Can subsurface damage be estimated from a knowledge of the abrasive size being used in a variety of grinding operations that use different process parameters to grind different optical materials? As a rule of thumb, using larger abrasives generally leads to deeper damage on optical glass and ceramic surfaces. In attempting to add precision to this practical rule of thumb, we are examining whether the size of the abrasive used can be used to provide such an estimate.

We have collected a large amount of data of measured subsurface damage in brittle materials. The list of all data, with detailed references on feeds and speeds, materials, measured surface roughness, damage, etc. can be found in the Center for Optics Manufacturing’s September 1999 Manufacturing Sciences Quarterly Report (available from COM; please contact Kelly Grover for a copy, phone 716-275-1093, e-mail: KGRO@LLE.ROCHESTER.EDU).

The grinding operations we examined included loose abrasive lapping, deterministic microgrinding with ring tools, pellet grinding, wheel (contour) grinding, and sawing. The abrasives ranged in size from 1 µm to 500 µm.

Brittle materials ground include many optical multicomponent glasses, laser glasses, fused silica, and zerodur, as well as glass ceramics and polycrystalline structural ceramics (alumina Al₂O₃, silicon nitride Si₃N₄, and silicon carbide SiC). Subsurface damage has been measured by sectioning methods, wafering methods, the dimple method, or the MRF variant of the dimple method. Surface microroughness was measured with white light interferometry.

Based on our detailed data analysis, which included the manufacturing conditions (feeds and speeds, etc.), abrasive sizes used, and the range of measured subsurface damage and surface microroughness, we have made the following observations:

1. Subsurface damage generally increases with increasing abrasive size.
2. The data indicate that at abrasive sizes greater than about 100 µm subsurface damage stops increasing with abrasive size, and reaches a plateau value.
3. Deterministic microgrinding consistently gives surfaces with less subsurface damage for the same abrasive size.
4. The amount of subsurface damage from contour grinding of structural ceramics is as expected.
5. The average subsurface damage expected can be estimated from the abrasive size used via: Average SSD (µm) = 1.07 x L^{3/4}.
6. However, the average SSD does not necessarily give us the range over which SSD is expected to vary. It is indeed possible to estimate the subsurface damage from the abrasive size in terms of an upper and lower bound. The results in Fig. 1 can be summarized as: 0.3 L^{0.68} < SSD (µm) < 2 L^{0.85}, where the abrasive size L is in µm.

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A PRACTICAL EXAMPLE:
Let us say that in a lapping operation, we use abrasive size $L = 10 \, \mu\text{m}$. Using the formula on the preceding page, the average SSD induced should be approximately $6 \, \mu\text{m}$. We can compute the range over which SSD is expected to vary for $L = 10 \, \mu\text{m}$ to be $1.4 \, \mu\text{m} < \text{SSD} < 14 \, \mu\text{m}$. This result is expected to hold for all feeds and speeds, and for all optical glasses or glass ceramics regardless of manufacturing conditions. There is a lot of room for engineering improvement in such a wide range, but having an approximate idea of where subsurface damage is expected to be gives the optician one more practical tool to apply.

For more information, please contact John Lambropoulos at the University of Rochester (phone 716-275-4071, fax 716-256-2509, email:jcl@me.rochester.edu).

REFERENCES

The following papers were presented by the University of Rochester’s Center for Optics Manufacturing, at the Optical Fabrication and Testing 2000 Conference (Quebec City, Canada):

1. **Next generation optics manufacturing**, Harvey M. Pollicove, Stephen D. Jacobs, Jeff Ruckman, Michele Richard.

2. **Deterministic contour grinding of conformal optics**, Edward Fess, Jeff Ruckman.


4. **Effect of tool wear on tool and workpiece profiles produced in contour grinding**, Yi Li, Paul D. Funkenbusch, Sheryl M. Gracewski, Jeff Ruckman.

5. **Chatter simulation and stability predictions for contour grinding of optical glasses**, Yi Li, Sheryl M. Gracewski, Paul D. Funkenbusch, Jeff Ruckman.

6. **From abrasive size to subsurface damage in grinding**, John C. Lambropoulos.


8. **Nanohardness of abrasive particles used in magnetorheological finishing (MRF)**, Aric B. Shorey, Stephen D. Jacobs.


Copies of these presentations are available to APOMA members by contacting Kelly Grover at COM (phone 716-275-1093, fax 716-275-7225, e-mail: KGRO@LLE.ROCHESTER.EDU).

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**Yuba College's Laser Optics Technology Program Benefits from Donations**

The Center for Optics Manufacturing has recently donated a Rogers & Clarke G150 to Yuba College in Marysville, CA. The machine will be used in Yuba's Laser Optics Technology program. Students in the Yuba program are studying basic optics and machine-shop techniques, and establishing proficiency in grinding and polishing glass substrates. This year's program graduated 20 students in May 2000; 40 students are registered to start the Fall 2000 program.

Additional equipment has been donated to the program by Lawrence Livermore National Laboratory, LaCroix Optical, Rodel, Universal Photonics, Schott Glass Technologies, United Lens Company, Advantech Machinery, and OCLI. APOMA members willing to donate equipment to the program should contact Mr. Gordon Soekland at Yuba College (ph# 916-316-0271; email: soekland@jps.net) or Breck Hitz at LEOMA - Lasers and Electro Optics Manufacturers Association (ph# 650-738-1492; email: breck@leoma.com).

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Stop by and visit COM on the web!
www.opticam.rochester.edu

Visit APOMA at www.apomanet.org
COM’s annual summer course, “New Machines, Tools and Processes for Modern Optics Manufacturing,” held at the University of Rochester in June 2000, was a resounding success! The attendees (pictured above) hailed from 26 different companies from across the USA, and from Mexico, Hong Kong, Canada, and Israel, for a total of 46 students. Representatives attended from: Applied Physics Specialties Ltd., Army TACOM-ARDEC, Centro de Investigaciones en Optica, A.C., Coherent Auburn Group, CVI Laser, Eastman Kodak Company, Edmund Scientific Company, ELCAN Optical Technologies, Gould Precision Optics, GSI Lumonics Inc., Hong Kong Productivity Council, LOH Optical Machinery Inc, Micro Craft Inc., MIT Lincoln Laboratory, NASA - Marshall Space Flight Center, National Research Council, Optical Coating Laboratory Inc., OptiPro Systems Inc., RAFAEL - Optical Fabrication Center, Raytheon Systems Company, Rochester Photonics Corporation, Shamir Optical Industries, Spectra Physics, SSG Inc., VLOC, and Volk Optical Inc. Attendee backgrounds varied from those being exposed to the technology for the first time, to shop floor supervisors with 25 years of optics experience. Twenty-seven speakers and instructors gave seminars and demonstrations over a four day period on a broad variety of fabrication-related topics. New presentations this year included a talk on glass by Dr. Alex Marker of Schott and a presentation by Prof. Axel Schindler, University of Leipzig, on ion beam processing of optics.

Some comments in response to the question: “How did this course fulfill your expectations?,” are below.

* Extremely well. I’m new to industry and I learned a lot about both technology that is available that we’re currently not using, and about immediate improvements that we can make right away.
* Unfortunately showed the void my company is operating in; incredible stuff taking place.
* Overall fantastic. I have gained several new ideas to try when I get home. The course notes will be referred to for years to come.
* This course did an excellent job of explaining the sciences and processes used in optics manufacturing. As someone new to the optics world, this course is very important to my optics education.
* I learned a lot more than expected, and would recommend that my colleagues attend this course.
* Very much so. It has provided so many possibilities for solving some of our problems. I will definitely send several people next year.
* Great presentations on all areas of optics fab. Excellent, practical, useful information that can be put to use today, plus info and overviews on state-of-the-art equipment and technologies that can be used in our equipment procurement activities.

The course sold out for the 4th year in a row, so please plan on registering early for next year’s course!
Snapshots from COM’s Annual Summer School
June 12-15, 2000
Rochester, NY

Alex Maltsev (UR/LLE) demonstrates classical optics fabrication using pitch polishing.

Michael Cumbo (OCLI) tutors students in micro-hardness testing.

Dennis VanGee (UR/COM) explains deterministic microgrinding to a summer course student.

Kathleen Richardson (UCF/CREOL) demonstrates glass melting for course attendees.

Ed Fess (UR/COM) demonstrates contour grinding on the Nanotech 500FG.

Students listen to a presentation on subsurface damage testing.

Alex Maltsev (UR/LLE) demonstrates classical optics fabrication using pitch polishing.

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The dates for this year’s American Precision Optics Manufacturers Association (APOMA) Industry Workshop were announced at the APOMA General Meeting in San Diego, CA on August 2, 2000 (co-located with SPIE’s Annual Meeting).

The 2000 APOMA Industry Workshop will be held on Monday and Tuesday, October 16-17, 2000. The event will again be held at the Center for Optics Manufacturing (University of Rochester, Rochester, NY). Corporate members of APOMA will receive invitations via mail for the event. Contact information, pricing and an agenda will be included. Registration will be coordinated by Robert Novak, APOMA Secretary.

### Sinclair Optics Fall 2000 Training Courses

**How to Use OSLO**

*October 30-31, 2000*

*Rochester, New York*

*Presented by Sinclair Optics at the Center for Optics Manufacturing*

*How to Use OSLO* is an introductory course for new users, or for current users who want to use OSLO more effectively. You and your partner will use OSLO to set up and solve a contemporary design problem and follow the demonstrations of how to use OSLO presented during lectures. Emphasis is placed on new features and ways to improve your productivity in optical design. After completing the course, you’ll be ready to use the program on your own or attend the more advanced courses.

**Optical Tolerancing**

*November 1, 2000*

*Rochester, New York*

*Presented by Sinclair Optics at the Center for Optics Manufacturing*

The criterion for the best solution to an optical design problem is changing from maximum performance to satisfactory performance obtained at minimum cost. This has a profound effect on the design process and makes tolerancing issues a primary concern of the optical designer. During the past few years, the tolerancing capabilities in OSLO have been extended to provide superior speed, usability, and flexibility. This course shows how to use them most effectively.

**Zoom Lens Design**

*November 2-3, 2000*

*Rochester, New York*

*Presented by Ellis Betensky at the Center for Optics Manufacturing*

Many, if not most, new lens designs are zoom systems, but little formal training is available showing the practical aspects of zoom lens design. This course shows you how to design standard zoom lenses using the OSLO optical design program. Taught by Ellis Betensky, a leading proponent of zoom systems, *Zoom Lens Design* emphasizes useful approaches to real-world design tasks. It will be assumed that you know the material from the *How to Use OSLO* course, as well as basic first-order optics.

To register, please contact Sinclair Optics, Inc., 6780 Palmyra Road, Fairport, NY 14450 (phone 716-425-4380, fax 716-425-4382, email: sales@sinopt.com). Additional information on the courses is available at [www.sinopt.com](http://www.sinopt.com) by clicking on **Learning**, and then **OSLO Classes**.
Job Postings

COMPANY: LaserPower Corporation
36570 Briggs Road
Murrieta, CA 92563
Attn: Human Resources
Fax: 909-926-9026
E-mail: dfisher@exotic-eo.com

Title: Laser Applications Engineer
Description: Provide applications engineering support and follow up to customers. Help define customer specification for manufacturing and engineering. Design or redesign product configuration based on customer needs. Write technical notes for customers, manufacturing and engineering. Provide suggestions for product improvement and propose new products for development.
Experience: BS degree or equivalent and a minimum of 3 years of experience with laser systems.

Title: Optical Engineer
Description: Design lenses and optical systems in response to customer inquiries. Develop lens drawings for manufacturing and engineering. Responsible for the development and test of prototype systems as well as null lenses and computer generated holograms.
Experience: BS degree or equivalent and a minimum of 3 years of experience with optical design software (Zemax preferred) and CAD systems. Experience in the design and analysis of infrared and laser systems, along with optical metrology, is highly desirable.

Please send resumes to address above.

COMPANY: Moore Nanotechnology Systems, LLC
P.O. Box 605
Keene, NH 03431
Attn: Len Chaloux
E-mail: chaloux@nanotechsys.com

Title: Sales/Applications Engineer
Description: Candidates should preferably have experience in the sale of specialized capital equipment, with a sound knowledge of electro-optical manufacturing technologies and applications. The position requires the ability to operate at all levels of an organization, both internally and externally, and demands excellent communication skills. The successful candidate will take on a broad range of responsibilities including direct sales, primarily in North America, applications support, and various marketing initiatives. Travel will be required.

Title: Electrical Engineer
Description: Candidates should have experience in the design of CNC machine tools with emphasis on fully integrated machine tool electrical systems. This position requires experience with CNC machine controller hardware and software (GE Fanuc and Delta Tau PMAC), servo systems, DC-brushless rotary and linear motors and PCB technology. Some travel for technical support and conference/seminar attendance will be required. The successful candidate should be ready to employ his or her skills in the implementation of compact, state-of-the-art electrical components and sub-systems into a growing product line of ultra-precision, nanometric accuracy machine tools.

Please send resumes to address above.

COMPANY: Zygo Corporation
Laurel Brook Rd.
Middlefield, CT 06455
Attn: Birgit Gillman
Fax: 860-347-3113
E-mail: bgillman@zygo.com

Title: Optical Coating Technician, 2nd shift
Description: Responsible for operating and monitoring vacuum chamber for deposition of optical coatings. Duties include cleaning of optics, set-up, loading, and maintenance of coating chamber, coating evaluations, and removal of coatings.
Experience: 1-3 years hands-on experience in the operation of vacuum systems and cleaning of optical components is preferred. Candidate must be able to work independently.

Title: Optician I, II, or III (all shifts available)
Description: Performs optical fabrication processes, including coring, sawing, curve generating, plano generating, beveling, blocking, grinding, polishing, cleaning, and testing. Performs moderately complex set-ups and operates optical fabrication equipment.
Experience: 1-3 years experience in an optical manufacturing facility is preferred, but trainees will be considered. Candidate must be able to read blue prints and work within a team environment.

Title: Optical CNC Machinist, 2nd or 3rd shift
Description: Operates CNC machines to perform any combination of machining operations such as drilling, milling, and shaping of glass materials to specification. Assembles and positions cutting tools in machines, loads and stores programs and verifies that the machine is operating to set specifications.
Experience: 3-5 years of related experience, ability to read and interpret blue prints are required.

Please send resumes to address above.

WELCOME NEW APOMA MEMBERS!

Applied Superabrasives, Inc.
PO Box 1017
East Windsor, CT 06088
Rep: Bill Herbst
Phone: (860) 654-1780
Fax: (860) 654-1782

Coastal Optical Systems, Inc.
4480 S. Tiffany Drive
West Palm Beach, FL 33407
Rep: Jay Kumler
Phone: (561) 881-7400
Fax: (561) 881-1947

CONVERGENCE • July/August 2000
**2000 Industry Events**

Representatives from COM will be attending the following optics industry events. Stop and see us at:

**APOMA Industry Workshop**, Rochester, NY  
October 16-17, 2000

**OSA Annual Meeting**, Providence, RI  
October 22-26, 2000

**ASPE Annual Meeting**, Scottsdale, AZ  
October 23-27, 2000

**Photonics East 2000**, Boston, MA  
November 6-8, 2000

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**Newsletter Mailing List Update**

Please let us know of any address corrections, additions, or deletions by completing this form. Mail or fax to Michele Stolberg at the Center, fax 716-275-7225.

Name: _______________________________
Title: ________________________________
Company: __________________________
Address: ____________________________
City, State, Zip: ______________________
Phone: ______________________________
Fax: ________________________________
E-Mail: ______________________________

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