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JODIE CHRISTNER, EDITOR

A MESSAGE FROM THE PRESIDENT



David Thompson

The Intermag Conference in Stockholm was wonderful, as we all expected. The papers were good, Stockholm was beautiful and interesting, the weather was superb, and our colleagues were as entertaining as ever.

There were a few items from the committee meetings that might be of interest to the membership. One was the reluctant decision to pursue an orderly phase-out of our Translation Journal on Magnetics in Japan, or TJMJ as it's called. This journal prints English translations of important magnetics papers that have first appeared in Japanese. It has a small circulation, and has always lost money. Equally important, it has consumed a lot of time, effort, and enthusiasm from the Magnetics Society volunteers who have worked so hard to make it a success. We are a volunteer organization that needs to conserve enthusiasm as much as it needs to conserve money. The TJMJ was and is a good idea, but we have to turn our attention to even better ones. I would like to express the Society's sincere thanks to those who have worked on TJMJ, and who will continue to do so to the end of the project.

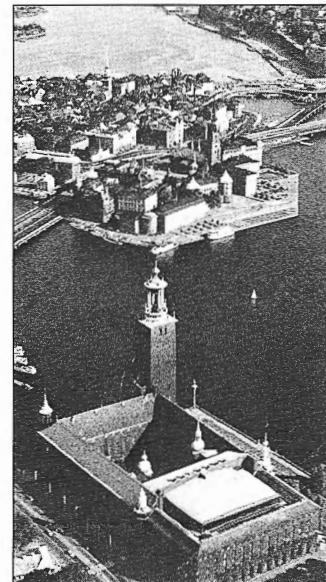
Another item that was discussed was moving the Magnetics Society into more modern methods of information distribution. The Magnetics Society Vice President, Celia Yeack-Scranton, reported on an IEEE proposal to begin distributing reports and notices by E-mail and floppy disks. I am particularly enthusiastic about the E-mail part, and would like to get the Magnetics Society into the forefront of this activity. The reason is that the printing and mailing of conference notices, calls for papers, program booklets, newsletters, and so forth have caused more disasters and more complaints than any other aspect of our operations. It's not that paper copies of these things would be eliminated in the first stages of the program. It's that people would be able to seek out early copies of important information if they need them.

For example, the program booklet for Intermag contains a lot of information, such as paper titles and especially invited

paper titles, that require last-minute revision by the program chairs. This retards the preparation and printing of the booklet. An E-mail synopsis with the session names and dates, travel information, and registration forms could have been available two months earlier than the actual booklets showed up in your mailbox. People who needed the information early would have been able to get it (even if they didn't have E-mail access themselves, and had to rely on the good will of a colleague).

Another possibility is that newsletter items could become available as the editor prepares them, rather than as the collection is printed as a single issue. In either case, E-mail subscribers would probably not get the mailings directly, but just a brief notice that a particular notice, identified by title or abstract, was available. An E-mail inquiry to a robot server would trigger sending of the full document.

The Society needs computer-literate volunteers to help get this thing going. John Nyenhuis (nyenhuis@ecn.purdue.edu) has agreed to act as coordinator. Help with the software will be needed, and also creative thinking about how to obtain and maintain the E-mail mailing list. If you want to participate, send a note to John.



INTERMAG '93, STOCKHOLM

Stockholm Sweden was the site of this year's INTERMAG conference. Session summaries begin on page 7.

TECHNICAL COMMITTEES UPDATE: MICRO-WAVE APPLICATIONS OF MAGNETIC FILMS

By Professor Carmine Vittoria

Magnetic films imply either metallic or ceramic oxide films. We will discuss the applications of both type of films at microwave frequencies. From past experience it usually takes about 10-15 years of developmental work to produce reasonable quality films once the fabrication of a new film is reported in the literature. There is no exception to this rule. For example, it is only recently that high quality films of permalloy are produced reproducibly, although permalloy films have been around for about twenty five years. Recently, ferrite films have been prepared by the laser ablation deposition technique. I will venture to say that it will take about ten years before high quality ferrite films may be produced routinely. As in earlier microwave applications the main advantage of ferrite films in the fabrication of planar devices is their non-reciprocal properties. By non-reciprocal we mean that the response at microwave frequencies of a ferrite film depends on the direction of wave propagation relative to the magnetization direction in the ferrite film. The response may be the phase or the amplitude or the power of the microwave signal, etc. There have been attempts in the past to circumvent the use of ferrite materials for non-reciprocal applications with the use of semiconductor materials. Clearly, these efforts tend to obfuscate the obvious and that is: it is most efficient to use ferrite materials for non-reciprocal microwave applications.

In general bulk ferrite components in waveguide configurations have been replaced by thin film ferrite device components. At least the demand nowadays is for planar devices in MMIC technology. Ferrite films have not been as successful as the bulk ferrites counterpart in waveguides. The problem is that the volume of films is intrinsically small and therefore the interaction between an electromagnetic field and the ferrite film is relatively small. The basic question is then: can there be useful microwave applications with the use of ferrite films? I believe that there are, but careful thought has to be given in enhancing the interaction between the film and the electromagnetic field. Clearly, the microwave technology has changed from large bulky devices to smaller and smaller devices. Much emphasis has been put on utilizing ferrite films for the MMIC technology. In this report I will discuss the use of magnetic films for MMIC as well as other planar device applications.

By its very nature metallic magnetic films are lossy at microwave frequencies, since the conductivity losses are high in comparison to insulating ferrite films. Thus, one needs to seek situations in which a metallic conductor is required as an integral part of the device, such as the ground plane of image dielectric lines, center conductor of microstrip lines, and interconnects, for example. It is not out of the question to consider metallic magnetic films in the design of a circulator circuit using image dielectric lines together with a magnetic metal film. Another requirement which allows for the use of metal films is the requirement of changing the current distribution in metallic magnetic patch

antennas. In this mode of development phase shifters may also be feasible using magnetic metallic films for ground plane. To my knowledge these types of devices have not been reported, but, perhaps one should explore the practicalities of such devices. It is the opinion of this author that market conditions of the future will require high risk exploration.

Insulating ferrite films, such as spinels, garnets, magnetoplumbite, etc. have always been the materials of choice for non-reciprocal application at microwave frequencies. This tradition will continue. Circulators as a rule require relatively large volume. For example, a circulator design at 35 GHz requires a disc thickness of 100 μm . Most of us in thin film research would not categorize a thickness of 100 μm as being "thin." Truly thin film circulators have been considered in the past, but they are narrow band devices. Some have argued that since the thin film design is based upon quarter wavelength segmented lines, it is intrinsically a narrow band device. Ferrite films stacked in a multilayer configuration may alleviate the problem of increasing the volume of interaction and, perhaps, the bandwidth.

The incentives for creating viable applications using ferrite films are many. In the past five years a new technology has evolved: Non-Destructive Evaluation, NDE, of materials. More and more industrial, government and University laboratories are devoting their research dollars in NDE research in large and small scale. Sensors are probably the most important part of NDE research. In particular, microwave sensors are needed for large and small scale NDE evaluations. By large scale we mean the size of a bridge metal structure, for example. By small scale we mean the detection of flaws down to 1 μm . Microwave sensors may be made of acoustic, optical, and magnetic materials. However, regardless of the type of sensor each have unique detection capability different from any other probe. The point is that one needs to consider the material to be evaluated carefully making sure to pick the appropriate probe. In particular NDE applications are sufficiently varied to include probes made of thin ferrite films.

Another interesting application in which ferrite films may have an impact is collision avoidance. There is a great need for collision avoidance in airport terminals, in automotive vehicles, and ground transportation. Usually large size radars are deployed for this purpose. The trend has been to use smaller and smaller radars which are also electronically steerable. Arrays of ferrite patch antennas may be suitable for this application provided the arrays are small enough and cost effective. Recent advances in patch antennas have included ferrites as the substrate material between the ground plane and the patch. Although the results are somewhat premature, they predict that it is possible to electronically steer an electromagnetic beam in two dimensions using arrays of ferrite patch antennas. It is clear to this author that if ferrite films are to be utilized in the future in large quantities, we in the ferrite community need to find economical ways to produce high quality ferrite films of the future. *Further information is available in a newly published book: "Microwave Properties of Magnetic Films," by Carmine Vittoria, World Scientific Publishing Co., Inc., New Jersey, USA.*

TECHNICAL COMMITTEES UPDATE: CHALLENGES IN MAGNETO-OPTICAL DATA STORAGE MEDIA

By T.W. McDaniel and M.R. Madison

Erasable magneto-optical (MO) data storage technology is being driven by computer users' seemingly insatiable demand for low-cost, high-capacity storage, and also by rapid advances in conventional magnetic storage. MO data storage uses thermo-magnetic writing on magnetic thin film media and the MO Kerr effect for readout [1]. MO storage provides users of information processing equipment an attractive option for low cost, high capacity data storage featuring removable media. Present day products provide areal recording densities of 0.5 Gb/in², and a complete recording demonstration at a density of 2.5 Gb/in² was recently reported [2]. A roadmap to 10 Gb/in² with current laboratory components is generally accepted. This represents an advance of 40X from first generation MO drives which arrived in the marketplace in 1988-1990. Figure 1 illustrates the historical growth in MO recording capability. A recent laboratory demonstration MO writing using near-field scanning optical microscopy (NSOM) created an array of reversed domains corresponding to a density of 45 Gb/in² [3].

Table I gives a comparison of MO recording and rigid disk magnetic recording attributes. Both technologies are advancing rapidly to meet the storage demands of advancing processor capabilities in personal computers and workstations, and these disk storage solutions provide complementary functions and opportunities. MO storage excels

when interchangeable media can be exploited, as in mass storage libraries, which can bring terabytes of data near-line at very low cost per bit. Workstation and PC applications handling large quantities of data can do so economically using MO storage. The recent appearance of hard disk (HD) drive-like mechanical performance in MO drives [4], along with the availability of direct overwrite (DOW) capability, is reducing the performance gap between the two devices. Table I shows that in spite of superficial similarities of MO and HD media technology, there are in fact fundamental differences, the most significant being media removability, which gives the user unlimited MO storage at dramatically lower cost per bit stored. The shrinking performance difference between MO and HD drives further solidifies MO technology's role in the data storage hierarchy.

In MO recording, data access is via a focused, diffraction-limited laser beam, whose controlling optics are precisely servoed electromechanically to remain some 2-3 mm distant from the storage thin films. A 1.2 mm thick cover sheet (disk substrate) keeps dust and dirt far from the focal plane. In contrast, the magnetic recording transducer is an electromagnet (head) with a precisely dimensioned gap whose leakage flux must couple strongly into the storage

TECHNICAL COMMITTEES UPDATE (Continued on page 4)

Figure 1. Areal density evolution in MO recording.

TABLE I. Comparing MO and MAGNETIC Disk Attributes		
Attribute	Magneto-Optic	Magnetic
1. Magnetic order	Ferrimagnetic, amorphous	Ferromagnetic, polycrystalline
2. Materials	Principally RETM alloys; Exploring Co/X multilayers (X = Pd,Pt), Heusler alloys, & polycrystalline garnets films	CoXY alloys; X,Y = Pt, Ta, Cr, or Ni
3. Thickness	~150 - 250 Å	~250 - 600 Å
4. Morphological feature size	Scale of inhomogeneity or "patches", ~ 100 Å	Crystalline grains (single-domain), ~ 300 Å
5. Coercivity (T = 300K)	6 - 20 kOe	1 - 2 kOe
6. Magnetic anisotropy (erg/cm ³)	⊥; 5 × 10 ⁵ to 5 × 10 ⁶	∥; 5 × 10 ⁴ to 5 × 10 ⁶
7. Signal	R Θ _K	Φ ∝ M _R Wδ (MR) or dΦ/dt (inductive)
8. Medium noise mechanisms	<ul style="list-style-type: none"> • Domain wall jaggedness • Inhomogeneity ⇒ H_c • Variance in R and Θ_K • Tracking pre-groove 	Grain decoupling
9. Density limit	$d \sim \frac{\sigma}{H_c M_R}$	$a \sim \left(\frac{M_R \delta}{H_c} \right)^n$; n = 0.5 or 1
10. Removable?	Yes - tolerant of dirt, dust	No - head disk interface constraint
11. Direct overwrite?	Difficult - requires media or system changes	Yes - natural

film for writing [5], requiring head-medium spacing ("flying height") of 50-200 nm. This close spacing enforces a requirement of extreme cleanliness that makes HD removability challenging.

Current MO head technology is diffraction-limited by the wavelength of the laser. Solid state laser technologies offers increased head resolution by switching from infrared to red wavelength lasers; however, shorter wavelength (green, blue) reliable diode lasers are still under development. In current MO media, amorphous rare earth-transition metal (RETM) alloys, the Kerr rotation decreases with decreasing wavelength; however, modifications of the RETM material, or switching to Co/Pt or Co/Pd multilayers, polycrystalline garnet, or a Heusler alloy, offers the promise of blue sensitive media. Furthermore, some improvement in op system resolution can be obtained through special apodization of the illumination aperture, or using masking of light detectors. Another proposed solution to increase the read resolution is to use magnetically-induced superresolution (MSR) [6]. MSR thermally masks the surrounding data using magnetic multilayers, and only "unmasks" the read data.

Overwritability differences originate from the fact that thermomagnetic recording is employed on MO media, an approach which results in the imprinting of unipolar reversed domains on a uniformly erased background in "normal" MO recording (without "direct overwrite" - DOW). Under the action of a constant bias magnetic field applied to the relatively distant storage film, the material coercivity is reduced locally by heating due to the film's absorption of focused radiant energy from the laser, and the magnetization is switched. Thus, a separate media erasure step prior to writing is implied in MO recording. In contrast, magnetic recording directly overwrites previously recorded data by simply changing the direction of the flux-producing electrical current in the gapped writing head. All recording takes place at ambient temperature. MO DOW recording requires modifications to the media or recording system [7]. However, the recent introduction of Sony's MiniDisc (MD) as a consumer device using inexpensive media with DOW capability attests to the expanding possibilities of MO technology. MD technology will likely find use in a data storage device.

The thin film materials in which the magnetic information is recorded are considerably different in morphology, magnetic anisotropy, and hysteretic properties. The ferromagnetic, RETM MO films usually exhibit a compensation condition near room temperature, where film magnetization goes to zero and coercivity diverges. The MO Kerr effect, which is used for readout, is associated primarily with the transition metal (TM) subnetwork, and it varies slowly in proportion to M_{TM} near 300K. A hysteresis loop of Θ_K versus H near 300K is very square ($S^* \approx 1$) with H_C typically > 6 kOe. Domain switching can be dominated by either wall motion or nucleation and growth, depending on the material composition and preparation process. In homogeneity in anisotropy and/or exchange on a length scale of 100 Å is a possible coercivity mechanism in the RETM alloys [8]. This inhomogeneity plays a key role in the sources of MO

media noise when a signal (magnetic domains) is written. Magnetic recording thin films tend to exhibit hysteresis loops with lower squareness (0.75 to 0.9) and lower coercivities. The degree of exchange coupling between crystal-line grains is a dominant factor in the magnetization switching (hysteretic) behavior. The cooperative grain cluster switching is directly correlated to the noise performance in magnetic recording film media.

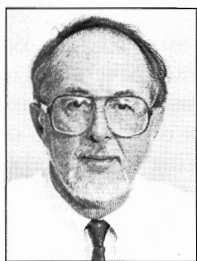
MO readout signal scales with the product of reflectance and Kerr rotation from the media. The signal from magnetic recording film media on the other hand is directly proportional to the leakage flux ϕ (or $d\phi/dt$ for inductive heads) emanating from the magnetized film, and the flux is proportional to $M_R W \delta$ (remanent magnetization times recorded track cross-sectional area). The meaningful figure of merit for recording media performance is its signal-to-noise ratio (SNR). The ultimate limits of achievable recording density depends on a length parameter for each type of media. For MO media, the upper limit on areal density is the minimum diameter of a stable circular (bubble) domain of reversed magnetization. This length scales proportionally to domain wall energy density and inversely with the product of remanence and coercivity. For magnetic recording media the relevant dimension is the magnetization transition length a which supports longitudinally recorded bit magnets. This reflects the competition between demagnetization and coercivity in sustaining a sharp boundary between head-on, oppositely magnetized bits. This is the effective width (along the track) of the well-known "zig-zag" domain wall that traverses the written track. The track width in magnetic recording is limited mainly by mechanical track following considerations, and today's rectangular bit shape has a high width-to-length aspect ratio (> 10).

For MO media, the future challenges clearly lie in finding means to support ever higher areal bit densities, as well as the direct overwrite function. Materials to support media SNR values at least as high as today's, but at shorter wavelengths, will be critical.

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DOYLE HONORED WITH ACHIEVEMENT AWARD



Prof. William D. Doyle

The 1992 IEEE Magnetics Society Achievement Award was given to Prof. William D. Doyle during the Plenary Session at Intermag '93 in Stockholm Sweden. Professor Doyle was born in Dorchester, Massachusetts. He received his B.S. and M.S. degrees from Boston College and his Ph.D. from Temple University - all in Physics. For more than 35 years, he has been involved in research, development and production of magnetic storage materials and devices. His career began in 1956 when, as a student technician at Lincoln Laboratory under Artman, Tannenwald and Seavey, he was the first observer of spin wave resonance modes. Another summer position at G.E., in the same group with Paine and Luborsky, exposed him to the development of single domain, iron particle magnets, preparing him for his first full time position at the Franklin Institute with Berkowitz, Flanders and Shtrikman studying the magnetic and structural properties of thin permalloy films.

For 15 years at Univac, (interrupted by a wonderful year in York with Prutton) his work with Coren, Mathias, Stein, Callen and Josephs focused on storage devices including plated wire, magneto-optic and bubble memories. He initiated and directed at Motorola an exciting, bubble memory start-up effort with Fairholme, Gill and Markham. This led to magnetic recording research at Kodak with Simonds, Lemke, Jagielinski, Jeffers, Freeman, Brock, Smith and Carr. The last stop on this odyssey is the University of Alabama, where he holds the MINT Chair in Physics and is the Director of the MINT Center, working with many faculty to establish a program in flexible magnetic media and heads. This provides an opportunity to share the rich heritage in magnetism which he was given by so many generous and patient mentors. His work is contained in more than 50 technical papers and patents.

Since 1963, he has been active in the organization of major magnetics conferences and has held various posts in the Magnetics Society, including President in 1987 and 1988. He is now serving as chairman of the Reynold B. Johnson Information Storage Award nominating committee. Within the Society, he led the development of programs to benefit its members such as the Magnetics Society Scholarship Program. He is most proud of his participation in the formulation of the Joint Intermag-Magnetism & Magnetic Materials Conference which established a spirit of cooperation rather than rivalry between the basic and applied magnetics communities.

The Achievement Award is given to honor a deserving member of the Magnetics Society for scientific and technical contributions, service to the society, and teaching. The Achievement Award Committee is chaired by Dr. Fred Luborsky. Prof. Doyle is the 12th recipient of the Achievement Award. Previous winners are F.E. Luborsky, H.W. Lord, H.F. Storm, J.J. Suozzi, F.J. Friedlaender, A. Bobeck, F.B. Humphrey, P.P. Biringer, D. Gordon, E.W. Pugh and Y. Sakurai.

JOINT MMM-INTERMAG CONFERENCE ALBUQUERQUE, NEW MEXICO, JUNE 20-23, 1994

The Sixth Joint Magnetism and Magnetic Materials - INTERMAG Conference (6M³I) will be held at the Albuquerque Convention Center, Albuquerque, New Mexico. It will be the only meeting of either of these two major conferences in 1994. The Conference is jointly sponsored by the American Institute of Physics and the Magnetics Society of the IEEE, in cooperation with the American Physical Society, the Office of Naval Research, the Metallurgical Society of the AIME, the American Society for Testing and Materials, and the American Ceramic Society.

Members of the domestic and international science and engineering communities interested in recent developments in magnetism and its associated technologies are invited to attend the Conference and to contribute to the technical sessions. The scope of the Joint Conference embraces all branches of fundamental and applied magnetism. The program will consist of invited and contributed papers. Contributed papers are solicited in all areas of experimental and theoretical research in magnetism, the properties and synthesis of new magnetic materials, new developments in applied magnetics, magnetic recording, various magnetic and other memory technologies, microwave magnetics, permanent magnet materials and technologies, magnetometry, magnetic separation, applied superconductivity, and field calculations.

For further information on the conference or who wish to be placed on the conference mailing list, contact Diane Suiters, 6M³I Conference Coordinator, 655 15th Street N.W., Suite 300, Washington, DC 20005; telephone (202) 639-5088, FAX (202) 347-6109. The General Chairman of the Conference is Stanley H. Charap (Carnegie Mellon University). Conference information may also be obtained from the Publicity Chairman; William C. Cain, Read-Rite Corporation, 345 Los Cochets Street, Milpitas, CA 95035; (408) 956-3301; FAX: (408) 956-3210.

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The objective of the **IEEE Magnetics Society Newsletter** is to publicize activities, conferences, workshops and other information of interest to the Society membership and technical people in the general area of applied magnetics. Copy is solicited from the Magnetics Society membership, organizers of conferences, officers of the Society and local chapters and other individuals with relevant material. The Newsletter is published in January, April, July and October. Submission deadlines are December 1, March 1, June 1, and September 1, respectively.

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W. Ken Dawson

Traditionally Newsletter and Magazine editors for the societies in Division IV have allocated space to the Division Director for reports on Board activities. With their indulgence topics that increase awareness of activities by other societies in the division as well as discussions of general issues also will be included. Your comments are always welcome and are very important in providing me, your society and the IEEE with the information required to make sensible decisions. My postal address is TRIUMF, 4004 Wesbrook Mall, Vancouver, BC Canada V6T 2A3; e-mail address is k.dawson@ieee.org; Fax number (604) 222-8325 and phone number (604) 222-1047.

A current problem shows all too clearly the hazards of basing the best intentioned decisions on incomplete information. I've only recently become aware of the difficulties caused by the elimination of chapter support as a term in the formula for Section rebates. While the total funds to Sections have remained about the same, some have gained and others have lost. The financially hard pressed ones now have little or no incentive to support chapter activities. With hindsight, I'm told, this was predictable but it was not a desired outcome. TAB is concerned and a motion asking RAB to reopen the question will be proposed at the TAB Administrative Council meeting in April. Don Bolle, the TAB Vice President, is setting up, with RAB participation, a TAB task force chaired by Mary Alys Lillard whose charge is to propose a new set of bylaws and policies that will better serve the needs of chapters.

In the first seven weeks of the year I managed to attend six society Ad Com or Board meetings plus an orientation session for new directors. (The seventh society has not yet met.) While each society has its own distinct personality there are a few constants. The principal one is the cooperative, friendly atmosphere in which serious discussions are held and hard decisions made. Service to members is a primary consideration, again pointing out the importance of your feedback or feedforward to your society's Ad Com or Board. Many societies are finding that the time and effort required to develop long- and short-term strategic plans are a good investment. Such plans provide a consistency of purpose (by damping presidential agendas, one person said!) and a tool by which a society's executive can gauge its performance.

An initiative by the Antennas and Propagation Society has worked its way up to the IEEE Board level where it received approval at the March meeting (which I missed because of a bad bout of the flu). The object of the initiative is to allow, during times of severe economic difficulties such as now, "recruiting activities by prospective employers at IEEE conventions and expositions, especially those directed toward the placement of unemployed engineers and scientists."

The economic climate has, understandably, made it more difficult for Ad Com and Board members to receive support from their employers for attendance at society business meetings. Whenever possible costs are minimized by holding meet-

ings on weekends and in conjunction with appropriate technical meetings. Despite this the problem remains and some committee members must use vacation time and their own funds in order to attend. Several societies in the division are looking for reasonable ways to support travel costs when necessary. An undue burden must not be placed on society finances, while at the same time assuring some level of support to those who need it. One does not want to limit committee membership to those who can find the funds to attend. It is not a simple problem, but it is being faced.

NEW IDEMA/UNIVERSITY PARTNERSHIP

The International Disk Drive Equipment and Materials Association (IDEMA), in cooperation with Carnegie Mellon University, and other universities involved in the data storage industry, have been working together to form a university group in IDEMA. The IDEMA charter is:

"To promote the global data storage industry by acting as a communications channel for all its participants, thereby fostering cooperation, progress, and growth."

We visualize the charter of the IDEMA/University Partnership to be:

MISSION

- To enhance the transfer of knowledge and new technology from universities to the data storage industry.
- To encourage university participation in research and education related to data storage.

MECHANISM

- Research projects jointly sponsored by universities and industry.
- Technical seminars jointly sponsored by IDEMA, its members and universities.
- On-site short courses.
- Credit courses at universities.
- Work-study co-op programs for students in industry.
- Continuing education programs for industrial personnel.
- International participation is encouraged.

BENEFITS TO UNIVERSITIES

- Opportunity to exhibit at annual DISKCON international trade shows free of charge.
- Listing in IDEMA Membership Directory.
- Free publicity of university programs/courses/events related to data storage through IDEMA publications.
- Opportunity to receive latest technical information from industry.
- Opportunity to make presentations at IDEMA technical conferences and symposia.
- Potential job outreach program for graduating students and pool of potential students from industry.

There will be a table top display at the following upcoming industry event where additional information can be obtained.

38th Annual Conference on Magnetism and Magnetic Materials (MMM):

November 15-18, 1993, Minneapolis, Minnesota

Questions concerning this initiative can be addressed to Blaine Carman, Director of Operations, IDEMA (Tel: 408-720-9352) or Laddie L. Stahl, Director, Technology Transfer Program, DSSC, Carnegie Mellon University (Tel: 412-268-6600).

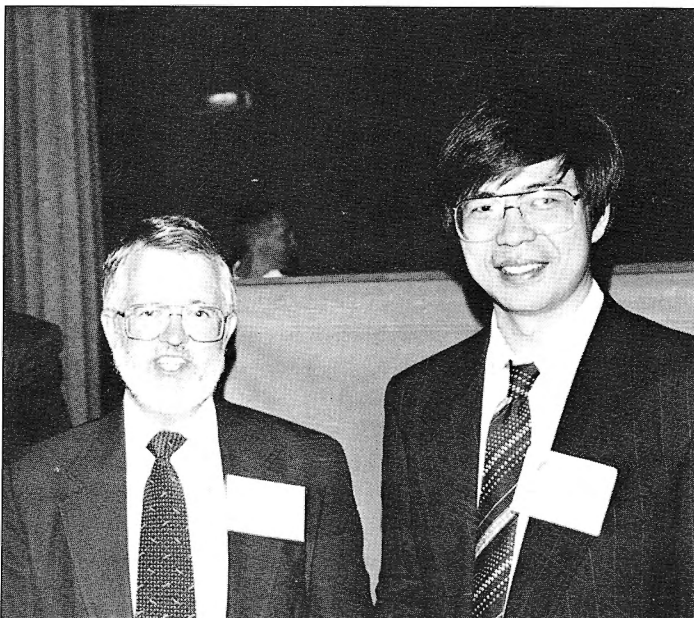
INTERMAG '93 SESSION SUMMARIES

Session AB — Particulate Media I

By Chair G. Bottoni — Dept. of Physics, University of Ferrara, Italy

The session firstly focused on new media consisting of two layers with different magnetic properties simultaneously coated on the substrate. This represents a promising technological development in the field of particulate recording media. Three papers on this subject have been presented, the first of which was an invited talk: H. Inaba, of Fuji Co., reported on two layered media, the upper of metal particles and the lower of ultra fine particles of Titanium dioxide. It allows combination of a thin magnetic layer, which is effective for high density recording, with a smooth surface, which eliminates noise and dropouts, generally connected with a rough surface in thin layer particulate media. D. Speliotis, of Digital Meas. Sys., compared two media obtained by simultaneous coating of a non-magnetic, or low coercivity, under-layer and a thin top layer of higher coercivity. The media were Ba ferrites over Co-modified iron oxides, and metal particles over non-magnetic Titanium dioxides. Y. Satoh, of Yamagata Univ., presented a tape with a double orientation structure: a perpendicularly oriented layer of metal particles over-coated on a longitudinally oriented layer of magnetite particles.

Another subject of interest in this session regarded the magnetic properties of Ba ferrite particles. J. Zhu, of the University of Minnesota, utilizing a micromagnetic model, investigated the effect on the magnetization reversal mechanism of the substitutions of Co/Ti ions in Ba ferrite particles, finding that the regions of the particles with reduced anisotropy, consequences of the Co/Ti substitutions, can act as nucleation centers for the switching of the magnetization. D. Speliotis reported on Ba ferrite particles incorporating surface treatments which greatly facilitate their dispersion, eliminating stacking, which in ordinary particles reflects in increased media noise.



M. Kryder, of the Carnegie Mellon Univ., studied the effects of long-term aging at high temperature on the erasability of various particulate media. The Ba ferrite media appeared the most stable, while corrosion can account for the erasure characteristics of ME, metal and Chromium dioxide media. T. Chin, of the Tsing Hua Univ., presented the effects of composition and preparation conditions on the magnetic properties of doped magnetite particles with high coercivity. W. Doyle, of the University of Alabama, studied the switching speed in magnetic media with iron oxide, Co-modified iron oxide and Ba ferrite particles, warning that it can have an effect in recording systems which operate at highest data rates. R. Veitch, of BASF AG, updated on the development of new iron-doped Chromium dioxide particles showing a significantly better SFD combined with smaller particle volumes, and consequently with improved recording performances.

Session AE — Microwave Magnetics: Materials and Devices I

By Chairs Ernst Schloemann and Conrad M. Williams

The nine papers presented at this session dealt with magnetostatic wave devices (3), magnetic solitons (2), millimeter wave and antenna applications (3) and circulators (1). B. Kalinikos from St. Petersburg gave an excellent review of the (mostly theoretical) work done by him and his collaborators on magnetostatic wave devices. This work has culminated in the development of CAD procedures for various types of delay lines and filters. The St. Petersburg group intends to make these CAD procedures commercially available. Y. Okamura from Osaka University described a new type of magnetostatic delay line in which the propagation characteristics are influenced by a thin metal layer adjacent to the magnetic layer, resulting in nonreciprocal propagation characteristics.

Magnetic solitons have been observed and studied in many laboratories. Solitons can be characterized as pulse-like nonlinear excitations, in which the natural tendency for pulse broadening (due to a frequency-dependent phase velocity) is largely compensated by pulse sharpening due to nonlinear effects. Energy dissipation is not eliminated by the nonlinear interaction and generally leads to attenuation of the pulse. In fiber-optic transmission lines, the soliton concept has practical significance, inasmuch as it helps to extend the range over which error-free transmission is possible. For magnetic solitons, no similar near-term applications are anticipated because of much higher energy dissipation, but their potential use for improving the performance of signal processing devices is being investigated.

Two papers by P. Kwan and C. Vittoria dealt with the ferrite loaded image guides at millimeter-wave frequencies, focusing on their filter-like transmission characteristics. N. Buris discussed the use of ferrites in frequency-selective surfaces and for beam steering. An improved circulator

design for L-band frequencies was discussed by H. How, R. Schmidt and C. Vittoria. This design enhances the bandwidth, when the circulator operates at a bias field larger than the field required for resonance ("high-field mode" of operation). In this mode of operation, the circulator can handle substantially more power than a circulator operated in the "low-field mode" of operation, because parametric excitation of spin waves is substantially suppressed.

Session AP — Magnetic Measurements: New & Improved Techniques I

By Co-chairs Johannes Sievert and John Nyenhuis

The problem of calibration with a nickel reference of open-circuit magnetometers was studied in detail by Eckert and Sievert. In addition to the temperature dependence of the saturation magnetization, the influence of the shape of the reference sample on parameters of the equation for the approach to saturation and the temperature dependence of the saturation magnetization were investigated. In a related paper by Martinez et al., it was shown that a digital voltmeter-based hysteresigraph is an easy-to-use and cheap apparatus for DC magnetic measurements which yields fairly accurate results.

Tejedor et al. developed an apparatus for measurement of the demagnetizing factor of cylinders and plates. For a circular Fe cylinder the measured demagnetizing factor was 6% larger than that calculated by other authors and it is concluded that increases in real demagnetizing factors must be taken into account in the design of magnetic devices.

Chen et al. developed a strip-line technique for wide-band measurement of the linewidth spectrum in magnetic garnet films from 0.5 to 20 GHz. At 9.2 GHz, their measurements of linewidth are in good agreement with those obtained with traditional single-frequency FMR.

A method presented by Leupold and Potenziani for determining the temperature stability performance of permanent magnets, which is based on the measurement of magnetization vs. temperature relation at constant B/H, seems to be a valuable tool for the assessment of the applicability of permanent magnet materials for various purposes. Enokizono et al. presented several methods of using permanent magnets and conducting materials for the shaping of DC and AC magnetic field patterns.

Two papers addressed the measurement of magnetic anisotropy. A method presented by Turilli for the determination of the anisotropy field using the second derivative of M vs. H was shown to furnish good results even if the magnetization curve is measured very slowly as the case with superconducting magnets. Abelmann and Lodder presented a useful theory and corresponding measurements for the determination of the magnetic anisotropy constants for thin films with oblique anisotropy.

Shin et al. developed in method in which a piezoelectric force sensor is used to measurement deflection of a thin film due to magnetostriction. Huang et al. extended the Small Angle Magnetization Rotation Method to measure the saturation magnetostriction constant of magnetic thin films with a sensitivity of about 2×10^{-9} .

Two interesting papers dealt with the measurement of



mechanical properties of materials using magnetic phenomena. Ng et al. showed that, by means of frequency-dependent measurements of the magnetoacoustic emission caused by changes in the domain structure, information about the stress situation in different depths of the material can be obtained. Chen et al. demonstrated that the measurement of Barkhausen signals during cyclic stress loading gives much more detailed information about the fatigue performance of the material than is obtained from usual hysteresis measurements.

Session AQ — Hard Permanent Magnetic Applications

By Chair Herbert A. Leupold

Session AQ was concerned with the innovative application of permanent magnets to mechanical and electrical devices. Fourteen papers were presented in four principal subject areas.

Papers 1 - 5 deal with a variety of static magnetic field sources. Paper AQ-1 discusses the design of field adjustable sources that provide flux densities of 0 - 4.0 T in slotted spaces both normal and parallel to the generated field. Paper 2 illustrates methods of keeping the fields of permanent magnet solenoids uniform and confined in electron beam tubes. In AQ-3, methods of improving field uniformities of MRI's are proposed and analyzed. AQ-4 shows how an inexpensive, low field and field-uniform proton resonance magnet can be designed for commercial use in the food industry. AQ-5 describes a magnetizing fixture that assures the proper field form for an optical gyroscope magnet.

Papers 6 - 8 and 10 - 12 describe the effects of various structural parameters on motors and actuators, e.g. magnet pole shape (AQ-7), armature fields and reactance (AQ-6), rotor magnet profiles (AQ-8), field homogeneity (AQ-9), magnet remanence in disk drives (AQ-10), and claw pole cross section in linear pulse motors (AQ-12).

Papers AQ-9 and AQ-11 describe ingenious magnetic bearings that involve no direct contact between moving parts, thereby reducing wear. AQ-9 concerns a levitated rotary bearing and AQ-11 a novel magnetic worm gear and associated worm wheel which bear on each other only through repulsive magnetic fields.

Paper AQ-13 was aborted and papers 14 and 15 tell of mathematical techniques for dealing with permanent magnetic sources. Paper 14 demonstrates a technique for finding relatively simple approximate solutions to very complex problems involving magnetic coupling. Paper 15 sets forth a method of calculating fields due to arrays of permanently magnetized rectangular prisms.

Session BB — Particulate Media II

By Chairs K. O'Grady and S.J. Greaves —
University College of North Wales, Bangor, U.K.

The first talk of the session discussed the characterisation of metal particle pigment dispersions and was given by Kevin O'Grady. There are considerable difficulties associated with monitoring dispersion quality during the production process. Standard magnetic characterisation techniques can give misleading results since the application of a magnetic field for any length of time can cause agglomeration of the magnetic particles in the dispersion, the agglomerates also change shape in the field. A theory has been developed to allow interpretation of IRM and DCD remanence curves taken from dispersions which provides an estimate of the average size and size distribution of agglomerates in the material. The average size of agglomerations was found to decrease with length of dispersion milling time. The effects of field exposure were found to be minimal for the IRM curve.

The second talk was given by Milap Mathur on behalf of the authors and concerned the interaction of binder components with magnetic particles in a dispersion. The interaction of hard and soft segments of a polyether-polyurethane binder with Co and Ti doped BaFe particles was investigated using flow microcalorimetry. This process showed that the hard segment of polyurethane has a higher affinity for BaFe than the soft segments. In addition the surface affinity was affected by water on the magnetic particle surfaces, washing in THF removed the water and reduced the subsequent molar heat of adsorption for the hard binder segment but increased it for the soft segment. This may allow the development of a

single wetting binder which can replace the separate dispersants and binders now used.

Next we heard another talk by Milap Mathur comparing measurements made on wet dispersions using the DIMAG technique with the quality of tapes made from the dispersions. To interpret the DIMAG results the dispersion was assumed to consist of either isolated magnetic particles (singlets) or pairs of particles (doublets). In the doublets the moments of the two particles were assumed to be in opposition but in a certain DC field the moments in a "soft" doublet would align. The wetting binder concentration in the dispersion was varied and it was found that for a concentration of less than 2% the number of agglomerates was unchanged. With a concentration of wetting binder in excess of 5% there was an increase in the singlet population. Milling was also found to increase the number of singlets. Removing the DC field from a dispersion with a low amount of wetting agent resulted in swift reagglomeration of the dispersion. Finally XPS measurements indicated a preference of the binder for Co sites.

Another possible method for determining dispersion quality was proposed in the fourth talk by Paul Sollis. Transverse susceptibility measurements were made on wet dispersions, this technique is sensitive to the break up of agglomerations during the dispersion process. For a good dispersion the inverse of the transverse susceptibility is a straight line. The time dependence of the transverse susceptibility was measured and was found to decrease with time as particles aligned with the applied field direction. At high fields the time dependent properties were similar whilst at low fields there was some variation which, it was postulated, could be interpreted as arising from the convolution of angular variation of the transverse susceptibility with time together with a time dependent orientational texture function. This could be a useful indicator of dispersion quality.

The fifth talk, delivered by Dr. Chin, concentrated on BaFe particulates used for perpendicular recording. The particles are produced by the calcining process which typically takes place at high temperatures of the order of 1000 C. Particulates were produced after doping with combinations of Co, Zn and Sn. After calcining the resulting particles had lower coercivity than the non-doped material whilst the magnetisation remained at 60-65 emu/g, almost the same as the undoped material. In addition doping reduced the calcining temperature to 630 C, the lowest yet reported.

The following paper, presented by David Nikles discussed the use of amine-quinone binders in metal particle tape. Metal tape is susceptible to corrosion but encapsulation of the particles reduces the saturation magnetisation. Amine-quinone binders have a high affinity for metals and displace water from the surface of iron. Because of the difficulty of synthesising polymers, amine-quinone monomers were used. Polyurethanes were prepared by melt and solution polymerisation and the amine-quinone monomer formed part of the hard segment in these. Tapes were prepared using 2-3% polymer by weight in the dispersion, the samples were exposed to a PH 2 solution and the time dependence of the saturation magnetisation was monitored. The polymer containing samples exhibited no loss of magnetisation over three hours whereas the standard samples





had lost all of their magnetisation after just two hours. Thus the modified binder bestowed protection against corrosion upon the iron pigment in the metal tape.

A 3D model of macroscopic magnetic and microscopic microstructural collective magnetisation processes was discussed by Jimmy Zhu in the seventh talk. Systems consisting of a cube of prolate and oblate spheroidal particles were considered, the packing fraction and interactions between the particles were also incorporated into the model. For prolate particles increasing the packing fraction causes a narrowing of the hysteresis loop and concurrently increasing the interactions between particles decreases the coercivity. The coercivity is higher where interactions are absent. For oblate particles (platelets) the hysteresis loop becomes squarer for increased packing fractions whilst the coercivity increases independent of any interactions. This is due to better orientation of the system at higher packing fractions. Simulated delta-M plots show a positive value for oblate particles with increasing height as the packing fraction increases and a negative value for the prolate case. It was found that lateral interactions dominate in the case of prolate particles.

Two papers concerning Preisach modelling ensued. The first was given by Ed Della Torre and considered asymmetry of major DCD remanence loops from floppy disc samples about the remanent coercivity. The amount of asymmetry depends upon the moving parameter, the squareness and the reversible magnetisation. This latter component is responsible for the second harmonic of distortion in DC recording. The asymmetry of the two halves of the remanence loops was normalised and the value of moving parameter required to reduce the asymmetry to zero calculated. A feature of the model is its lack of susceptibility to noise.

Following this we heard from Aphrodite Ktena who has used a 2D simulation to model signals on tape media both before and after erasure. The model used was based on the scalar Preisach models but in addition vector properties have been incorporated and use of the Stoner-Wohlfarth model allows both rotational and switching behaviour to be simulated. Utilisation of the model within a recording simulation allows good agreement with experimental results to be obtained. Recording has been simulated at various current levels and frequencies and also after DC, AC, longitudinal

and vertical erasures by means of a trajectory separating the regions of positive and negative magnetisation on the Preisach plane.

The final presentation was given by Mohammed el-Hilo who focused on time dependence and reptation measurements in CrO_2 media. It has been proposed that the effects of time dependence may be eliminated when considering reptation data from a sample provided that the waiting time before taking readings is kept large. Then the effects of reptation would give a direct measure of interactions in the material. However, experimental data from reptation experiments performed on CrO_2 media using a wide range of waiting times would seem to refute this, it was shown that even after waiting for three hours time dependence effects were not negligible in the specimens and thus the interactions could not be separated out.

Session BC — Computational Magnetics I

By Chairs D.A. Lowther & J.P. Webb —
McGill University, Montreal, Canada

The session had two distinct themes; micromagnetics and numerical analysis. The micromagnetics component was dominated by 2 papers presented by Ed Della-Torre. These dealt with acceleration of the magnetization modelling by using mode pushing for speeding up stiff mode convergence - this is purported to give speed gains of several orders of magnitude. The second paper provided an example of the method in operation. Isaac Mayergoz discussed a new vector Preisach model which provided a more accurate solution than previous approaches. This was backed up by experimental evidence which showed a numerical implementation of the method. His second paper applied an integral equation solution of a 3d magnetic recording problem. This demonstrated erasure by a dc field and overwriting - this was backed up by experimental measurements. Dirk Philips from Gent showed a practical implementation of a Preisach model compared with measurement. These papers all indicated that magnetic material modelling is coming of age and, at least at the research level, the computer solution of the hard magnetic material problem is becoming relatively routine. This work on micromagnetics was complemented by papers concerned with magnetostriction (Ian Reed), showing measured and calculated results; and an analysis of composite magnetodielectric materials by Gary Bush. Computing the dipole moments of these materials resulted in a dense matrix. Conjugate gradient techniques were proposed as the best way to solve these problems, providing robustness, accuracy and speed - a combination of properties which seemed difficult to obtain with any other solver technology.

Igor Tsukerman presented a very promising piece of work relating to the use of a multilevel preconditioning system with a conjugate gradient solver. This seemed to suggest a large gain in solver speeds over conventional ICCG. His second paper considered node and edge based elements for modelling discontinuous fields. Edge elements produce no loss in the order of accuracy while node based elements converge slowly ($O(h^{*0.25})$).

Doug Lavers provided a contribution to Blot—Savart integration which combined analytical and numerical integration to avoid cancellation errors and provide a signifi-

cant gain in speed. These new algorithms were produced for both solid and stranded conductors in the form of bars and arcs.

Finally, David Lowther discussed an equivalent circuit view of upper and lower bounded solutions. This suggested that the convergence properties of a solution were dependent not only on the solution potential but also on the source types. This lead to the conclusion that eddy current problems would not be bounded but that the solution would oscillate around the true value as the mesh was refined.

Session BD — Amorphous Materials

By Chair Fausho Fiorillo — IEN Galileo Ferraris, Torino, Italy

The versatile properties of amorphous alloys, the complexity of the physical processes lying behind their magnetic phenomenology and the promise they still convey for future evolution, all contribute to continuing interest in their study, both in applications and basic research. The INTERMAG session here outlined has provided interesting information on the work being carried out at present, both in the study of basic problems and in the investigation of application oriented properties. The presented papers were basically concerned with two types of materials: conventional metallic glasses and amorphous wires.

The debated problem of moment canting in metallic glasses has been discussed by C.D. Graham, Jr., M.R.J. Gibbs and co-workers in a couple of experimental papers. In the first paper the authors report on remarkable experiments on the field dependence of magnetization, up to fields as high as 20 T. The results show that amorphous alloys may have much greater high field susceptibility than crystalline ferromagnets, a fact convincingly pointing to appreciable moment canting in metallic glasses. The Chudnovsky wandering mean moment theory is shown to agree with the experimental results, a conclusion substantiated by the second paper, which reports about experiments using spatially resolved Mössbauer spectroscopy. Anisotropy in amorphous ribbons has been discussed in papers by Tejedor et al. and by F. Fiorillo et al. The communication by Tejedor et al. is aimed at understanding the origin of the ever found in-plane anisotropy. The authors compare their measurements of the uniaxial anisotropy constant K_u in Co based alloys with a magnetostatic model, intended to emulate the role of the anisotropic surface defects. They reach the conclusion, somewhat in contrast with previous literature results, that such a role is relatively unimportant. F. Fiorillo et al. focus their attention on the random anisotropies generated by the quenched-in stresses. They investigate in theory and experiment the evolution of the spatial distribution of the local easy axes as a function of applied tensile and compressive stress. One interesting feature of the experimental method is the possibility to discriminate between coherent moment rotations and domain wall motion. The presented model is shown to predict to a good extent the dependence of the initial susceptibility on stress in Fe and Co based alloys. H.T. Kim et al. have presented a systematic investigation on the effect of small additions of Ni and Nb on the high frequency properties of FeBZr alloys. They demonstrate that the $Fe_{83-x}Zr_7B_{10}Nb(or Ni)_x$ ($x = 0.5 - 1$) alloys exhibit reduced magnetostriction and domain width, with ensuing decrease

of power losses at high frequencies.

Several phenomena connected with domains, stresses and bistable behavior in amorphous wires have been the subject of investigations presented in a successive series of papers. M.R.J. Gibbs, P.T. Squire and co-workers have carried out experiments on FeBSi wires. In a first communication they report about efficient stress release by pulse annealing, which proves superior to conventional furnace annealing. Coercivities as low as 0.2 A/m are obtained by pulse annealing under applied tensile stress. The stress generates a slight plastic elongation of the wire during annealing and, consequently, enhanced alignment of the magnetic moments. The dependence of Young's modulus E on the applied field has been investigated in a second paper, in combination with domain observations. The observation of an abrupt small change of E correlated with the magnetization reversal leads to the conclusion that the reversal in the core induces a slight rearrangement of domains in the sheath region of the wire. A couple of papers dealing with phenomena in Co based wires have been illustrated by M. Vazquez and co-workers. Switching field and remanence have been measured as a function of applied stress in negative magnetostriction $Co_{72.5}Si_{12.5}B_{15}$ amorphous wires. The results are qualitatively understood on the basis of the distribution of magnetic anisotropies inside the wire. In the case of non-



magnetostrictive wires bistability is not observed. Vazquez et al. show, however, that a bistable behavior can be recovered in as-quenched wires with either of two methods: 1) decrease of temperature below 250 K; 2) application of a tensile-torsional stress. The first method exploits the increase of magnetostriction with decreasing temperature. In the second case a helical anisotropy is induced. The observation of domains in Fe and Co based wires is discussed in a final paper on this subject by F.B. Humphrey et al. It is demonstrated that the Fe based wire consists of shell and core domains, while no clear core domain can be observed in the Co based wire. The domain structure is induced in the first case by the combination of shape and stress anisotropy, while exchange energy appears to combine with shape anisotropy to induce the magnetization reversal in the Co based materials.

Random local anisotropy is also the subject study of Rivoire et al., who investigate the role of Tb concentration

in $(\text{Co}_{0.93}\text{Zr}_{0.07})_{100-x}\text{Tb}_x$ amorphous thin films. They establish, through initial susceptibility and ferromagnetic resonance measurements, that K_{loc} increases with increasing Tb content.

Session CA — Magnetic Recording Heads I (Magnetoresistive Type)

By Chair H.S. Gill — IBM Corporation

The session CA on Magnetoresistive recording heads (MR) consisted of 9 papers: 3 invited and 6 contributed. The paper CA:01 by I. Imagawa et al. of Hitachi research discussed novel structures for MR heads. It was shown in this paper that there was adequate exchange coupling between antiferromagnetic NiO and the ferromagnetic NiFe sensor. The blocking temperature was similar whether NiO or NiFe were deposited first. To achieve a high coupling field and blocking temperature, it was necessary to use lower Ar sputter gas pressure for RF magnetron sputtering. For Ar pressures below 1 mTorr, the coupling field and blocking temperature were 20 Oe and 200 C, respectively. Higher Ar pressures yielded NiO films with rougher surfaces and thus reduced exchange coupling. Furthermore, the NiO was porous and the grains did not couple well leading to lower blocking temperatures. It was also shown that NiO films have higher corrosion resistance in comparison with Fe-Mn films and their exchange coupling and blocking temperatures were independent of thickness up to 50 nm. The NiO material was utilized to build a "Stabilized Active Region" MR heads. To maintain high permeability for this type of MR head design, a ferromagnetic spacer layer of $(\text{Ni}_{.81}\text{-Fe}_{.19})_{.92}\text{-Nb}_{.08}$ was employed between the NiO and NiFe to lower the exchange coupling by diluting the spin density at the interface. The authors furthermore implied that the temperature dependence of the exchange coupling for the structure with NeFeNb was similar to the one without this layer. Using these developments, shielded MR heads having a soft-adjacent-film type of biasing were fabricated and characterized. It was concluded that the baseline instability was absent.

A combined yoke type MR read and inductive write head for DCC applications was described by T. Komoda et al. of Sharp Corp. in paper CA:08. Some of the fabrication steps of the read and write heads were combined by placing the read/write structures in the same plane. For example, the conductor leads for the MR sensor were deposited at the same time as the coil for the write head. A pole of the write head and a shield were shared in this design. The write efficiency was enhanced by providing larger separation between the top and bottom yokes of the write head. This design provided significant simplification for the fabrication process as well as eliminating the MR sensor degradation often caused by the write head fabrication on top of MR read in conventional designs.

The paper CA:05 by D. Heim et al. of IBM described their analysis and experimental results for the orthogonal MR head where sense current runs orthogonal to the air bearing surface. The data showed that the sensitivity was greatly affected by the magnetic field induced by the sense current. The effect was similar to that of higher anisotropy magnified by $1/\cos^3\theta$, with θ being the angle of the magne-

tization away from the easy axis. However, the signal was independent of track width at a constant current density and by the proper orientation of intrinsic and stress induced anisotropy, the weakness described could be overcome. Then the design would become attractive for narrow track width applications.

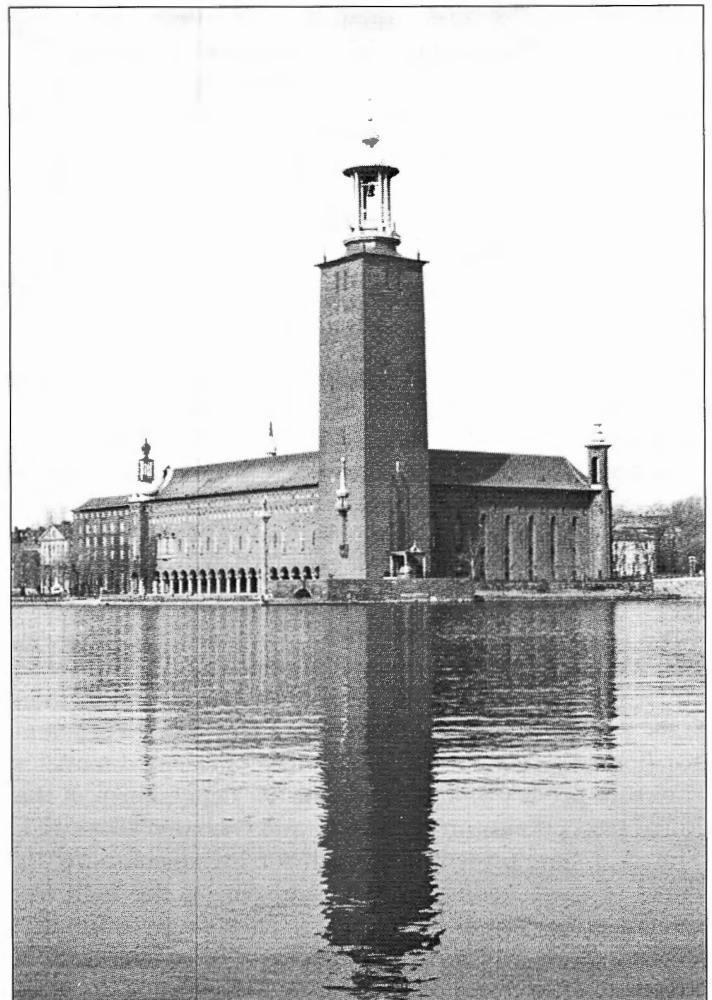
The papers CA:02,03 discussed the recording performance and micromagnetic behavior of MR structures. The paper CA:04 described the link between the Barkhausen noise and easy axis orientation and stress induced anisotropy. The paper CA:09 showed a method to find the location of the Barkhausen noise in a yoke type MR head.

Session CD — Silicon Iron

By Chair Claes Bengtsson — ABB Transformers

Nine contributions were presented at the session. The main attention was given to problems related to measurements and calculations of losses under non-sinusoidal flux conditions. The need of a deeper understanding in this area is driven by the interest to improve the performance of motors and transformers. Six papers discussed this aspect. The remaining three contributions were related to structural properties of soft magnetic materials.

In the group of non-sinusoidal magnetization, paper CD-04 discussed the effect of keeping the induction constant at different instants in the magnetization cycle. It was shown that if an interval of non-changing induction occurred at the maximum induction, losses still increased even if the





time derivative of the flux is constant. This was attributed to domain rearrangements. A method of measuring B-H curves in arbitrary directions was presented in paper CD-05. The method allows for measurements up to 2.0 T in the rolling direction of g.o. SiFe, and to 1.7 T in the transverse direction. Measurements of power loss under both rotating H and rotating B were discussed in paper CD-06. In many electrical machines, the conditions are closer to rotational H than to rotating B, and hence such measurements are of interest. Paper CD-08 also discussed rotational magnetic properties, and related the anisotropy of the material to the vector relationship between B and H. Two contributions, CD-07 and CD-09, dealt with theoretical aspects of rotational losses. The former discussed the case of non-purely rotating flux, and the latter classical eddy current loss under elliptical field conditions using a 2D calculation of the skin depth.

The first contribution on structural properties was CD-01, which presented the effect of grain size on the magnetic properties of 35 μm grain oriented SiFe. The material was produced by cold rolling of conventional g.o. SiFe followed by tertiary recrystallization. The produced material showed a sharp Goss texture with B_8 over 1.95 T. It was shown that there exists an optimum grain size for each frequency, and that the loss of these materials are equal or better than the corresponding amorphous ribbons. Paper CD-03 presented an improved metallurgical process leading to the formation of a cube-on-face texture in SiFe. The material is considered as an alternative to pure iron or low Si steels in small and medium power machines. Finally, paper CD-10 discussed soft magnetic properties related to the microstructure in sputtered FeSiAlRuTi films for recording applications. By annealing, the dislocation density, mainly along grain boundaries, decreased leading to an increase in permeability and a decrease in coercivity.

Session CE — Fine Particles I

By Co-chairs Bernard Barbara and A.S. Arrott — CNRS Laboratoire de Magnétisme L. Néel (Grenoble)

Bob Shull from NIST gave an excellent presentation of his recent work on the giant magneto-caloric effect in superparamagnetic nano-particles. The well known magneto-caloric effect is used in simple paramagnets (or ferromagnets near a phase transition) to transfer energy from the phonons to the spin subsystem and therefore to cool the material (adiabatic demagnetization). This effect is much larger in the case of superparamagnetic particles simply because the magnetic moment of each particle is much larger than the atomic moment of any usual paramagnet. Although the number of particles per unit volume is necessarily smaller than the number of atoms, there remains a gain factor of order N, the number of atomic moments per particle. Bob Shull showed that the replacement of paramagnets by superparamagnets is really efficient near room temperature. This opens the way to real-life applications of refrigeration by adiabatic demagnetization!

Session CQ — Hard Magnets: Nitrides/Carbides I

By Chair Saoshi Hirose — Sumitomo Special Metals Co., Ltd.

Seven papers were actually presented in this session. Yamamoto et al. of Meiji University, Japan, reported that partial substitution of Fe by Co in $\text{Sm}_2\text{Fe}_{17}\text{N}_x$ results in decrease in the spontaneous magnetization while anisotropy fields show a broad maximum at around 20-50% substitution. Temperature coefficient of Br and H_{c1} measured on epoxy-bonded magnets are $-0.07\%/C$ and $-0.53\%/C$, respectively, which are slightly inferior to those of Co-free materials. Related to this subject was hydrogenated or nitrogenated SmFe_3 reported by Yau et al. of Tsing Hua University, Taiwan. This phase exists as an impurity Sm-rich phase in $\text{Sm}_2\text{Fe}_{17}$ homogenized alloys. It was found that SmFe_3H_x readily forms on hydrogenation at 195 C while at 480 C disproportionation occurred. Nitrogen does not enter SmFe_3 lattice but forms SmN upon nitrogenation of SmFe_3 . Colucci et al. of Universidade Estadual de Campinas, Brazil, showed that the light-rare-earth 2:17 compounds have step-like nitrogen profile, indicating that there is no intermediate nitrated region. In a collaboration paper among three institutions, Universidad del Pais Vasco and Instituto de



Ciencia de Materiales de Madrid, Spain, and Siemens AG, Germany, Murillo et al. characterized precursor materials for Sm-Fe-N magnets produced via the mechanical alloying process. Elemental powder mixture of $\text{Sm}_{30}\text{Fe}_{70}$ becomes a mixture of amorphous Sm-Fe and α -Fe as the result of mechanical alloying. Crystallization temperature of the amorphous phase depends upon the milling conditions, indicating the actual composition depends not only on the nominal composition but on milling conditions. Ohno et al. from Toho University, Japan, studied carbon interstitial compound $\text{Er}_2\text{Fe}_{17}\text{C}_x$ and detected very sharp spin-reorientation at $x=0.2$ by means of magnetic measurements. Calculation suggests that the transition is between easy c-axis and easy c-plane and that it can be first-order at $x=0.2$. For smaller $x(>1.2)$, transition becomes second order, which can be attributed to a decrease in the crystal field coefficient in the absolute value.

Unfortunately, papers from The Peoples Republic of China were not presented at the conference. Available information, however, indicates that researchers of Institute of Metal Research, Academia Sinica, and International Center for Material Physics, have made some progress using the mechanical alloying technique. Yang Jinling et al. achieved a room temperature H_{cJ} of 70.9 kOe in $\text{Sm}_{26}\text{Fe}_{65}\text{Ti}_9$ after a heat treatment at 840 C for 30 min. The high coercivity is attributed to development of the $\text{Sm}_5(\text{Fe,Ti})_{17}$ phase, the Curie temperature of which ranges from 160 to 180 C. Wang Qun et al. obtained H_{cJ} of 43.5 kOe, B_r of 7.9 kG, and $(BH)_{\text{max}}$ of 13.8 MGOe from $\text{Sm}_2\text{Fe}_{17}\text{N}_x$ and attributed the magnetic hardening to development of metastable SmFe_7N_x with the TbCu_7 structure. Zhao Tong et al. studied effects of manganese substitution of V in $\text{Sm}_{15}\text{Fe}_{70}\text{V}_{15-x}\text{Mn}_x$ alloys. $\text{Th}_2\text{Zn}_{17}$ structure becomes more favorable than ThMn_{12} when Mn content increases. H_{cJ} of 23.0 kOe was obtained in $\text{Th}_2\text{Zn}_{17}$ type $\text{Sm}_{15}\text{Fe}_{70}\text{V}_2\text{Mn}_{13}\text{N}_x$ after annealing at 800 C for 30 min and nitrided at 450 C for 2 hours.

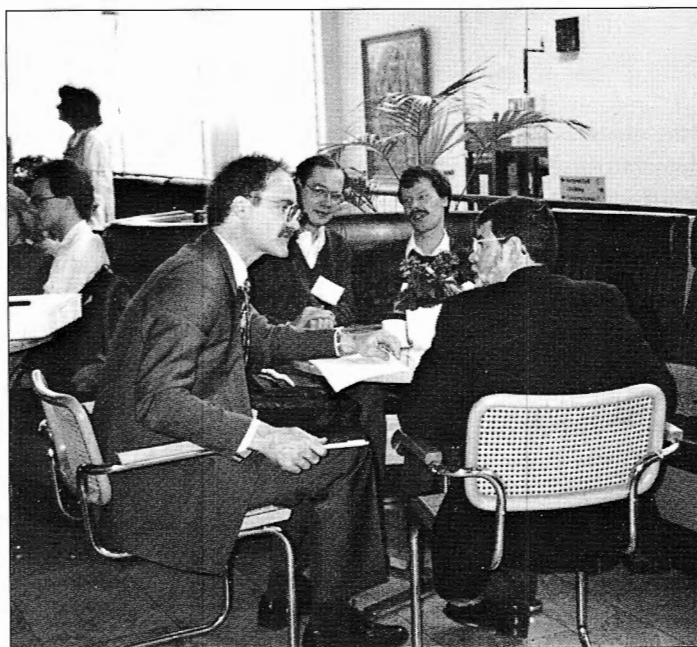


Session CR — Magneto-optic Media (Not Storage)

By Chair Merritt Deeter

The posters presented during Session CR represented a broad technical and geographical cross-section of current research in the field of magneto-optical materials. Five posters were presented by authors from Spain, Germany, the United States, and Russia.

The scientific and technological importance of magneto-optical films was particularly evident during the session. Rudashevsky et al. (CR-02) used a magneto-optical technique to investigate the coupling of FMR resonances and elastic waves in LPE-grown garnet films. Traeger et al. (CR-05) developed a theory to predict the magneto-optical response (including diffraction) of non-uniformly magnetized thin-film structures. Nistal et al. (CR-06) described geometrical-based optical phase shifts in channel waveguides which are used as the basis for various magneto-optic devices. Finally, Fumagalli et al. (CR-07) discovered some unique magneto-optical properties exhibited by III-V magnetic semiconductors (InMnAs) grown as hetero-structures.



Session DD — Optical Storage: Materials, Recording Processes, Systems

By Chair Mark Schultz

Papers addressing several of the important current issues in Magneto-Optic recording were presented in this session. Three papers addressing direct overwrite issues were presented. Paper DD01 presented the results of improvements in single layer constant bias field direct overwrite. A result of 46 dB CNR for 1.2 micrometer bits was shown. Papers DD08 and DD11 addressed issues concerning direct overwrite using magnetic field modulation. Paper DD08 showed a theoretical analysis of a double layer structure which allows a significant reduction in the necessary field modulation for direct overwrite, with possible application to the MSR approach to improving density. Paper DD11 showed that Pt/Co multilayer films may be used for magnetic field modulation recording with a CNR of at least 46 dB, but that the modulation field

necessary to achieve such a CNR is about 200 Oe. Paper DD-06 presented a multiple write pulse method which allows effective use of mark edge encoding in magneto-optic recording. This results in a significant density increase over the current mark position encoding method. In other high density news, paper DD03 presented results on a Nd based multilayer structure which provides a CNR of near 47 dB at 532 nm wavelength and 1.0 micrometer mark period. On the materials analysis front, papers DD02 and DD05 presented the results of investigations of the thickness dependences of composition and magnetic behavior in rare earth/transition metal films. While interest in short wavelength materials remains high, neither of the two anticipated papers on polycrystalline garnets was presented. Finally, paper DD10 stepped outside the disc storage area to examine magneto-static interactions between the elements of an array of garnet cells, providing a variable variance Preisach model explanation for the observed phenomena.

Session DE — Magnetic Solid State Memories

*By Co-chairs R. Katti — Jet Propulsion Laboratory;
and K. Matsuyama, Kyushu University*

In Wednesday afternoons session on Magnetic Solid-State Memories, nine papers were presented on vertical Bloch line (VBL) storage technology and two papers were presented on magnetoresistive random access memories (MRAM). The first four papers were on experimental results pertaining to VBL devices, while the second four papers were concerned with numerical simulations of VBLs. The last presented VBL paper was a study on VBL propagation. The final two papers of the session were concerned with the use of giant magnetoresistance (GMR) in memory cells. In the first of these papers, current requirements were reduced by the use of GMR materials; and in the second paper, an improved sensing method was presented for use in a GMR-based memory cell.

Paper DE-01 from Hitachi Corporation discussed the use of self-organized domain structures in magnetic thin films to serve as a bit stabilization method for a VBL memory. Such a bit stabilization technique differs from conventional bit stabilization techniques including hard magnetic material deposition, stress-induction, and topological contouring. Self-organized domain structures are intended to increase areal storage density by eliminating the need for lithographic definition of bit cells. This method was reported to support bit stabilization at areal storage densities greater than 1 Gbit per square centimeter.

Paper DE-02 from Kyushu University described the use of patterned sputtered TbFeCo thermomagnetic material films with perpendicular anisotropy as a means for stabilizing data storage domains. This stabilization method is an alternative to conventional garnet grooving techniques. For magnetic domains with stripe widths of 5 micrometers, bias field margins in excess of 100% were achieved in experimental results which were confirmed in simulation results.

Paper DE-03 from Kyushu University discussed the static and dynamic collapse field characteristics of magnetic domains with stripe widths of 1 micrometer. The relationships between bubble collapse field, bubble diameter, wall energy, and pulse amplitude and shape were used to infer Bloch

line characteristics. Bubble collapse fields were measured and found to be quantized, corresponding to the quantization of Bloch line numbers. The critical wall energy, with a value of 1.1 ergs per square centimeter, as predicted by maximum bubble collapse field data was found to agree with the value predicted by dynamic bubble collapse field pulse widths. In an experiment relating to VBL bit propagation, VBLs were found to be stable against a series of ten million 80-0e bias field pulses.

Paper DE-05 from the Jet Propulsion Laboratory discussed the use of partially grooved rectangular and ring grooves to stabilize magnetic domains in a VBL memory array. This bit stabilization method is an alternative to the conventional use of complete grooving. It was found experimentally and through simulation that the bias field margin ranges for domains stabilized by the two methods, using materials with 2 micrometer domains, were approximately the same, though domains in rectangular grooves were stable at higher fields than ring shaped domains.

Paper DE-06 from Boston University was concerned with computer simulations of magnetic domain structure dynamics based on the Landau-Lifschitz-Gilbert equation. Numerically applying domain-compressing fields with small field amplitudes showed that domain walls smoothly approached a new equilibrium position. However, a sufficiently large field pulse led to domain wall overshoot and the related generation of a horizontal Bloch line (HBL). The subsequent annihilation of the HBL allowed the domain wall to return to its nominal equilibrium position.

Paper DE-07 from Boston University was concerned with three-dimensional computer simulation results of magnetic domain structure dynamics based on solution of the Landau-Lifschitz-Gilbert equation. At low gyrotropic drive fields, a simulated winding VBL pair in a domain wall segment propagates stably. A transition however is observed when the drive field is applied in excess of 70 Oe in a 2 micrometer domain-width material with a saturation magnetization of 410 G and damping of 0.5. In this event, the wall and VBL mobilities abruptly change, with the VBL mobility slowly decreasing and the wall mobility increasing with increasing field. At this transition, the winding VBL pair is observed to separate into two discrete VBLs.

Paper DE-08 from the University of Electro-Communications was concerned with a computer simulation which modeled the annihilation process of a VBL pair in conjunction with Bloch point writing. After applying a limited writing field from a simulated conductor, a structure corresponding to a Bloch point was nucleated at the top film surface which propagated to the bottom film surface and annihilated the VBL pair. For large writing fields, multiple Bloch points were observed, with nucleation sites at both film surfaces and in the middle of the film.

Paper DE-09 from Moscow State University described a micromagnetic simulation. This simulation technique allowed for the generalized simulation of VBL dynamics in three dimensions.

Paper DE-10 from Moscow State University studied VBL propagation using in-plane field propagation. Polarized-light, anisotropic, dark-field observation (PADO) and high-speed photography were used to observe VBLs directly. VBL

velocities were observed to increase and then saturate with increasing in-plane drive field. VBL displacements were observed to increase linearly during drive pulses, and to continue typically for 100 ns beyond the removal of 100 ns to 200 ns field pulses. Evidence using the PADO technique, along with computer simulation results, suggested that Bloch loop formation could be observed in association with propagating VBLs.

Paper DE-12 from Iowa State University and Nonvolatile Electronics Corporation described random access memory cells using giant magnetoresistance (GMR) materials. Two thin NiFeCo layers separated by a thin Cu spacer were shown to have a GMR coefficient approaching 7.5% and an anisotropic magnetoresistance (AMR) coefficient around 1%. Memory cells using GMR materials with large outputs and significant differences of resistance for binary storage states in the absence of sense currents are possible which operate at low currents and can be operated statically. Memory cells using GMR materials use resistance changes that depend on the angle between magnetizations in the magnetic layer, as opposed to AMR-type cells that depend on the angle between magnetization and current.

Paper DE-13 from Iowa State University and Nonvolatile Electronics Corporation described a method for sensing the output of GMR memory cells. Sensing times of 200 ns were proposed using two-phase sensing, a single state auto-zero, and output signal levels of 1.7 mV based on memory cells using materials with a GMR coefficient of 6.8%. This sensing time is reduced from the sensing time in conventional MR elements because of the increased signal level, increased from 0.5 mV, and the elimination of two-stage auto-zeroing.

Session DQ — Transformers and Inductors

By Chair R.M. Del Vecchio

A majority of the papers in this session were concerned with the design and fabrication of miniature transformers and inductors. These are produced by sputtering, etching, and photolithography techniques directly onto substrates which contain or eventually will contain other electronic components. These devices have areal sizes \sim mm², thicknesses \sim 10 μ m, and operate at frequencies of \sim 10 - 200 MHz. A common theme of these papers was the finding that the deposition of magnetic layers to produce core structures or simply to complete the magnetic circuit greatly enhanced the properties of these devices. The magnetic layers were typically made of amorphous material and were sometimes layered or subdivided in order to reduce losses.

Another type of device treated in several papers is the orthogonal core variable inductor. These devices have been around for a while. A paper by K. Tajima, et al. presents a method of calculating the flux-mmF relationship of such a core which can then be used to determine its operating characteristics. This method subdivides the core and surrounding space into 3-D prisms. A network of reluctances is constructed with branches emanating from nodes in the centers of these prisms. These reluctances can have nonlinear characteristics so that the nonlinear B-H core material can be modeled. The resulting network equations are then easily solved using a program such as SPICE. The virtue

of this technique over standard finite element methods is that the 3-D problem can be solved relatively quickly which is useful for design purposes.

In a paper by O. Ichinokura, et al. two orthogonal core variable inductors are combined in a scheme using diodes to produce a more nearly sinusoidal output than can be achieved by one of these devices alone.

A paper by D. M. Servidio and A. B. Bruno deals with modeling a split-core transformer. Such devices are used to transmit power across a gap and have many applications. Because they were interested in relatively large air gaps, simple design procedures were inadequate. Using the finite element method, they modeled a pot-core transformer (r-z geometry) with a series of air gaps. Parameters such as leakage inductance were obtained from the finite element program output and used in a T equivalent circuit model to predict the transformer's performance. Their calculated results were compared with data from a prototype unit at various air gaps and the agreement is quite good.

A new method was proposed by M. E. A. Hijazi and A. Basak to distinguish fault current from inrush current in power transformers. Such a distinction is necessary in order to activate a protective relay when a fault occurs but not when the unit is switched on. The conventional method uses the amplitude of the second harmonic relative to the fundamental to make this distinction. Their method is to compute the ratio of the peak value of the current in a cycle to the integral of the current over the cycle. Using analytical expressions for fault and inrush current, they showed that this method discriminates well between the two types of current.

A paper by H. Pfützner, et al. compared the performance of step-lapped transformer cores (# steps > 1) with single step or overlap joint cores. They found that, whereas excitation power and sound level decrease for step-lapped versus overlap joint cores, this is not always true for the power loss. Here a distinction must be made between model cores and actual transformer cores. Due to the precise control one has over gap spacing in model cores, they find that the losses are relatively unaffected by the number of steps. However in actual transformers, this precise control is generally lacking so that a loss improvement occurs for the step-lapped arrangement compared to the simple overlap joint.

Session EB — Thin Film Recording Media I

By Co-chairs Jian-Gang Zhu and Thomas Arnoldussen

Session EB is the first session on thin film recording media. There were about 80 people who attended the session and twelve papers were presented. Paper EB-01 presented by Dr. Marry Doerner showed that CoPtCr films with relative high Cr concentration deposited at relatively high substrate temperature exhibits high signal to noise ratio as well as relatively high coercivity. These low noise thin film media also exhibit relatively high coercive squareness S^* .

Paper EB-02 presented by Dr. Ken Johnson is an experimental study on film medium noise with varying M_s and film thickness independently. They found that medium noise (normalized with M_s decreases significantly with reducing M_s . Paper EB-03 by Prof. Guruswamy is a high resolution TEM

study on a CoPtCr film medium with focusing on microstructure and composition in magnetic grain boundaries. Both microscopy and nano-probe chemical analysis provided clear experimental evidence of the segregation of Cr and Pt along the high angle grain boundaries.

Paper EB-04 presented by Prof. Lambeth showed that in CoCrTa films increasing either the bias voltage or Ta content yields an increase of lattice spacing based on X-ray analysis.

Paper EB-05 presented by Dr. Ed. Teng demonstrated that in double-layer CoCrPt film medium, film coercivity and SNR are optimized with a very thin, about 10 Å, Cr interlayer while the film coercive squareness remains around $S^* = 0.95$.

Paper EB-06 presented by Dr. Chang talked about high coercivity, as high as 3000 Oe, sputtered gamma-Fe₂O₃ thin films with Co-Mn modification. Post-heat treatment were applied. Paper EB-07 presented by Mr. Pawel Glijer showed surface microstructure change with various Pt concentration in CoCrPt/Cr films with some nice AFM pictures.

Both papers EB-08 and EB-09 were presented by Dr. A. Nakau. The two papers talked about how to increase the film coercivity by proper heat treatment after sputtering and related film microstructure changes. Paper EB-10 presented by Prof. Guruswamy showed that in CoCrPt films how the columnar structure develops as film thickness increases. Paper EB-11 presented by Dr. N. Mahvan talked about improving CoCrPt/Cr film disk by properly exposing of sputtered Ni₃P substrate to air. They attributed the improvements of the recording properties to the oxidation of the seed layer. Paper EB-12 presented by Dr. B. Cord a nice production sputtering system for CoCrTa bilayer film disks.

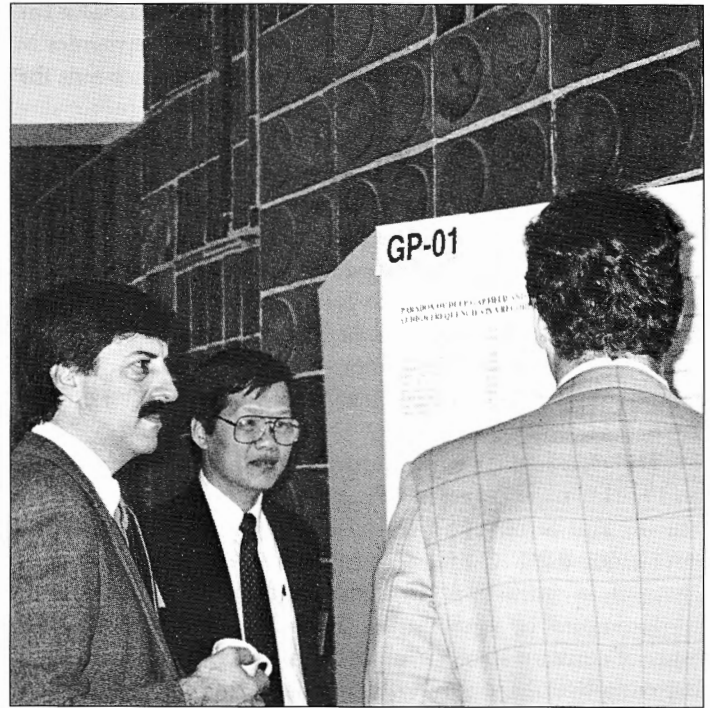
Session EC — Magnetic Recording: Analysis, Characterization & Modeling

By Chair Dean Palmer

The session had a total of 11 contributed papers featuring nonlinear behavior, signal and noise analysis, track edge effects, and recording models. Ce et al. used the pseudorandom sequence method to identify the partial erasure of closely spaced transitions which was shown to be a large factor at high recording densities and not correctable by precompensation. Nonlinear waveform responses were modeled in two papers by Yamauchi and Cioffi and by Sands and Cioffi; in the first case each transition is characterized by two parameters: shift and width, and in the second the sequence is generated by a finite state machine and Volterra series representation of the nonlinearities.

Tsang and Tang presented an analysis of disk noise and showed that transition jitter noise is predominant, followed closely by background (DC erase) and edge noise. A time domain correlation analysis was used by Mian and Howell to obtain a closer representation of the signal-to-noise ratio for real recording waveforms than is derived from the high, constant frequency patterns used in frequency domain analysis.

Micromagnetic modeling by Ye and Zhu of the overwrite behavior at the track edge showed that for isotropic magnetic films there is a distinct erase band whereas for oriented films there is significant overwrite interference at the



edges. Wiesen et al. reported a significant difference in the widths of the left and right side erase bands depending upon the skew of the head; a geometric model explained the qualitative differences.

Huber and Fisher presented an error rate model which couples the bit and track densities through the density-dependent pickup of adjacent track interference and through the SNR dependence on the track width. For typical recording component parameters they found that the resulting optimal bit aspect ratio was much lower than typically found in existing disk drives. The Williams and Comstock recording model has been extended by Stupp et al. for recording on media with an arbitrary easy axis. Modeled results show expected asymmetries about 0 degrees and can be used to simulate vector recording processes. Tagawa and Nakamura incorporated the interparticle interaction into their numerical magnetization model by using mean field theory. Their calculations show that the recording properties for perpendicular media are very dependent on the mean field interaction. Baas and Melbye developed an empirical formula relating the offtrack read capability of a set of components to recording parameters, such as signal-to-noise ratio and overwrite measurements.

Session EE — Soft Materials: Modelling and Magnetoelasticity

By Chairs R.D. Greenough and D.C. Jiles

The session on soft materials: modelling and magnetoelasticity was well attended. It opened with a paper by Jiles, Ames Laboratory, in which the frequency dependence of hysteresis curves was modelled. A time dependent component of magnetisation calculated from an averaging of the effects due to damped harmonic domain wall motion is superimposed on a DC hysteresis curve and the change in shape of dynamic B-H loops with frequency successfully modelled.

Beatrice, Maraner and Mazzetti from the Instituto Elect-

trotecnico of Torino used a numerical approach to solve the differential equations that represent Bloch Wall dynamics in amorphous ribbons (Metglas 2605SC) taking into account the wall surface energy density. The Bloch Wall magnetic skin effect in the body of material was calculated and predicted wall displacement phase shifts between the surface and body compared with experimental data.

Bertotti, Fiorillo and Pasquale, Istituto Electrotecnico and GNSM-INFM Torino, presented calculations of loss and B-H loop shape dependence on peak induction (B_m) and frequency of AC driven amorphous Fe-B-Si compounds. Good agreement was found between theoretical and experimental data for B-H loops at 0.5 Hz and 200 Hz with $B_m \sim 0.5T$.

The effects of stress on induction, differential permeability and Barkhausen count in a ferromagnet were considered by Maylin and Squire, University of Bath. Experimental B-H data from 0.2% C 3% Ni steel which exhibit irreversible changes in induction with the application of 50 MPa of compressional or tensile stress, are compared with the behaviours of constant stress permeability and Barkhausen data but the complexities of the problem appear to preclude the use of such data to predict how induction will change with subsequent applications of stress.

Rousselle, Autissier and Ravel, CEA/DAM, Broyeres le Chatal, examined the microstructure and composition of carbonyl iron after annealing at ~ 300 C in hydrogen and correlated crystallite size and residual stress with experimental dynamic permeability data up to ~ 20 kHz.

Guyot, Rouabhi, Cagan and Krishnam, from CNRS Laboratoire de Magnetisme et Matinaux Magnetique presented experimental work on domain wall pinning and hysteresis losses in amorphous cobalt-niobium-zirconium films, in which it was shown that the permeability along the nominal "easy axis" can be lower than along the "hard axis", if the domain wall is oriented so that it is strongly pinned at the surface of a thin film. However, as the film thickness is increased this effect is reduced so that eventually the permeability along the "easy axis" is higher than along the "hard axis," which is the conventional or expected result.

Iwasaki, Ohsawa, Akashi and Ohta of Toshiba reported on the magnetic properties of sputtered cobalt-iron-tantalum-nitrogen films. In this it was shown that the addition of iron to Co-Ta-N thin films raised saturation induction B_s and reduced coercivity H_c .

Zeltsen and Jagielinski of Eastman Kodak Company, San Diego, presented work on the magnetic properties of iron-gallium-silicon thin films with inidium, ruthenium and rhenium additions. It was found from this investigation that the addition of inidium reduced the hard axis differential permeability from 2700 at 0 at% to 300 at 7.5 at%. Also, the uniaxial anisotropy field was increased from 1 Oe to 13 Oe over the same range of composition. The effects of ruthenium or rhenium additions were less dramatic.

Clark, Wun Fogle, Restorff and Lindberg discussed the magnetisation and magnetostriction in Tb-Dy alloys. It was found that the highest magnetostriction was obtained in alloys of composition $Tb_{0.6}Dy_{0.4}$, but the material needs to be operated at lower temperatures. For example, it has been found suitable for incorporation into electronic devices such as

ultrasonic sonar devices based on high temperature superconductors operating at 70 K. It was also found that while the magnetization of all specimens of the alloy decreased with compressive stress the magnetostriction of rolled specimens increased with stress, and it was conjectured that refinements of the annealing process will lead to higher magnetostrictions still.

Finally, Jenner, Prajapati and Greenough reported on the magnetic and magnetostrictive properties of Tb-Dy-Fe with aluminium additions. The aluminium increased the resistivity and therefore increased the range of operating frequencies of devices based on this material.

Session ER — Domains and Domain Walls: Imaging, Theory and Other II

By Chairs Dr. Phil Bissell and Prof. John Chapman — University of Central Lancashire, Preston, UK; University of Glasgow, UK

ER-02 "Domain Wall Motion in Re-Tm Films With Different Thickness," by Pokhilt, T. (Russian Academy of Sciences, Russia).

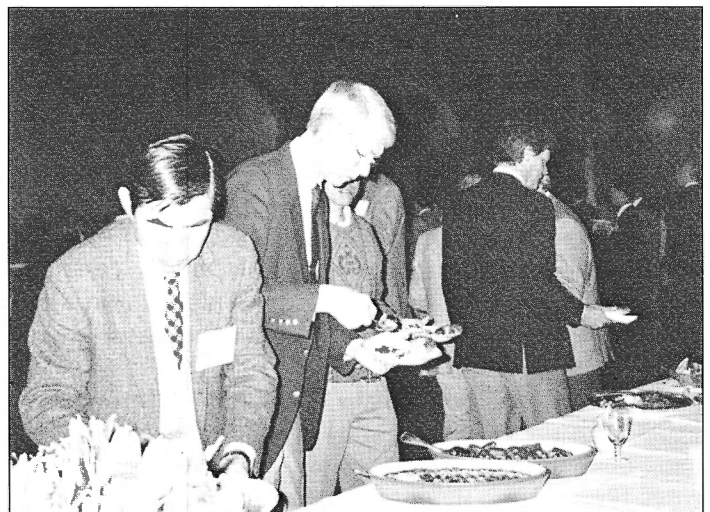
Observations of thermally activated domain wall motion using a magneto-optic setup on RF sputtered TbFe thin films as a function of film thickness were described. The authors reported that activation volume increased non-linearly from 2×10^{-18} to 7×10^{-18} cm³ as thickness increased from 25 to 400 nm.

ER-03 "Re-Modified Kondorsky Function and Asymmetric Wall Structure," by Huang, H. and Lee, T. (National Taiwan University, Taiwan).

The authors considered the dependence of domain wall energy on an oriented external magnetic field in the case of uniaxial ferromagnetic materials with a large quality factor ($Q=K/4\pi M^2 > 1$). The analytical expression was used to remodify the Kondorsky function. It was concluded that the Kondorsky mechanism contributes to the angular dependence of switching fields in the case of low coercivity samples.

ER-04 "Equations of Domain Wall Motion in Ferromagnetic Medium with $Q > 1$," by Huang H., Sobolev, V., and Chen, S. (National University of Taiwan, Taiwan).

Here the authors attempted to derive a Slonczewski type dynamic equation for domain wall motion for materials with $Q > 1$ taking the azimuthal angle of magnetisation into



account. They concluded that the equations reduced exactly to those of Slonczewski where Q is much greater than unity.

ER-06 "Mechanism of Re-Entrant Flux Reversal in Fe-Si-B Amorphous Wires," by Yamasaki, J., Takajo, M. and Humphrey, F. (Kyushu Univ. of Tech., Japan).

This included a description of domain observations on Fe-Si-B amorphous wires in which a core and shell were identified. Attention was focussed on the ends of the wire where the core was found to have a residual reverse domain attributed to the demagnetising effects. The residual domain was stabilised by flux closure through the shell which was found to increase the threshold field for domain growth and resulted in predominant re-entrant flux reversal.

ER-07 "Numerical Micromagnetics in Low-Anisotropy Materials," by Hubert, A., Berkov, D. and Ramstock, K. (Institut WW6 der Universitat, Germany).

The authors explored the various numerical methods available for modelling domain wall structures in low anisotropy materials. Particular attention was paid to the computational efficiency of the algorithms and relationship between speed and numerical accuracy attainable.

ER-08 "Progress in Quantitative Magnetic Domain Observation," by Hubert, A., Rave, W., Reichel, P., Brendel, H., McCord, J. and Heilbronn, A. (Institut WW6 der Universitat, Germany).

Here the emphasis lay on extracting quantitative information from magneto-optic images. A practical scheme was proposed and demonstrated for mapping complex magnetisation distributions. Computer processing allowed any direction to be highlighted with the result that attention could be focussed on walls or domains with magnetisation pointing in a user-selected direction.

ER-09 "Modelling of Reversible Domain Wall Motion Under the Action of Magnetic Field and Localized Defects," by Chen, Z. and Jiles, D. (Iowa State University, U.S.A.).

The importance of localised defects in pinning domain walls is widely recognised. Here the authors explored the relation between the initial permeability and reversible domain wall motion. Good agreement was recorded between predictions and experimental results recorded from spheroidised iron carbon samples with different carbon content.

ER-10 "Domain Walls in Antiferromagnetically Coupled Multilayered Films," by Fujiwara, H. (University of Alabama, U.S.A.).

Walls in coupled films can differ significantly from those in single layers. Here antiferromagnetically coupled multilayers were under investigation and the form Néel and Bloch walls assume was described.

Session FA — Computational Techniques in Applied Magnetics

By Chair Göran Engdahl — ABB Corporate Research

The invited presentations during the symposium covered a wide range of knowledge areas.

First, I.D. Mayergoyz presented a new, globally convergent iterative technique for the solutions of 3-D eddy current problems. Then H.A. Leupold gave a presentation on how permanent magnet circuit design can take benefit of analytic methods including applications of Maxwell's equations, the magnetic moment rotation theorem and mag-

netic "mirrors." Some novel devices resulting from these applications also were presented.

J.D. Lavers reviewed the area of electromagnetic field computation in Power Engineering. The presentation covered typically used models, basic methods, a variety of current applications, recent research on parallel processing, neutral networks and inverse & optimisation problems.

A presentation of advances in electromagnetic design of fusion devices was held by R. Albanese, who focused on the impact of computational tools in the electromagnetic design of large Tokamaks. Both 2-D axisymmetric codes and 3-D codes are used. It is also desirable to include methods for treating coupled electromagnetic - mechanical problems with 3-D eddy currents in the presence of ferromagnetic materials. It was stated that fields as Non-Destructive Testing and Nuclear Magnetic Resonance can take advantage from current methods in nuclear fusion research.

Finally, J. Oti gave a presentation on numerical techniques and their applications to Magnetic Force Microscopy calculations. The presentation also focused on the importance of calculation tools in the design process. An overview was given of numerical solution techniques of micromagnetic problems. Modeling of exchange, anisotropy and magnetostatic interaction fields in magnetic films was discussed and micromagnetic modeling of magnetic force microscopy was presented.



Session FD — Magnetic Recording Systems: Coding, Detection, Servo

By Chair Roger Wood

This session focused almost entirely on the information and evaluation of advanced data detectors for the readback channel. G. Kerwin (FD01), in an invited talk, gave an update on IBM's "second generation" PRML channel used in the 2 Gbyte 3.5" files. The talk emphasized the improved equalization and the diagnostic function built into the chip. H. Thapar, IBM, then presented the first published results with Trellis coded partial response on a rigid disk showing up to 20% density increase over PRML (FD02). The following two papers (FD03 and FD04) described advanced detection schemes for 1,7 coded data. R. Behrens, Cirrus Logic, described a chip implementing a 10-state Viterbi algorithm. In contrast, the detector presented by A. Patal, IBM, avoided this iterative algorithm altogether. H. Shafiee, U. of Min., quantified the advantages of (0,k) EPRML over (1,7) peak

detect (FD05), while R. Wood, IBM, introduced a new add-on circuit claiming to yield EPRML performance from a PRML detector (FD06). T. Suguwara, Fujitsu, described a chip implementing both PRML and EPRML at 5.3 MB/s (FD07) and showing considerable performance gain. H. Matui, NEC, presented a RAM-based reduced state adaptive detector offering advantages on a nonlinear channel (FD08). J. Moon, University of Minnesota, presented a simulation of the effect of sampling phase on performance for various detectors.

With the possible exception of the IBM invited paper on PRML, paper FD10 presented by T. Takeda, Sony, on the new discrete track media generated most interest. A glass disk embossed with discrete tracks and servo patterns was read with an MR head at a data density of 400 Mbits/sq.in. The read clock was also recovered from the embossed servo pattern. The final paper, FD11, from L. Barbosa, University of California, San Diego, dealt with the estimation of track-position using an array head.

Session FQ — Magnetics in Life Sciences I

By Chairs Jukka Knuutila and Tomoya Sato — Helsinki Univ. of Technology, Low Temperature Lab., 02150 Espoo, Finland (JK), and Fukushima Medical College, Dept. of Radiology, Fukushima, 960 Japan (TS)

The poster session presented a variety of interesting studies of magnetism related to biology, medicine, and medical engineering. The main topics covered were magnetic stimulation and transcutaneous energy transmission, including hyperthermic heating, MRI reconstruction, magnetoencephalographic or -cardiographic analysis, artificial magnetically enhanced cardiac valves and transplantable magnetic actuators, effect of magnetic fields on blood fibrin and studies of magnetotactic bacteria.

Le Pocher et al. (FQ-1) had applied finite element analysis to calculate the magnetic and electric fields of stimulator coils. It was found that the usual analytical approximations based on single-turn line elements give inaccurate results since the actual distribution of windings substantially affects the electric field distribution. In another FEM study by Mouchawar et al. (FQ-12) the eddy current distribution of time-varying gradients employed in MR imaging were calculated to find safe limits for pulsed gradients to prevent magnetic stimulation of the patient. An important conclusion was that the inhomogeneity of the thorax region must be taken into account; otherwise the safe limit may lead to a threshold overestimation by as much as 100%.

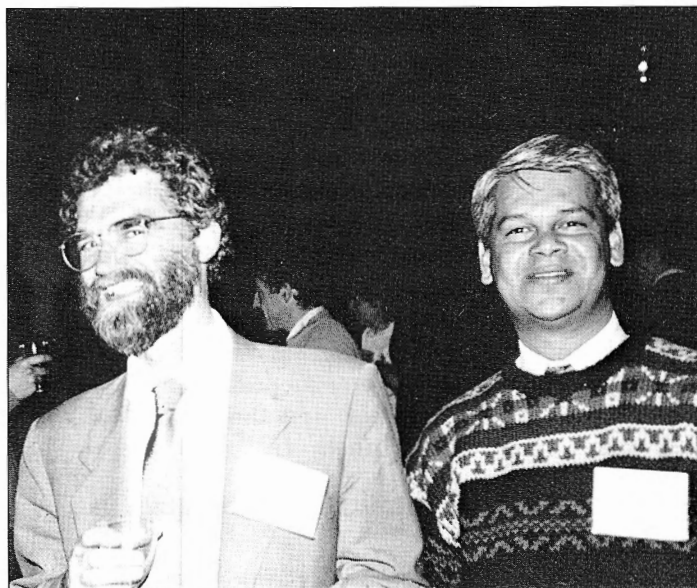
The temperature rise in the tissue when energy is transferred transcutaneously between two coils, one on the skin and the other implanted in the body, was studied by FEM by Matsuki et al. (FQ-4). It was found that the optimum spacing between the coils is 9-13 mm; although the inductive coupling is reduced while the coil separation is increased, the cooling effect of blood flow is enhanced at the same time.

Sato et al. (FQ-2) had developed a self-regulating interstitial heating device made of a ferrite core and a gold ring. When excited with rapidly varying magnetic field, the temperature of the capsule increases up to the Curie temperature, typically slightly over 40 C. No further temperature control or measurement is necessary.

In the poster of Ota et al. (FQ-3), 3D FFT interpolation of image slices was applied to make thinner slices without sacrificing the signal-to-noise ratio of the images. Therefore, the authors could apply the multiplanar reconstruction method to obtain slices of arbitrary direction.

Two posters were devoted to the problem of finding a biomagnetic inverse. Iwahashi and Ueno (FQ-10) considered possible ambiguous solutions in the sampled pattern method (SPM) where, basically, a discretized "trial" current distribution is adjusted to give a field pattern matching the measured values. Saotome and Saito (FQ-8) applied symmetry relations easily recognizable in cylindrical or spherical coordinate systems to reduce the computational task of the SPM. The resulting method is somewhat similar to a discrete minimum-norm estimate.

Y. Sonoda et al. (FQ-5) and K. Mohri et al. (FQ-7) applied ferromagnetic materials to sensors to detect fine biomechanical movements, e.g. those of the tongue while speaking. These studies will be put into clinical use in various medical fields before long. J. Delamare et al. (FQ-9), M. Watada et al. (FQ-14), and D. Ebihara et al. (FQ-15) presented studies of magnetically assisted artificial heart in order to develop a clinically usable, reliable artificial heart or mechanical valve. These kinds of studies are indispensable for development of an artificial heart for practical use. However, further studies of the field are desired from the medical standpoint. A.S. Bahaj et al. (FQ-13) applied magnetotactic bacteria to data analysis and enhancement of recorded images of biological systems. The study will contribute to medical science as well as electrical engineering. The combination of magnetotactic bacteria with antibodies of the cancer cell, as commented by Sato et al. in the conference, may be useful for early diagnosis of cancers.



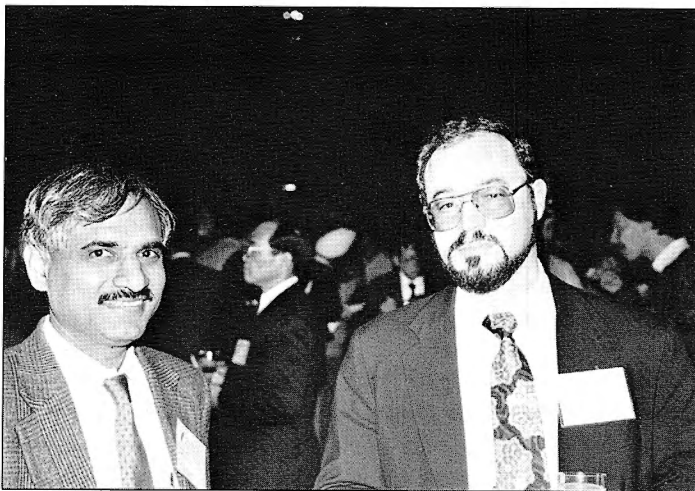
Session GC — Computational Magnetics IV

By Chair Ed Della Torre

This session focused on the solution of practical problems by various numerical techniques. The problems included electromagnetic heating, vibration elements, eddy currents and levitation melting and cross field heating. Techniques used included integral equations, finite element analysis, new

constraint techniques, the use of edge elements and the solution of the inverse problem. The session also included some theoretical papers that discussed such topics as the significance of gauge conditions and analytical solutions for periodic arrays.

A topic of growing importance addressed by some papers is the solution of coupled problems such as obtaining simultaneously current and temperature distributions, the solution for eddy currents in moving conductor problems, or maintaining enough force to overcome gravity in levitation melting. Improving the uniformity of the magnetic field in giant magnetostrictive materials was also addressed. The papers in this session are very useful to someone interested in the state of the art of practical field computation problems.



Session GE — Magnetic Properties & Fabrication in Thin Films and Multilayers III

By Chair Erik van de Riet — Philips Research Laboratories, Eindhoven, The Netherlands

The first three contributions to this session were on Fe_{16}N_2 , which is a soft-magnetic material with an extremely high B_S (2.9T). Many attempts have been made to reveal the structure of this material. Progress has been made, but the structure has not been fully clarified yet. The first talk on this subject was given by M. Kinoshita (invited). He demonstrated that it is possible to grow FeN films with various N contents with ordered (α') and disordered (α'') B.C.T. structure, using an Fe evaporation source and a reactive N_2 plasma. Although he was able to deposit the α' phase and although he was able to vary the c/a ratio, his material does not have the high B_S .

The second talk on Fe_{16}N_2 was given by Y. Sugita. He has grown Fe_{10}N_2 layers on $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ with MBE. He analysed these layers with VSM, XRD and Mössbauer spectroscopy. He demonstrated that after annealing, B_S increases from 2.4 to 2.9 T and the phase changes from α'' to α' . He also showed that there is no significant difference in H_i of Fe and of Fe_{16}N_2 , and no difference in H_i of the three different Fe sites in α'' .

W.D. Doyle and C. Gao gave the last talk on Fe_{16}N_2 . They performed annealing experiments on reactively sputtered Fe_{16}N_2 films, and analysed them with TEM and XRD and measured $M_S(T)$. They presented results on the effect

of annealing and of the N_2 flow rate on M_S and on the TEM and XRD spectra and drew some conclusions on the formation and stability of Fe_{16}N_2 .

H.D. Shieh and C. Chang grew a stack of 100 nm Cu, 100 nm Pd and 2 or 200 nm $\text{Ni}_x\text{Fe}_{100-x}$ and 100 nm Pd on Si(100) with $x=83, 79$ and 50, and measured MH-loops as a function of the substrate orientation. They demonstrated that the Si(100) substrate induces an in plane anisotropy in the NiFe layer when the Cu and Pd layers are grown epitaxially between them, and not when the NiFe is grown directly on the substrate.

I. Nakatani gave a talk on the fabrication of micro arrays of vacuum deposited NiFe stripes with a width of 470 nm and a period of 1 μm , fabricated using e-beam lithography. Ferromagnetic resonance studies (FMR) were made of these arrays of stripes. They showed that long wavelength magnetic dipolar standing waves can be excited in these arrays by RF fields.

M. Miura presented the magnetic and structural properties of FeTaC thin films grown at 300 and 800 W RF sputter power. He showed that the composition and saturation magnetisation does not depend on the sputter power, but the coercive field and the XRD spectra do. He explained his results by a broken intergranular coupling between the Fe crystallites by an FeC phase.

P.E. Wigen showed that his group is able to grow metallic multilayers with a new CVD method in which no carrier gas and a relatively high vacuum is used. XPS, FMR and AES depth profiling showed that the impurity concentration in the deposited films is low and that the interfaces in Fe-Co and Co-Ru are sharp.

A talk on the anisotropy in CoZrRE was given by G. Suran. His group made a systematic investigation of the influence of the magnetic field during deposition, the substrate temperatures, the RF sputter power and the sputter gas pressure on anisotropy in a RE substituted $\text{Co}_{93}\text{Zr}_7$ alloys.

The last contribution was an invited paper on sputtered multilayers for thin film media given by J. Numazawa. He demonstrated that his group is able to sputter deposit in a facing target configuration $0.33 \mu\text{m}$ $\text{Co}_{70}\text{Cr}_{21}/\text{Co}_{67}\text{Cr}_{33}/\text{Ni}_{80}\text{Fe}_{20}$ on a 10 μm thick polyimide sheet, in which the CoCr has a small standard deviation of the anisotropy field and the NiFe has a high permeability.



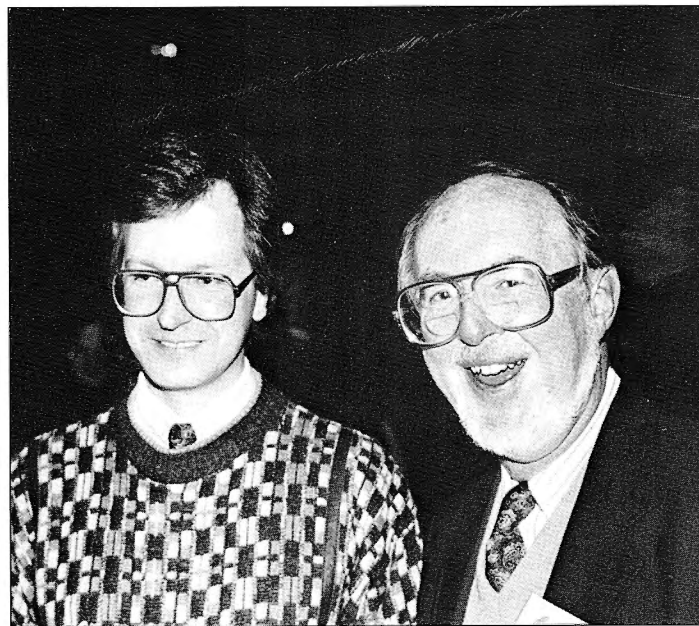
Session GP — Magnetic Recording Heads: Ferrite, MIG & Others

By Chair N. H. Yeh

Fifteen papers were presented in this poster session. Six (GP-01, GP-05, GP-06, GP-07, GP-08, and GP-13) of them dealt with head field analysis, two (GP-10, and GP-14) on recording performance, two (GP-12, and GP-16) on low inductance MIG heads, three (GP-02, GP-04, and GP-15) on parametric heads, and the other two (GP-09, and GP-11) on magnetic films.

GP-01 analyzed the deep gap field and the far field of a complex permeability head, concluding that the actual recording field was quite different from the far field flux loop measurement. GP-05 used a four section transmission-line model to analyze the flux distribution in a thin film head. Head impedance and step response were calculated taking skin depth into consideration. GP-06 studied a finite trackwidth SAL/MR sensor which had the boundary exchange-coupled. The optimum boundary-exchange-bias level seemed to be very sensitive to the stripe height. GP-07 investigated the grain influences on the MIG head domains and readback pulse distortions using Kerr microscopy. The authors suggested that large-grain ferrite having suitable grain orientation may have the same low noise characteristics as the very fine grain ferrite heads, while the head efficiency could be much higher. GP-08 compared and correlated overwrite performance with scanning Kerr microscope measurement in MIG heads. An analytical solution to Lorentz microscopy of head fields was presented in GP-13.

GP-10 reported the recording performance of a FeTaN



laminated hard disk head. The higher saturation moment was reflected in the superior overwrite on a 2400 Oe coercivity disk. The authors also claimed good symmetry and stability in the playback waveform. GP-14 experimentally verified a reduced transition noise with improved head field gradient in thin film disk recording.

The next two papers described methods to reduce the MIG head inductance by lowering the leakage flux. In



GP-12 a thinner ferrite core was used and mounted on the side of a head slider. In GP-16, part of the ferrite core was thinned down and decoupled from the winding coil by inserting a piece of non-magnetic ceramic material into the head structure.

Three papers were presented on various types of parametric heads. They were all based on the concept of modulating a high frequency carrier signal with the reproduced magnetic flux. Both GP-02 and GP-15 used rf carrier frequency. The former had a single side gapped structure and the latter used a toroid. GP-04 employed a microwave carrier and enhanced the response with ferromagnetic resonance.

GP-09 applied the Monte Carlo method to the analysis of unidirectional anisotropy resulting from the exchange coupling of ferromagnetic and anti-ferromagnetic layers. GP-11 investigated the uniaxial anisotropy and local fluctuation of CoFeNb films as a function of Ar pressure and sputtering power.

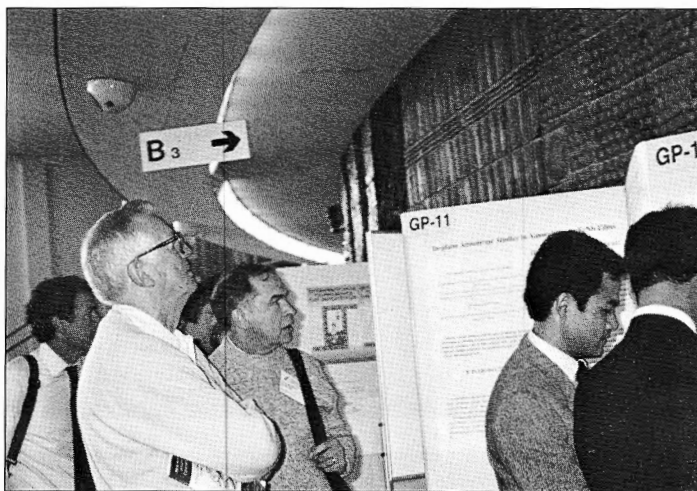
Session HB — Magnetic Recording Heads: Inductive Thin Film

By Chair Mark Steinback — Applied Magnetics Corporation

The authors in this session sailed through a wide variety of topics. Mallory from Digital began the session with an invited talk on their DIAMOND technology. By modifying the topology of the standard thin film disk head, he created a higher efficiency, lower inductance and noise configuration head with distinct advantages for low velocity drives. He conveyed this information well with a series of diagrams, graphs and tables laying out his theory and experimentation. Continuing the topic of improved disk heads, Yoshida of TDK presented a paper on the elimination of undershoots. Their method consisted of ion milling the pole tips from the air bearing surface, starting about 0.5 μm away from the gap at a bias angle. By doing so they totally eliminated the undershoots (as illustrated), creating a head they used for a PRML channel experiment. Trouilloud of IBM then delved into a future problem facing thin film heads: how to create appropriate micromagnetic structures for very narrow pole tips. He presented work his group did on creating a vortex type structure (with domains closing

through the thickness rather than the plane) in test patterns, explicating on how the theoretical and experimental portions held together.

The topic then switched to video heads. Okumura of NEC reviewed the requirements for long play cassette type heads and then discussed their approach of using Fe-Ta-N. He presented his group's work showing the advantages of heads they had built in comparison to ones of Sendust. Next up, Sakai of Mitsubishi presented modeling and experimental work on laminated VCR heads. They compared heads with the magnetic material staggered one half or one full lamination at the gap for read and write characteristics.



Once again the topics returned to disk heads. Ishi of NEC showed results on dynamic characteristics of laminated permalloy films (albeit very thin - 200 nm - ones) using a concept of "immovable walls." For wide structures of 10 μm and greater his results coincided with edge curling wall models, whereas for narrower ones they did not. Oshiki of Fujitsu then described his group's efforts to develop a platable, high saturation moment, low corrosion material of Co-Fe-Ni. Although they arrived at a solution incorporating the above and built heads, their last line - "further study for minimizing wiggles is necessary" - sets the challenge ahead of them. Shi of Carnegie Mellon University spoke next on results of measuring phase lag in the response of the permalloy in thin film heads relative to the driving current. They observed various areas for two designs of thin film heads at frequencies up to 100 MHz. Using modeling and experiment, they divided the lag into read and write portions, employing saturation effects to explain some of this interesting phenomena.

The theme shifted again, with Sakai of Mitsubishi delivering a paper on VCR heads. His group modeled various pole tip configurations three dimensionally to optimize performance for cross talk given the mechanical wear constraints. To confirm the work they then fabricated and tested several of their designs. The final paper of the session (and the conference) came from Suwabe of Carnegie Mellon University. In a total change from all that had come before, he discussed a microstructural investigation of Co-Hf-C films. In order to retain high permeability for use in heads, they found that they needed to present the growth of the fcc Co particles during anneal. They managed this

through the dispersion of fine grain HfC particles, as they documented through TEM and high resolution TEM photos. All in all, the audience enjoyed a session both wide and deep in content.

Session HP — Magnetic Levitation & Propulsion II

By Chair Prof. Dr. I. Kirschner — Dept. Low Temperature Physics, Eötvös Univ., Budapest, Hungary

As its title showed, session HP was dealing with the actual problems of the magnetic levitation and propulsion. The investigations were devoted mostly to the experimental questions which were supplemented by some up-to-date calculations.

In the paper of Tsutshimoto et al. mechanical vibrations were investigated experimentally in order to evaluate electromagnetic force on nonmagnetic and ferromagnetic thin plates. The electromagnetic forces are evaluated from the peak deflection of cantilevered acrylic beam with test pieces. The Lorentz force and the drag force are discussed from experimental results.

Kano et al. have used the finite element method for analyzing the magnetic field of the Linear Electromagnetic Solenoid. The 3D magnetic field is computed using two dimensions since the linear electromagnetic solenoid has a cylindrical symmetry.

In the paper of Salazar and Stephen a bearingless induction motor system is proposed. The theoretical assumption is tested experimentally using a four-pole, two-phase machine without a mechanical bearing.

A new levitation-melting apparatus with flux concentration cap is developed in the paper of Enokizono et al. to get a stable levitation. The relationship between the diameter of the cap's hole and the high-frequency power is measured. The flux distribution of the apparatus is investigated by using the approximate axisymmetric boundary element analysis including the terminal voltage. It is shown, that this apparatus is useful to stationary levitation.

In the paper of Sinha et al. Neural Network models for control and data filtration are proposed. Inverse statical and direct dynamical Neural Network models are obtained and applied to the Electromagnetic Suspension System.

To solve the problems of the surface processing in thin iron plats Ebihara et al. have been dealing with a simplified model apparatus in which an iron plate is levitated by using two electromagnets.

Credit for many of the memorable conference photos are due to Ken Johnson and Greg Christner. Thanks!

INTERMAG '93 AWARDS CEREMONY

Several IEEE and Magnetic Society awards were made at the INTERMAG Conference. IEEE President, Martha Sloan, presented the first IEEE Reynold B. Johnson Information Storage Award to John Harker. (See details in this issue of the Newsletter.) The contributions of the new 1993 Magnetics Society Fellows were recognized as Dr. Sloan presented plaques to Dr.

Hideo Fujiwara and Dr. Celia E. Yeak-Scranton. (Two others, Dr. Tatsuo Fujiwara and Prof. Takayoshi Nakata, were unable to attend. The April 1993 Newsletter describes the work in magnetism of all of the new Fellows.) Dr. David Thompson, Magnetics Society President, honored Prof. William D. Doyle by presenting the IEEE Magnetics Society Achievement Award. (Details are in this issue of the Newsletter.)



WORKSHOP ON GRANULAR MAGNETIC FILMS ANNOUNCED

On October 19, 1993 at the University of Alabama, Professor John Barnard, Metallurgical and Materials Engineering, and Professor Martin Parker, Electrical Engineering, will jointly hold a one-day workshop on granular magnetic films. The workshop, which will be tutorial style, will focus on magnetic, magnetoresistive, structural, and other related aspects of these film systems. A list of guest speakers will be available at a future date.

Attendance will be limited to fifty participants. If you are interested in participating in this workshop, please contact:

Ms. Donna Snow
Center for Materials for Information Technology
The University of Alabama
P.O. Box 870209
Tuscaloosa, AL 35487-0209
Telephone: 205-348-2507 • FAX: 205-348-2346.

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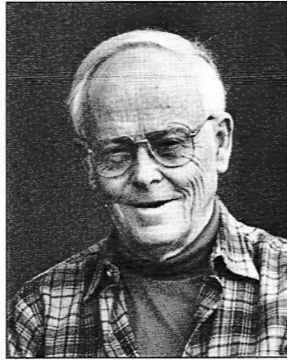


TA-93

YOUR IEEE MEMBERSHIP - THE PROFESSIONAL AND TECHNICAL EDGE

HARKER HIGHLY HONORED

The IEEE Reynold B. Johnson Information Storage Award was presented for the first time in 1993 to John Harker



John M. Harker

“For leadership in the development of information storage devices, including key contributions to the design of many generations of magnetic disk files.”

John Harker was born in San Francisco on June 29, 1926. He served in the U.S. Navy and was an Electronics Technicians Mate 1c when discharged. He graduated from Swarthmore College in 1950 with a B.S. in Mechanical Engineering and from U.C. Berkeley in 1951 with a Masters in Mechanical Engineering. Mr. Harker later attended Stanford University and received an M.S. in Electrical Engineering in 1962.

In 1952 he joined IBM at its newly established laboratory in San Jose, California. He was a design engineer on the first Random Access Disk File, the IBM RAMAC 350. He later led a small group that established the parameters for successful design of self-acting air bearings and incorporated them in the first parallel head disk file, the IBM 1301. Mr. Harker then initiated development of the first removable disk pack file, the IBM 1311.

After his return from Stanford Mr. Harker became the engineering manager for a “trillion bit” photodigital mass storage system developed for and delivered to the Atomic Energy Laboratories at Berkeley, Livermore, and Los Alamos.

In 1969 Mr. Harker was made manager for all of IBM’s Disk Storage Technology. With his leadership the work leading to the “Winchester” magnetic recording technology was started, and the initial activities on thin film recording heads and disks were moved from Research to Development.

At the end of 1970 Mr. Harker was named Product Manager, Direct Access Storage Products, responsible for technology, product development, and business management of the disk file product line. This included successful introduction of the “Winchester” technology in the IBM 3340 and 3350 disk drives. In 1972 he became the Director of the San Jose Development Laboratory.

In 1974 Mr. Harker was named an IBM Fellow. Since that time he has served as Director of Technology for the General Products Division, has been involved in many technology and development projects including the many models of the IBM 3380 and 3390 disk drives, and the IBM 3800 High Speed Laser Printer. He retired in 1987 and has worked as a consultant for IBM for the past five years.

Mr. Harker was elected a Fellow of the IEEE in 1988.

He and his wife Betsy live in Palo Alto, California. They have three sons, two daughters-in-law, and three grandchildren.

IEEE REYNOLD B. JOHNSON INFORMATION STORAGE AWARD



The IEEE Reynold B. Johnson Information Storage Award was established by the Board of Directors in 1991 and may be presented annually “for outstanding contributions to the field of information storage, with emphasis in the area of computer storage.” Recipient selection is administered by the Awards Board through its Technical Field Awards Council.

The Award consists of a bronze medal, certificate and five thousand dollars, and is sponsored by IBM Corporation. It is named in honor of Reynold B. Johnson, who is renowned as a pioneer of magnetic disk technology and was founding manager of the IBM San Jose Research and Engineering Laboratory, San Jose, California in 1952, where IBM research and development in the field was centered.

The Award was presented for the first time in 1993 to: JOHN M. HARKER.

CALL FOR NOMINATIONS:

REYNOLD B. JOHNSON INFORMATION STORAGE AWARD

- An IEEE Field award for significant contributions to information storage.
- Nominees will be judged on the historical significance and the impact of their contribution on the evolution of computer storage systems.
- The recipient will receive \$5,000 and a medal.
- Nomination forms are available from:

Maureen Quinn, Manager
IEEE Awards and Recognition
345 East 47th Street
New York, NY 10017
Phone: 212-705-7882
FAX: 212-223-2911

MAGNETICS SOCIETY CHAPTERS, 93-94

Chairman: Dr. Subrata Dey
Storage Technology Corporation
2270 S. 88th Street, MS 8110
Louisville, CO 80027-8110
Bus: (303) 673-6494
Home: (303) 581-9809
FAX: (303) 673-6540
e-mail: Subrata_Dey@stortek.com

1. Santa Clara Valley

Tom Campbell
833 Hierra Court
Los Altos, CA 94024
Home: (415) 948-5277
Meeting day and time: 3rd Tuesday, 8:00 P.M.

2. San Diego

Dr. Fred Jeffers
Eastman Kodak Company
San Diego Laboratories
3985 Sorrento Valley Blvd.
San Diego, CA 92121-1402
Bus: (619) 535-6919;
Fax. # (619) 535-6990
Meeting day and time: 3rd Thursday, 7:00 P.M.

3. Pittsburgh

James G. Benford
Allegheny Ludlum Steel Corporation
Alabama and Pacific Avenues
Brackenridge, PA 15014
Bus: (412) 226-6301
Meeting day and time: 2nd Thursday, 7:00 P.M.

4. Twin Cities

Patrick J. Ryan
Seagate Technology
7801 Computer Avenue, MS NRM 20M
Bloomington, MN 55435
Bus: (612) 830-7530
Fax: (612) 844-7016
Meeting day and time: No fixed day, 7:30 P.M.

5. U.K. and Republic of Ireland

John N. Chapman
5 Campbell Avenue
Milngavie
Glasgow, B-62-6DL
Scotland, U.K.
Bus: 44-41-3304462
Fax: 44-41-3349029

6. Central New England Council (Boston)

John Judge
11 Magrath Road
Durham, NH 03824
Bus: (603) 868-1644
Meeting day and time: No fixed day, 6:00 P.M.

7. Los Angeles

Werner Treitel
22040 Celes Street
Woodland Hills, CA 91364
Bus: (818) 715-2635
Meeting day and time: 3rd Wednesday, 8:00 P.M.

8. Philadelphia

Prof. Bryen E. Lorenz
School of Engineering
Dept. of EE
Widener Univ., Chester, PA 19013
Bus: (215) 499-4050
Fax: (215) 376-9751/(215) 499-4059

9. Washington, D.C.

Prof. M.P. Horvath
EECS Dept.
George Washington Univ.
Washington, DC 20052
Bus: (202) 994-5516

10. West Lafayette, IN

Herbert Pietsch
7740 N. 100 W.
West Lafayette, IN 47906
Bus: (317) 497-0077

11. Tokyo

Yo Sakai
4-22-4 Tsuganodai
Chiba-shi 260 Japan
Bus: 81-43 2511111

12. Houston

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Dept. of Electrical Eng.
4800 Calhoun Road
Houston, TX 77004
Bus: (713) 749-2782
Home: (713) 482-4678
Fax: (713) 741-2614

13. Denver

Dr. Richard Dee
Storage Technology Corporation
2270 S. 88th Street, MS 8110
Louisville, CO 80027-8110
Bus: (303) 673-3976
Fax: (303) 673-6540

14. Milwaukee

Abd A. Arkadan
Marquette University
Electrical and Computer Engineering
Milwaukee, WI 53233
Bus: (414) 288-5180

CONFERENCE CALENDAR

- AUGUST 23-28, 1993** **EMMA-European Magnetic Materials and Applications.**
Kosice, Czecho-Slovakia.
P. Sovak, Dept. of Exp. Physics, Faculty of Sciences, nam.Febr.vitazstva 9,
041 54 Kosice, Czecho-Slovakia. TEL: xx42-95-21128.
- SEPTEMBER 13-15, 1993** **The 4th Magnetic Recording Conference (TMRC'93).**
University of Minnesota, Minneapolis, MN.
E.S. Murdock, Seagate Technology, 7801 Computer Avenue South,
Minneapolis, MN 55435. TEL: 612-844-4400, FAX: 612-844-8074.
- OCTOBER 10-13, 1993** **Gallium Arsenide Integrated Circuit Symposium.**
San Jose, California.
Todd Cokinos, Cadence Design Systems, 555 River Oaks Parkway -
MS3A1, San Jose, CA 95134. TEL: 408-428-5273, FAX: 408-944-7265,
E-mail: tcokinos@cadence.com.
- NOVEMBER 15-18, 1993** **38th Conference on Magnetism and Magnetic Materials (MMM).**
Minneapolis, MN.
Ms. Diane Suiters, Courtesy Associates, 655 15th St. NW, Suite 300,
Washington, DC 20005, TEL: 202-639-5088, FAX: 202-347-6109.
- MAY 24-26, 1994** **2nd Workshop on Finite Element Methods in Electromagnetic Wave Problems.**
Certosa di Pontignano, Siena, Italy.
Giuseppe Pelosi, Department of Electrical Engineering, University of
Florence, Via C. Lombroso 6/17, I_Florence, Italy.
TEL: +39-55-4796759, FAX: +39-55-4796767, E-Mail:
SIENA94@INGFII.CINECA.IT.
- JUNE 20-23, 1994** **6th Joint MMM-INTERMAG Conference**
Albuquerque, New Mexico.
Ms. Diane Suiters, Courtesy Associates, 655 15th St NW, Suite 300,
Washington, DC 20005, TEL: 202-639-5088, FAX: 202-347-6109.
- AUGUST 24-26, 1994** **4th International Symposium on Magnetic Bearings.**
ETH Zurich, Switzerland.
International Center for Magnetic Bearings, ETH Center/LEO, 8092
Zurich, Switzerland. TEL: +41-1-256 3584, FAX: +41-1-252 0276. E-Mail:
AMB@ifr.ethz.ch.

