

CMRR Report

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Center for Magnetic Recording Research

Number 16

Fall 1992

Knudson Receives IBM Fellowship

Kelly Knudson, a graduate student in Professor Jack Wolf's group at CMRR, has received her third IBM Graduate Fellowship supported by IBM Almaden Research Center and AdStar. This fellowship provides a \$12,000 stipend and registration fees for the 1992-93 academic year.



KELLY KNUDSON

Kelly's technical liaisons at IBM will be Paul Siegel and Hemant Thapar, who will maintain close communication with her during the fellowship year.

Kelly has recently been advanced to candidacy in the Ph.D. program in electrical engineering—communication theory and systems. At CMRR her research involves coding and detection of partial response channels for magnetic recording. Kelly can be reached at (619) 534-6587.

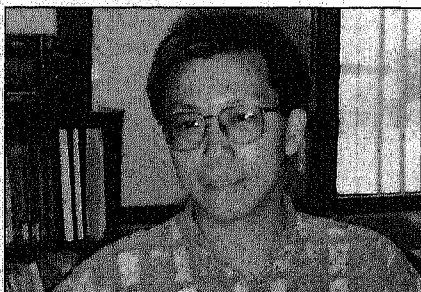
Wenjie Chen

In March 1992 doctoral student Wenjie Chen was awarded his Ph.D. in physics. The title of Chen's dissertation, which is available through CMRR's Information Center, is "Micromagnetics Studies of Small Ferromagnetic Particles Using Finite Element Method." Professor Donald R. Fredkin, UCSD Department of Physics, was the supervisor for this research.

Prior to coming to UCSD in 1986, Chen received his B.S. in physics from the University of Science and Technology of China. After working for six months on experimental high-energy physics, Chen began his graduate studies with Professor Fredkin. Joint funding from the NSF and CMRR supported his graduate research.

continued next page

WENJIE CHEN



NSIC Wins Major DARPA Grant

The National Storage Industry Consortium (of which CMRR is a member) has been notified by DARPA that they have been awarded a grant of \$10.7 million for long-term, pre-competitive research on advanced recording technologies. The grant will be used over the first two years of a five-year set of joint research programs that the consortium members have planned. The programs will address magnetic tape and disk recording as well as optical recording technologies.

The five-year targets for the consortium programs are technologies which will enable:

Magnetic disk recording at a density of 10 gigabits per square inch;

Magnetic tape recording providing storage of one Terabyte per cubic inch;

and Optical recording at 10x current densities.

The programs will involve fourteen companies and fifteen universities in a matrixed set of program teams. NSIC will provide central coordination and will manage administrative and accounting functions.

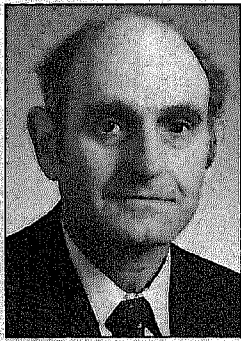
CMRR will participate in both the magnetic disk and tape programs. The CMRR program costs will total over \$2 million over the next two years. Approximately half of these costs will be reimbursed from the DARPA funds.

This new NSIC/DARPA program is in addition to another NSIC program addressing Ultra-High Density Magnetic Recording Heads which will be funded in part by the Advanced Technology Program of the Department of Commerce. CMRR will also play a key role in this program which officially began on August 1, 1992. The NSIC/ATP Heads program totals \$11.3 million over five years. ATP will provide \$5.5 million of that total. CMRR will receive about \$720,000 from the ATP funds.

For further information, call either Sheldon Schultz at CMRR (619) 534-6210 or John Simonds at NSIC (619) 621-2550.

Current CMRR Sponsors

- Ampex Corporation
- Applied Magnetics Corporation
- Carlisle Memory Products
- Conner Peripherals
- Digital Equipment Corporation
- Eastman Kodak Company
- Hewlett Packard
- IBM Corporation
- Iomega Corporation
- Maxtor Corporation
- Metrum Information Storage
- Quantum Corporation
- Seagate Technology
- Storage Technologies



From the Director

In this issue you will find an announcement of two new grants that have just been announced to the NSIC (National Storage Industry Consortium). One grant is from the ATP (Advanced Technology Program) under the Department of Commerce, and the other is from DARPA. CMRR joins in saying congratulations to John Simonds and all the others who contributed to this important development

for our industry.

The combination of these two grants provides significant support for an industry-university joint project to develop the pre-competitive technology for future generations of magnetic disc drives and tape systems. CMRR is very pleased and honored to have been selected to play a major role in the university part of two projects; disc storage at 10 GBits/in² and tape storage at 1 Terra Byte/in³. Both of these projects represent increases in storage density of approximately two orders of magnitude, so clearly some new, perhaps even dramatic, technical developments may have to be forthcoming. As we progress, and milestones are reached, there will be further coverage in this Newsletter, but the best way to stay informed is through more direct contact with researchers at the center. Which brings me to the next paragraph.

As so many of you know, twice a year CMRR presents a two-day complete Research Review open to all personnel associated with our industrial sponsors. The most recent review was held on October 21 and 22, 1992, and included a joint presentation by the center

faculty outlining their plans and responsibilities for both the ATP and DARPA projects. For those who were not at this last meeting, please note that we tried a new format for the presentations and lab tours which was very well received. In brief, we used to have all the talks squeezed into one day, which left a very limited time for lab tours. Frankly, as we expand our programs, it just got to be too much technology for anyone to absorb in one day. Also, we realized that many of you may be mainly interested in only one specific group's work at a given time, and once here wish to be able to have a more lengthy interaction with the students and staff. So, each group's presentations are now on one of the two days, leaving time for more meaningful personal interactions.

Another benefit of visiting the center is an opportunity to visit the Information Center and speak with our information manager, Dawn Talbot. Many of you make use of some of the Information Center's services, such as document retrieval, searches, etc., but there is much more that she can do to help you. Incidentally, please note that another way to really improve your company's use of the Information Center is to invite Dawn to visit. She has a brief video, and makes a concise presentation that has been very well received. So, if you can arrange for a group of your staff to get together, just give Dawn a call at 619-534-6213 and she will plan to make a visit to your facility.

If you were unable to join us at the October Review, remember you are welcome to visit at any time. Please give me a call, and I'll be happy to arrange for your schedule.

Shelly Schultz

Chen continued from page 1

While a graduate student, Wenjie Chen presented two seminars in the weekly CMRR seminar series. The first, "Magnetization Reversal in Spherical Particles" (VT-89-031) was given October 10, 1989, and more recently "Micromagnetic Studies of Submicron Permalloy Particles," on February 25, 1992 (VT-92-007). Both are available to CMRR sponsors on videotape and can be requested through the Information Center.

Papers resulting from Chen's research are listed below:

Wenjie Chen, D.R. Fredkin. "Magnetization Reversal in Spherical Particles." J. Appl. Phys., Vol 67, 4508 (1990).

Wenjie Chen, S. Zhang, and H.N. Bertram. "Energy Barrier for Thermal Reversal of Interacting Single Domain Particles." J. Appl. Phys., Vol 71, 5579 (1992).

Gary A. Gibson, S. Schultz, Wenjie Chen, and D.R. Fredkin. "Magnetic Force Microscopy Study of the Micromagnetics of Submicron Magnetic Particles." Presented at the SPIE International

Symposium on Laser Spectroscopy, Los Angeles, California, January 19-24, 1992, to be published in SPIE Proceedings (1992).

Wenjie Chen, D.R. Fredkin, T.R. Koehler. "Micromagnetic Studies of Interacting Permalloy Particles." IEEE Transactions on Magnetics, MAG-28(5), pp 3168-3170, 1992.

D.R. Fredkin, Wenjie Chen, T.R. Koehler. "Hysteresis in Random Collections of Isotropic Interacting Particles." IEEE Transactions on Magnetics, MAG-28(5), pp 2380-2381, 1992.

Wenjie Chen, D.R. Fredkin, T.R. Koehler. "Micromagnetics of Imperfect Permalloy Particles." To be presented at the 37th Annual Conference on Magnetism and Magnetic Materials, Houston, Texas, December 1-4, 1992.

T.R. Koehler, B. Yang, Wenjie Chen, D.R. Fredkin. "Simulation of Magnetoresistance Response in a Small Permalloy Strip." To be presented at the 37th Annual Conference on Magnetism and Magnetic Materials, Houston, Texas, December 1-4, 1992.

Wenjie Chen, D.R. Fredkin, T.R. Koehler. "A New Finite Element Method in Micromagnetics." Submitted to IEEE Transactions on Magnetism, 1992.

Since March, Chen has been a postdoctoral student in Professor Fredkin's group. In collaboration with Professor Sheldon Schultz, director of CMRR, they are studying gamma ferric oxide particles of prolate ellipsoidal shapes with a view to improving the properties of these particles which are used in particulate recording media. Other studies, again in collaboration with the Schultz group, involve modelling time dependence of magnetization in order to improve the stability of long-term data storage.

Since October 12, Chen has been working for Maxtor, San Jose, as a head media engineer, reporting to Tony Eppstein.

Bertram Lectures at NATO Institute

A NATO-ASI Summer School in Applied Magnetism was held July 1-12 in Erice, Italy. Professor H. Neal Bertram joined nine other distinguished magneticians on the program. Topics included:

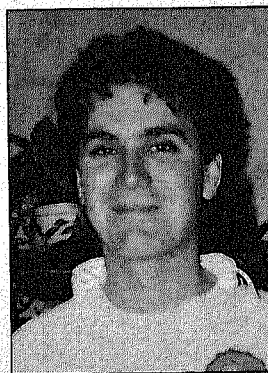
- Permanent magnets: G. Asti, University of Parma
- Physics of magnetic recording: H. Neal Bertram, CMRR
- Magnetic fine particles: R.W. Chantrell, University of Keele
- Magnetic separation: R. Gerber, University of Salford
- Magnetic recording devices and media: M.H. Kryder, Carnegie Mellon University
- Magneto-optic media and systems: M.H. Kryder, Carnegie Mellon University
- Thin film magneto-optics: P. Lissberger, Queen's University, Belfast
- Magnetoresistance: D. Mapps, Plymouth Polytechnic Southwest
- Domains and domain walls in soft magnetic materials: J. Miltat, Universite de Paris-Sud
- Computational magnetism: P. Sylvester, McGill University
- Microwave and optical magnetism: D. Stancil, Carnegie Mellon University

The purpose of the summer school was to bring together leading senior scientists and postdoctoral and postgraduate researchers for a scholarly review of applied magnetism. Within this environment it is expected that the young researchers would gain an appreciation of the opportunities and complexities associated with applied magnetism. The lecture format was augmented with tutorials and workshops in order to encourage lively debate and discussion between lecturers and students. A limited number of poster sessions were presented by students as an opportunity for them to outline their areas of study. Some sixty to seventy students from around the world attended, three from CMRR—David Margulies, Janyce Mitchell, and

Richard Kodama. Proceedings from this meeting will be published late fall by Kluwer Academic in a book titled *Applied Magnetism*. CMRR can provide preprints of professor Bertram's section to members of our sponsor companies. Contact Jan Neumann, Phone: (619) 534-6199, FAX: (619) 534-2720.

Students Graduate from Wolf Lab

Recently three of the graduate students from Professor Jack Keil Wolf's lab at CMRR have been awarded their Ph.D.'s. Brief information about these students follows:



Alan Armstrong

Alan Armstrong graduated from San Diego State University in 1987 with a B.S. in electrical engineering. He received his M.S. in electrical engineering (communication theory and systems) from UCSD in 1988. In the summer of 1988, Alan worked for Recording Physics Inc., in San Diego. Returning to UCSD, he completed his graduate studies in November 1991 with a Ph.D. in electrical engineering

from the Center for Magnetic Recording Research.

Alan's thesis is titled "Magnetic Recording: Coding and Characterization." Other research papers written while at the center include:

Armstrong, A; Wolf, J.K. "Coded Partial Response Signalling with Peak Detection." GLOBECOM '90, IEEE Global Telecommunications Conference Record, pp. 1782-1786, 1990.

Barndt, R; Armstrong, A; Bertram, H.N.; Wolf, J.K. "A Simple Statistical Model of Partial Erasure in Thin-Film Disk Magnetic Recording Systems." IEEE Transactions on Magnetism, MAG-27 (6), pp. 4978-4980, 1991.

Armstrong, A; Wolf, J.K. "Performance Evaluation of a New Coding Scheme for the Peak Detecting Magnetic Recording Channel." IEEE Transactions on Magnetism, MAG-27 (6), pp. 4804-4806, 1991.

Armstrong, A; Bertram, H.N.; Barndt, R; Wolf, J.K. "Nonlinear Effects in High Density Tape Recording." IEEE Transactions on Magnetism, MAG-27 (5), pp. 4366-4376, 1991.

Barndt, R.D; Armstrong, A.J; Wolf J.K. "Media Selection for High Density Recording Channels." presented at TMRC '92, Santa Clara, July 1992.

Throughout most of Armstrong's graduate career, he was a part-time consultant to various companies in the magnetic recording

industry, including Metrum Information Storage, Recording Physics Inc., and Cirrus Logic Inc..

After spending seven months as a postdoctoral research engineer at the Center for Magnetic Recording Research, working with professors Jack Kell Wolf and H. Neal Bertram, Alan Armstrong has moved to Broomfield, Colorado, to work for Cirrus Logic, Colorado, a chip supplier to many of CMRR's sponsoring companies.

At Cirrus Logic, Colorado, Alan is doing research on advanced algorithms and architectures for digital storage channels. He is also part of the team developing a state-of-the-art recording lab for the evaluation of Cirrus products. In July 1992 Alan was nominated as a distinguished speaker of the IEEE Communications Society.



Rick Barndt

Rick received his B.S. in physics from the University of Washington in 1980. After working for several years as a field engineer Rick came to UCSD in 1987 as a master's student in electrical engineering. In 1988 he started working in Jack Wolf's lab and went on to complete his graduate studies this year. His thesis topic was "Signal Processing and Channel Modeling for Magnetic Recording." Rick presented

papers at Intermag, the Magnetic Recording Conference, and GLOBECOM while here at the center. His published papers include:

Barndt, R; Armstrong, A; Bertram, H, Neal; and Wolf, J. "A Simple Statistical Model of Partial Erasure in Thin-Film Disk Magnetic Recording Systems." IEEE Transactions on Magnetics MAG-27(6) pp. 4978-4980, November 1991.

Armstrong, A; Bertram, H, Neal; Barndt, R; and Wolf, J. "Nonlinear Effects in High-Density Tape Recording." IEEE Transactions on Magnetics MAG-27(5) pp. 4366-4376, 1991.

Barndt, R; Armstrong, A; Wolf, J. "Media Selection for High Density Recording Channels." Presented at TMRC '92, Santa Clara, CA, July 1992.

Barndt, R; Wolf, J. "Nonlinear Intersymbol Destruction versus Linear Intersymbol Interference on High Density Disk Drives." Submitted to GLOBECOM '92, IEEE Communications Society, 1992.

While here at CMRR, Rick was instrumental in establishing the lab for the signal processing group. He introduced much of the hardware and implemented data collection and analysis software. When not in the lab Rick could be found cycling around San Diego with the UCSD cycling team.

Rick has accepted a position with Hewlett Packard Labs in Palo Alto where he will be working with Richard Baugh.



Paul Bender

Paul received his B.S. in electrical engineering from UCSD in 1988. Upon graduation, Paul received a Powell Foundation fellowship which paid his tuition fees and a stipend for the 1988-89 academic year. During this time he completed the required courses preliminary to undertaking a Ph.D. in communications theory and systems in electrical engineering. After spending the summer working in Professor

Wolf's lab here at CMRR, Paul received an Industrial Liaison Fellowship from the ECE department for the 1989-90 academic year.

Paul's thesis is titled "Redundancy Reorganization for the Magnetic Channel." Paul's research led to two new algorithms, one for charge constraining of run length limiting binary sequences, and the other for data compression that lends itself very well to the constraints of magnetic hard disk drives.

Papers presented by Paul during his time at CMRR include:

Bender, P.; Wolf, J. "An Improved Sliding Window Data Compression Algorithm Based on the Lempel-Ziv Data Compression Algorithm." GLOBECOM '90 IEEE Global Telecommunications Conference Record, pp. 1773-1777, 1990.

Bender, P; Wolf, J. "New Asymptotic Bounds and Improvements on the Lempel-Ziv Data Compression Algorithm." IEEE Transactions on Information Theory, IT-37(3), pp. 721-729, May 1991.

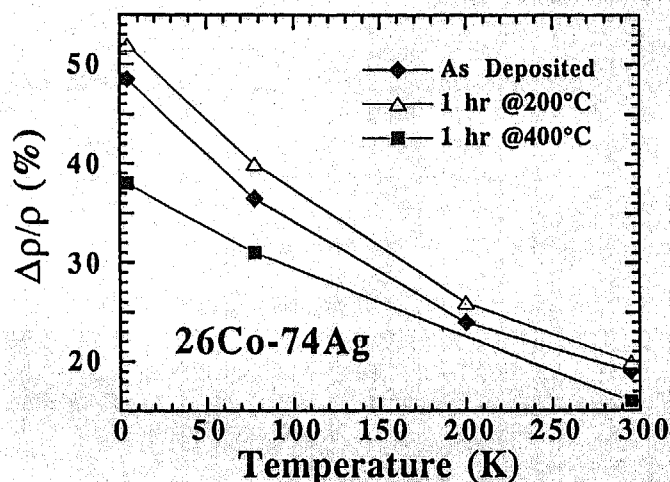
Bender, P; Wolf, J. "An Improvement to the Lempel-Ziv Data Compression Algorithm." presented at IEEE International Symposium on Information Theory, Budapest, Hungary. Proceedings of the 1991 IEEE International Symposium on Information Theory, p. 106, June 1991.

Starting August 17, Paul is working at Qualcomm here in San Diego as a senior engineer, working with Roberto Padovani.

All of the theses and papers mentioned above are available to members of CMRR's sponsoring companies by contacting Jan Neumann at the Information Center. Phone (619) 534-6199, FAX (619) 534-2720

Giant Magnetoresistance

The June 22 issue of *Physical Review Letters* contained a report on recent research carried out in the Berkowitz lab at CMRR. Titled "Giant Magnetoresistance in Heterogeneous Cu-Co Alloys," this paper reports on the observation of giant magnetoresistance (GMR) in single layer films of heterogeneous alloys. Previously GMR has been reported only in multilayer films. These new magnetoresistive materials hold significant promise for use in magnetic read heads. They are formed by sputtering and undergo a 20 percent change in resistivity at room temperature, and as much as a 40 percent change if cooled to minus 400 degrees Fahrenheit. This is 10 to 20 times greater change than occurs in currently used materials.



Graph shows more recent data for very large magnetoresistive ratio $\Delta\rho/\rho$ as a function of temperature for heterogeneous silver cobalt thin film at room temperature (290 degrees K). This film has a maximum magnetoresistance of 20 percent at room temperature, which is an order of magnitude larger than with permalloy which is currently used for MR readout heads.

CMRR Students Spend Summer Working in Industry

Michael Wahl, a graduate student in Professor Frank Talke's group at CMRR, spent his third summer at one of CMRR's sponsoring companies—lomega in Roy, Utah. After having spent three months at the University of Stuttgart, Michael then flew to Utah where he began at lomega on August 4. While there he worked on mechanical aspects of the Bernoulli head/disk interface. This includes numerical simulations using finite element analysis that was started during the last year. Michael returned to the center on October 14.

Min Yang, another of Professor Talke's students, worked over the summer at Western Digital, San Jose. Western Digital is a supplier of 3 1/2 inch and smaller form factor drives. While there she worked with Steve Smith, manager of the tribology group. Min has been looking at different lubricants in order to optimize performance

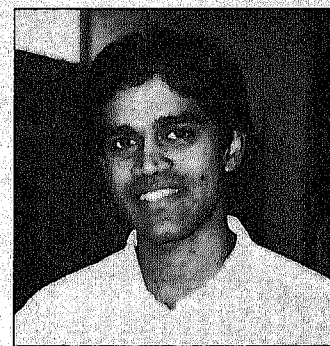
of the thin film head/disk interface. While at Western Digital, Min has been provided with the opportunity to work with a broad range of equipment which will speed up her research on return to UCSD. She is using FTIR, gas chromatography, and mass spectroscopy for wear evaluation and has learned to tear down drives for failure analysis. After her return to the center in mid-September, Min is completing an environmentally controlled chamber which will enable her to study the effect of environmental conditions on the tribology of the head/disk interface. At CMRR Min Yang will be entering her third year with Professor Talke. She had already completed two years of graduate study at UCSD before coming to work at the center.

Jim Fitzpatrick, a student of Professor Jack Wolf, spent the summer at Kodak, Rochester, N.Y. Since July 28 he worked in the Optical Heads and Systems research laboratory under the direction of Jim Barnard. His project focused on developing new models of the recording and playback processes from a signal processing perspective. Through this effort, it has become obvious that certain signal processing techniques used in magnetic recording are impractical for optical recording. Since the physics of optical recording and playback are entirely different from that of magnetic recording systems, the signal processing solutions for each system are quite different. It is hoped that these models which Jim is working on will lead to new and improved recording strategies. Jim returned to the center in mid-September.

Postdoc to Applied Magnetics Corporation

S.K. Ganapathi recently completed eighteen months as a postdoctoral research scientist at CMRR with Professor Frank Talke, where he worked on tribology and wear problems of the head/disk interface. In particular, Ganapathi investigated the effect of tribochemistry on the wear of carbon overcoated disks, studied the initiation of wear of thin film disks using scanning and transmission microscopy, and investigated the correlation between start/stop and continuous speed drag tests.

In June of this year, Ganapathi accepted an offer to work for Applied Magnetics Corporation, in Goleta, CA. At AMC he is working on tribology and mechanics issues relating to magnetoresistive heads.



Future Conferences

- | | | | |
|------------------------|---|------------------|--|
| Nov. 16-20, 1992 | COMDEX, Las Vegas, NV
For info: The Interface Group, 300 First Ave.,
Needham, MA 02194-2722 (617) 449-
6600, (617) 449-2674 Fax | Dec. 6-9, 1992 | GLOBECOM '92, Orlando, FL
For info: Ed Ellis, Siemens Stromberg-Carlson,
902 Red Bird Lane, Altamonte Springs, FL
(407) 834-3319, (407) 333-5155 Fax
Note: Special session on Signal Processing
and Coding for Recording Channels
For info: Michael Marcellis, Dept. of Electrical
and Computer Engineering,
University of Arizona, Tucson, AZ
(602) 621-6190, (602) 621-8076 Fax |
| Nov. 30 - Dec. 4, 1992 | MRS Fall Meeting, Boston, PA
For info: Merry Gell, 9800 McKnight Rd.,
Pittsburgh, PA 15237 | | |
| Dec. 1-4, 1992 | 36th Conference on Magnetism and
Magnetic Materials (MMM) Houston, TX
For info: Courtesy Associates, 655 15th St.,
NW, Suite 300, Washington, D.C. 20005
(202) 639-5088 | Jan. 18-22, 1993 | IEEE International Symposium on Information
Theory, San Antonio, TX
For info: Prof. Costas Georgiades, Dept. of
Elec Eng, Texas A & M University,
College Station, TX 77843
(409) 845-7408 |
| Dec. 1-3, 1992 | Technology 2002, Third National Technology
Transfer Conference and Exposition,
Baltimore, MD
For info: Technology Utilization Foundation,
41 East 4th St., Suite 921,
New York, NY 10017
(800) 944-NASA or (212) 490-3999 | Feb. 21-25, 1993 | TMS (Minerals, Metals, Materials) 1993
Annual Meeting, Denver, Co
For info: TMS Technical Programming Dept.,
420 Commonwealth Dr.,
Warrendale, PA 15086
(412) 776-9042 Fax (412) 776-3770 |
| Dec. 6-8, 1992 | Magneto-Optical Recording International
Symposium '92 (MORIS '92) Tucson, AZ
For info: Prof. Masud Mansuripur,
Optical Sciences Center,
University of Arizona, Tucson, AZ 85721
(602) 623-9034, mm@mm.optsci.arizona.edu | March 1-5, 1993 | International Symposium on Metallic
Multilayers (MML '93), Kyoto, Japan
For info: T. Shinjo, Institute for Chemical
Research, Kyoto University,
Uji, Kyoto-ku 611, Japan
01-774-331247 Fax |

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