Multilayered Optical Data Storage Builds on Proven Technologies

New techniques for recording and reading digital information in a three-dimensional optical memory provide a multilayered format that can increase the capacity of audio CDs and computer archival disks at least 100 times, according to Cornell University scientists.

The techniques, described in the November 15 *Optics Letters*, rely on proven technologies that are ready for commercial development, say Watt Webb, a professor of applied physics, and graduate student James Strickler. The two have created random and ordered patterns of dots that easily could be ordered to contain encoded information recognizable by computer programs, they say.

The team achieved storage of digital information at the ultrahigh density of a terabit per cubic centimeter by superimposing 30 layers of data in a single film of light-sensitive plastic. They foresee no difficulty in increasing the number of layers of data to 100. If 100 layers were filled to capacity, a single five-inch CD-ROM disk could be made to contain 10 million pages of text.

Because each layer is less than 3 μm thick, the multilayered product is as thin as an ordinary compact disk. The two predict their invention will supersede single layer "write-once-read-many" (WORM) devices that are rapidly becoming popular for mass information storage.

A multilayer format, they say, may be an important development for the distribution of digitally stored images since each of these typically require upwards of a million bits of memory.

"Our method can have the advantages of the floppy disk," Strickler said, "in that we get rapid access to archived information, but it has the enormous storage capacity of mass storage magnetic tape. The price of the medium will be measured in pennies per megabyte instead of dollars, and information can't be inadvertently destroyed by head crashes or accidental erasure."

Webb is confident that writing speed can be increased for commercial feasibility by increasing the laser power and selecting more sensitive materials.

While the team expects that the first writing instruments might cost around $100,000, due to the need for an expensive laser, they point out that such lasers are rapidly becoming simpler, more reliable, and less expensive. Read-only instruments, in contrast, require inexpensive lasers and would resemble existing CD players, they say.

To write information on a single plane of a multilayered structure without contaminating adjacent planes, the researchers have exploited a technique known as two-photon absorption. It requires using a laser capable of emitting 100-fs bursts of light that reach a brightness at the focal plane which is 100 billions times that of the sun.

"Only at the focal point of this highly focused beam, and only during these brief pulses, is the light bright enough so that two photons are absorbed simultaneously and molecules of the light-sensitive plastic are excited," Webb explained. This excitation triggers a reaction that alters the refractive index of the plastic, and permits the recording of data. The information may then be read out with a method (interferometric microscopy) that is sensitive to changes in refractive index only at the focal planes.

Stickler developed this new method of information storage while experimenting with two-photon excitation in a laser microscope that he and former graduate student Winfried Denk had invented with Webb for precise chemical manipulations in living cells as well as three-dimensional imaging that reveals details of cell structures. This work also permits biologically active molecules sequestered by inert molecular "cages" to be released at precise points in the cell by means of a flash of laser light.

The Cornell Research Foundation has applied for a patent on the multilayered optical data storage and recovery methods. A U.S. patent recently was issued for their invention with Denk of two-photon excitation in laser scanning microscopy.

Birnbaum, Draper Appointed to Argonne Board of Governors

Howard K. Birnbaum and E. Linn Draper have been appointed to the University of Chicago Board of Governors for Argonne National Laboratory. The board provides guidance, oversight, direction, and advice to the laboratory's management. Its 21 members are drawn from the University of Chicago trustees, officials and faculty, representatives from other universities, and industry leaders.

Birnbaum is director of the Materials Research Laboratory at the University of Illinois at Urbana-Champaign. Draper is chairman, president, and chief executive officer of Gulf States Utilities Co.

Birnbaum, professor of physical metallurgy, heads the Materials Research Laboratory's metals and ceramics program. Among his awards are Department of Energy prizes for outstanding research in

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metallurgy and ceramics. He is a fellow of the American Physical Society and the American Society for Metals, and a member of the National Academy of Engineering, the American Institute of Mining and Metallurgical Engineers, the American Association for the Advancement of Science, and the Materials Research Society.

Draper, previously a member of the faculty and director of the nuclear engineering program at the University of Texas at Austin, is past president of the American Nuclear Society, and has served as a consultant to utility companies, several federal and state agencies, and industrial firms. He has also served on the National Academy of Sciences Committee on Waste Management, the Secretary of Energy's Advisory Panel on Alternative Means of Financing and Managing Radioactive Waste Facilities, and the Texas Radiation Advisory Board.

Bell Makes Tiniest Lasers

AT&T Bell Laboratories scientists report making and operating semiconductor lasers only 5 μm in diameter and 400 atoms thick, the smallest semiconductor lasers ever produced. The lasers look like microscopic thumbtacks attached to their semiconductor substrate by thin posts. The small, fast, and low-power microdisk lasers are part of Bell's research in future switching and computing technology. The lasers may be used either as surface-emitting or side-emitting devices.

Each semiconductor disk laser is made of one or more layers of indium gallium arsenide sandwiched between layers of indium gallium arsenide phosphide. Bell researchers used metalorganic chemical vapor deposition and microlithography to fabricate the tiny disks.

Bell has yet to see if the diminutive laser can meet, in a cost-effective way, certain requirements for applications, including room-temperature operation, efficient coupling, high yield, very low thresholds, thermal stability, and electrical power drives.

Penn State Presents Bridge-Builder Awards

The Materials Research Laboratory of Pennsylvania State University presented its 1991 Bridge-Builder Award to three Japanese scientists who have "built bridges" to the United States by working with colleagues at Penn State. The award ceremony was conducted at the U.S. Embassy in Tokyo. This year's recipients were:

- Shigeo Aramaki, University of Tokyo. Aramaki, Japan's leading volcanologist and an internationally known geoscientist, spent two 1-2 year periods at Penn State where he produced one of the classic papers in basic materials science, the phase diagram for the system Al_2O_3-SiO_2.
- Seiuemon Inaba, president and chief executive officer, FANUC, Ltd. Head of a well-known robot manufacturing firm, Inaba has established a strong connection with Penn State's program in manufacturing science, particularly through the FANUC Professorship in Industrial Engineering. Inaba was represented by his wife, Nozomi Inaba.

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■ Shigeyuki Kimura, National Institute for Research in Inorganic Materials. Kimura, a Senior Group Leader in the National Institute for Research in Materials with an outstanding reputation in crystal growth and high temperature materials, was acknowledged as an uncommon bridge builder, having received his PhD from Penn State.

Eric Cross, former director of Penn State's Materials Research Laboratory, presented the medals. Citations for the three awardees were delivered by Della M. Roy, professor of materials science, Inyong Ham, FANUC professor of manufacturing science, and Robert E. Newnham, Alcoa Professor of Solid State Science. Rustum Roy, Evan Pugh Professor of the Solid State, organized the event.

Reflectance Modulator Uses Common Laser Wavelength

Researchers at Sandia National Laboratories have constructed electrically controlled semiconductor mirrors that can modulate reflectance for 1.06 μm laser light. Previously, reflectance modulators had been limited to a narrow operating range near 0.87 fm, the gallium arsenide wavelength.

Optical connections in computers, radars, and smaller-scale communications to remote sites could benefit from the new wavelength modulators, especially in hostile environments or areas with limited power supplies, since this type of modulator allows messages to be sent with low power.

The design concept of the modulator allows for the construction of similar devices for use at various wavelengths. The modulator is based on strained layer superlattices. The wavelength for operation of reflectance modulators is set by geometry and natural frequencies of the fabrication materials. The construction consists of lattice mismatched quantum wells in a stable structure.

The multilayers for the modulator were prepared by computer-controlled molecular beam epitaxy using wafer rotation during growth. Multiple alternating thin layers of indium gallium arsenide and aluminum gallium arsenide form quantum-well resonators, which are surrounded by thicker layers of indium gallium arsenide and indium aluminum arsenide that form mirrors.

Glass Fibers Add Strength to Bone Fixation

Researchers from industry and academia recently showed that glass fibers containing iron oxide are stronger and dissolve slower than fibers containing alumina. Polymer composites incorporating these fibers may aid the healing process better than the metal pins used today.

Steve L. Lin of Zimmer, Inc., Warsaw, Indiana, noted that orthopedic metal pins have disadvantages, including the need for surgical removal when the bone has healed. A bioabsorbable implant would not only eliminate the need for a second operation, but would also place less strain on the healing bone. Implants that degrade as the bone heals prevent stress-shielding-induced osteoporosis, Lin said.

He also said that polymer pins have been used for small bone fractures but have not been strong enough for larger breaks. Lin's team, which includes William C. Lacourse of the New York State College of Ceramics in Alfred, Binod Kumar of the University of Dayton Research Institute in Ohio, and Steve L. Krebs of Zimmer, Inc., has found that phosphate glass fibers enforced with iron oxides have enough strength to be used with larger breaks while still allowing the implant to degrade when support is no longer needed.

ACS Forms Materials Chemistry Secretariat

Eleven divisions of the American Chemical Society (ACS) became charter members of the Materials Chemistry Secretariat last August, reflecting a growing materials emphasis in chemistry. The Secretariat, this one the fifth to be formed at ACS, is a spontaneous, unofficial mechanism that allows divisions to do joint programming in interdisciplinary areas.

Ripudaman Malhotra from SRI International and secretary-general of the new Secretariat says that the Materials Chemistry Secretariat transcends the ACS's standard divisions, effectively fulfilling a growing need for materials understanding and design within many subdisciplines of chemistry. The needs went beyond what chemists could answer alone, he said.

Peter Lykos, secretary/treasurer of the new Secretariat, proposed the Secretariat to officers of the ACS technical divisions in July 1988 after working on the idea with other scientists in the Chicago area. Lykos, professor of chemistry at the Illinois Institute of Technology, credits Gerry Liedl, Purdue University, for inspiring him to action by requesting a contribution on materials chemistry for an *MRS Bulletin* issue (May 16-June 15, 1987, p. 34) dedicated to materials education. Liedl was the guest editor of the issue.

In the 1988 proposal, Lykos suggested the Secretariat would signal chemists and nonchemists that materials chemistry is an important new and exciting component of chemistry. It also would open avenues of response to scientific opportunities by creating symposia that would draw people from different subdisciplines, as well as promoting cross-fertilization with researchers from other professional societies such as MRS, the American Physical Society, American Institute of Chemical Engineers, and American Ceramic Society, he said.

The Materials Chemistry Secretariat's first major effort will be to organize symposia on materials and energy as part of the National ACS Meeting scheduled for Spring 1993 in Denver. The overall theme of the meeting is energy.

The 11 charter divisions of the Materials Chemistry Secretariat are analytical chemistry, biological chemistry, chemical marketing and economics, colloid and surface chemistry, fuel chemistry, inorganic chemistry, organic chemistry, physical chemistry, polymeric materials: science and engineering, and polymer chemistry. Two additional divisions, carbohydrates and chemistry education, have applied for membership.

The Secretariat's secretary-general-elect is Theodore Davidson, University of Connecticut, Storrs.

NSF Centers Form Partnerships with Pacific Rim Institutions

Five research centers funded by the National Science Foundation (NSF) have established "Partnerships for Science and Engineering" with education and research institutions in Southeast Asia. The purpose of these partnerships is to help accelerate economic and technological development by forging bonds between the participating institutions and technology-based industries in their home countries. Each of the NSF centers will receive a two-year award of $100,000 from the Agency for International Development (AID) to implement a joint program of research, education, and information exchange in specific technical areas.

The five Partnerships and their areas of concentration are:

1. Engineering Research Center (ERC) for Data Storage Systems at Carnegie Mellon University and the Magnetic Technology Centre of the National University of Singapore (data storage technology);

2. Industry/University Cooperative Research Center (I/UCRC) for Hazardous Substance Management at the New Jersey Institute of Technology and the University of Indonesia in Jakarta (hazardous waste management);

3. I/UCRC for Ceramic Research at Rutgers University and the Standards and

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Industrial Research Institute of Malaysia (advanced ceramics);

4. I/UCRC for Parallel, Distributed, and Intelligent Systems of the University of Pittsburgh, the Department of Mathematics of the University of Malaysia, and the Institute of Systems Science of the National University of Singapore (multimedia, multilingual knowledge-based engineering; and

5. I/UCRC for Design of the Analog-Digital Integrated Circuits at Washington State University and the Universiti Teknologi Malaysia (electronics).

The Partnerships for Science and Engineering are formed under a U.S. State Department initiative, the Asian Pacific Economic Cooperation (APEC) Partnerships for Education, which is being implemented and administered by AID.

Dow, Sandia Sign Silica Processing CRADA

Dow Corning Corporation and Sandia National Laboratories have signed a cooperative research and development agreement (CRADA) to investigate new silica processing methods. Sharing in research but not parties to the CRADA are the University of Cincinnati and University of New Mexico.

The R&D program builds on Sandia's and the two universities' expertise in silica chemistry, mixing of organic and inorganic substances, and special scattering techniques to characterize the manufacturing process. Nuclear magnetic resonance and scattering instrumentation will be used to measure filler content, structure, and interface mixing.

Dow Corning and other U.S. companies supply approximately half the annual silicone elastomer world production worth more than $2 billion, but the U.S. share is threatened as technology and product quality abroad improve. The Sandia/Dow CRADA seeks to contribute to U.S. competitiveness by transferring technologies developed at national laboratories to U.S. industry.

The vehicle of this mandate is the National Competitiveness Technology Transfer Act of 1989 which authorizes DOE laboratories to enter into CRADAs with private industry. Under the provisions of this act, sponsored by U.S. Senators Pete Domenici and Jeff Bringaman of New Mexico, the laboratories can negotiate directly with industry, dispose of intellectual property developed in a CRADA, and withhold for up to five years publication of commercially valuable information developed under a CRADA.

Researchers Speed Tests of Chip Reliability

A computer program developed at the University of Illinois may decrease from months to minutes the time needed to test the speed and reliability of newly designed "smart" chips. Chip manufacturers can correct timing and reliability defects early in the design process, said Sung-Mo Kang, the research leader and a professor of electrical and computer engineering. Cramming several million electronic components into a semiconductor chip can lead to electrical shorts or circuit breaks, a problem manufacturers work hard to avoid.

The program, ILLIADS (Illinois Analogous Digital Simulator), achieves its speed by using computers to solve complex equations in a new way. The new method of symbolic manipulation is far more efficient than the conventional approach of using computers to process vast amounts of data. In 10 minutes, the program, which can be used at most computer workstations, simulates the aging of a quarter million transistors. The largest number of transistors handled by previous programs that simulated chip aging was approximately 20,000, and that took may days at conventional workstations, Kang said. ILLIADS achieves results comparable in accuracy to those of the most reliable programs now used.

The development of the program, now in the hands of industrial designers who are to comment on the simulator, has been funded by the Semiconductor Research Corporation, U.S. Joint Services Electronics Program, and Rome Laboratory.

IBM, Lam to Develop Plasma Etch Source

IBM and Lam Research Corporation, Fremont, California have signed a contract to co-develop a low-pressure, high-density, inductively-coupled plasma source for etch requirements in fabricating advanced DRAM semiconductor devices.

The high-density plasma source, based on technologies independently developed by IBM and Lam, will be designed into existing and future Lam platforms and will be commercially available.

The co-developed source will operate at low pressures to facilitate the mass transport features required in quarter-micron regimes. It will be able to produce high plasma densities to ensure high etch rates and high throughput. It will also feature independent dc bias control—minimizing etch-related damage—and excellent wafer temperature control. This technology will be extendable to 300 mm wafer processing.

While many new plasma sources have recently been proposed, commercial reactor configurations typically dictate a compromise between performance and productions costs. The new plasma technology is expected to offer a lower cost-of-ownership solution since it is a simple way of generating a high-density, uniform plasma. Production costs will be further minimized by incorporating the new plasma source into Lam's established etch product platform.

According to IBM, the work that IBM and Lam have independently accomplished in characterizing the new plasma source shows that it has the potential to address 0.25 micron device requirements, indicating a practical, low-cost way to generate high-density plasmas for critical etch requirements.

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