satellite surveillance are changing how wars are fought. Industry uses optical methods in everything from the production of computer chips to the construction of tunnels. Harnessing Light surveys this multitude of applications, as well as the status of the optics industry and of research and education in optics, and identifies actions that could enhance the field's contributions to society and facilitate its continued technical development.

This text examines the technology behind the plethora of modern industrial and domestic technologies which incorporate micro-optics eg. CDs, cameras, automated manufacturing systems, mobile communications etc. It includes a simple but comprehensive introduction to micro-optical developments design, and an overview of fabrication and replication technology. The theoretical, practical and industrial developments in micro-scale optoelectronics continue apace in the late 1990s. In this book, a distinguished group of physicists and engineers describe the current state of research and applications in micro-optics. It provides the theoretical background and an overview of current technology, with several chapters taking a deeper look at specific recent applications and future trends. The book concentrates on diffractive and refractive micro- optical elements, such as lenses, fan-out gratings, optimized phase elements and polarisers. Sections are included on the simulation and optimization of design for micro-optics and subsequently the efficient transformation from design to real optical elements, using techniques such as e-beam writing, laser beam writing, lithography, etching and thin film deposition.

The technologies for product assembly and manufacturing evolve along with the advancement of enabling technologies such as material science, robotics, machine intelligence as well as information and communication. Furthermore, they may be subject to fundamental changes due to the shift in key product features and/or - gineering requirements. The enabling technologies emerging offer new opportunities for moving up the level of automation, optimization and reliability in product assembly and ma- facturing beyond what have been possible. We see assembly and manufacturing becoming more Intelligent with the perception-driven robotic autonomy, more flexible with the human-robot coupled collaboration in work cells, and more in- grated in scale and complexity under the distributed and networked frameworks. On the other hand, the shift in key product features and engineering requirements dictates the new technologies and tools for assembly and manufacturing to be - veloped. This may be exemplified by a high complexity of micro/nano system products integrated and packaged in 3D with various heterogeneous parts, com- nents, and interconnections, including electrical, optical, mechanical as well as fluidic means.

The Special Issue Machining—Recent Advances, Applications and Challenges is intended as a humble collection of some of the hottest topics in machining. The manufacturing industry is a varying and challenging environment where new advances emerge from one day to another. In recent years, new manufacturing procedures have retained increasing attention from the industrial and scientific community. However, machining still remains the key operation to achieve high productivity and precision for high-added value parts. Continuous research is performed, and new ideas are constantly considered. This Special Issue summarizes selected high-quality papers which were submitted, peer-reviewed, and recommended by experts. It covers some (but not only) of the following topics: High performance operations for difficult-to-cut alloys, wrought and cast materials, light alloys, ceramics, etc.; Cutting tools, grades, substrates and coatings. Wear damage; Advanced cooling in machining: Minimum quantity of lubricant, dry or cryogenics; Modelling, focused on the reduction of risks, the process outcome, and to maintain surface integrity; Vibration problems in machines: Active and passive/predictive methods, sources, diagnosis and avoidance; Influence of machining in new concepts of machine–tool, and machine static and dynamic behaviors; Machinability of new composites, brittle and emerging materials; Assisted machining processes by high-pressure, laser, US, and others; Introduction of new analytics and decision making into machining programming. We wish to thank the reviewers and staff from Materials for their comments, advice, suggestions and invaluable support during the development of this Special Issue.

A temperature and strain rates dependent fracture model is developed based on Weibull statistics to quantitatively describe the brittle-ductile transition of glass fracture in precision glass molding process. Under the assistance of FEM simulation, this fracture model can be used to calculate the fracture probability of glass during the precision glass molding process. Meanwhile, the most probable fracture timing, location of fracture initiation and fracture pattern can be also predicted.

In this thesis, femtosecond lasers are explored for the fabrication of fiber Bragg gratings (FBGs) in suspended core fibers (SCFs) as well as direct writing of integrated optical devices in bulk fused silica glass. The FBGs fabricated in suspended core fibers with different core geometries were demonstrated with femtosecond laser exposure through a Talbot interferometer. In this case, the use of a femtosecond laser system was crucial as it eliminates the need for the use of photosensitive fibers, which is the case for SCFs, while the Talbot interferometry setup provided flexibility in the definition of the grating periodicity, while simultaneously protecting the optical components used in the fabrication process from the high intensities reached during exposure in the proximity of the fibers. These Bragg gratings were employed to show simultaneous strain and temperature sensing. Using a femtosecond laser direct writing system, novel point-by-point fabrication arrangements, with detailed attention to the computer controlled laser beam modulation, were developed in order to correctly introduce modulation of the refractive index profile during the waveguide fabrication process. This technique enabled the development of phase and frequency control required for advanced Bragg grating waveguide (BGW) fabrication and arbitrary spectral shaping. Procedures were demonstrated for the fabrication of chirped and phased shifted BGWs for applications in temporal pulse shaping and spectral shaping that showed significantly improved feature resolutions for sensing applications. The BGWs were used as a practical sensitive tool to determine and study the waveguide birefringence inherent to the nonlinear absorption processes typical of femtosecond laser-material interaction. The control of form and stress birefringence was developed in order to accomplish the fabrication of integrated optical components for polarization control, like guided wave retarders and polarization beam splitters. Tuning of this waveguide birefringence was achieved by the introduction of stress inducing laser modification tracks that enabled the ability to both enhance or reduce the inherent birefringence. Characterization techniques were developed for the absolute determination of the birefringence based on BGWs spectrum splitting, together with crossed polarizer measurements, while novel data analysis procedures were demonstrated for the study of polarization dependent and polarization independent directional couplers with the introduction of a polarization splitting ratio which is wavelength and coupling length dependent. All of the improvements made in the understanding of waveguide birefringence control provided increased flexibility to simultaneously fabricate low polarization mode dispersion circuits, as well as more efficient and compact polarization dependent devices. The polarization aspects detailed here, together with the point-by-point fabrication system, may be further developed in the future towards the fabrication of more complex integrated devices that combine spectral, temporal, and polarization control, all achievable with the same femtosecond laser writing system. These flexible processing techniques will open new directions for writing additional functionalities in optical circuits with more compact three-dimensional geometries.

Comprehensive Materials Processing provides students and professionals with a one-stop resource consolidating and enhancing the literature of the materials processing and manufacturing universe. It provides authoritative analysis of all processes, technologies, and techniques for converting industrial materials from a raw state into finished parts or products. Assisting scientists and engineers in the selection, design, and use of materials, whether in the lab or in industry, it matches the adaptive complexity of emergent materials and processing technologies. Extensive traditional article-level academic discussion of core theories and applications is supplemented by applied case studies and advanced multimedia features. Coverage encompasses the general categories of solidification, powder, deposition, and deformation processing, and includes discussion on plant and tool design, analysis and characterization of processing techniques, high-temperatures studies, and the influence of process scale on component characteristics and behavior. Authored and reviewed by world-class academic and industrial specialists in each subject field Practical tools such as integrated case studies, user-defined process schemata, and multimedia modeling and functionality Maximizes research efficiency by collating the most important and established information in one place with integrated applets linking to relevant outside sources

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