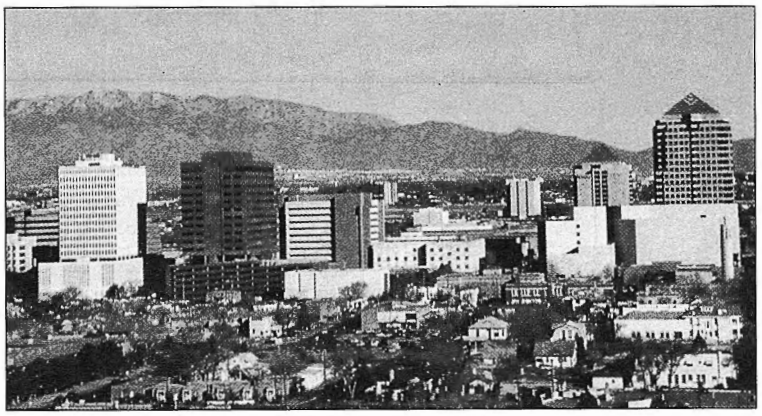
IEEE
MAGNETICS
SOCIETY NEWSLETTER

VOLUME 31, NO. 3 ISSN 1059-8340 July 1994

JODIE CHRISTNER, EDITOR

6th Joint INTERMAG-MMM Conference Albuquerque, NM — June, 1994



Albuquerque, NM

BARKER HONORED WITH ACHIEVEMENT AWARD

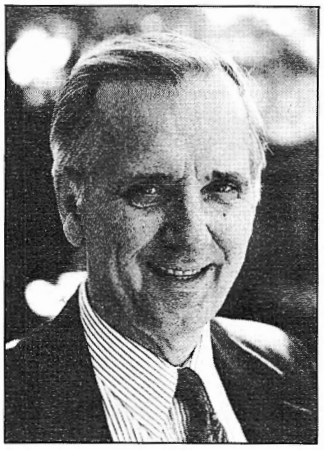
The 1994 IEEE Magnetics Society Achievement Award was given to Prof. Richard C. Barker during the Plenary Session at the 6th MMM-INTERMAG Conference in Albuquerque, New Mexico. Prof. Barker is Director of the Center for Microelectronics Materials and Structure at Yale University, New Haven, Connecticut USA. He graduated from The Choate School near New Haven in June 1944 and immediately entered the U.S. Navy's Electronics Training program. After serving as head of the Major Electronics Overhaul group at the Coco Solo Naval Air Station, Panama, he began his undergraduate education at Yale. As a senior at Yale, he showed that bistable circuits could be made using magnetic amplifiers. He became an Instructor at Yale in 1952, teaching communications theory. His Ph.D. dissertation on the Theory of Magnetic Amplifiers (1955) demonstrated the way in which these and other nonlinear magnetic devices depend on the dynamic flux reversal properties of the magnetic materials involved.

In 1956, Prof. Barker established a course on the physics and applications of magnetic materials. He published several papers with his graduate students on field dependent magnetic flux reversal in metal-tape wound cores and single crystal ferrites. He worked on the theory of single-core fluxgate magnetometers with the Naval Ordinance Laboratory, and on analog storage and readout of multipath ferrite cores with Sandia Labs. He launched a mostly theoretical effort on spin and coupled magnon/phonon resonance modes in ferromagnetic films. He has worked on industrial applications of Wiegand Wire, which has become a prominent security access system.

In 1961 he started a project with NASA on basic technologies and algorithms for data encoding including the nondestructive readout and run-length encoding of polycrystalline ferrite memory cores. Working with Herb Storm between 1959 and 1963, Dick played a major role in making the transition between the AIEE Nonlinear Magnetics Conference and the IEEE INTERMAG by persuading the computer magnetics and magnetic recording people to meet and publish with the nonlinear magnetics people in this new and broader community. The INTERMAG proceedings, as part of the Transactions on Magnetics set the scope and agenda for what would become the Magnetics Society. He organized a Conference on the Physics of Magnetic Flux Reversal at Yale in 1962 which evolved into the International Colloquium on

 (Continued on page 3)

IEEE AWARDS PRESENTED AT 6TH JOINT CONFERENCE



Dr. Denis Mee

Dr. Lubomyr T. Romankiw

1989 IEEE President Emerson W. Pugh presented two prestigious awards at the Plenary Session of the 1994 6th MMM-INTERMAG Conference on June 20, 1994 in Albuquerque, New Mexico.

Denis Mee received the 1994 IEEE Reynold B. Johnson Information Storage Award with the citation "For contributions to the design of optical, mangeto-optical, and magnetic recording files." Dr. Mee was born in Loughborough, England. He received the B.Sc. degree in Physics from London University in 1948. He then obtained a Ph.D. degree in 1951 and a D.Sc. degree in Physics in 1967, both from Nottingham University.

Dr. Mee held positions as a research physicist at the Steel Company of Wales, and the MSS Recording Company in London. He started his magnetic recording career in designing recording tapes for a project on digital control of machine tools at Cambridge University in 1954. In 1959 he joined CBS Laboratories in the United States where he developed a magnetic recording system for a high density magnetic tape audio stereo recorder. He received an IEEE Audio Society award for his work on magnetic recording in 1964.

In 1962, Dr. Mee joined IBM as manager of the magnetic devices group at the Thomas J. Watson Research Center, where he developed technologies for multilayer magnetic thin film devices and novel ferrite structures for memory elements. He also started a project in magneto-optical recording technology using magnetic garnet recording media and argon lasers.

In 1965, Dr. Mee transferred to the Advanced Technology project at San Jose, California where technologies for data storage were under development. Over the period 1965-1972, he started projects in magneto-optical recording, holographic storage and magnetic bubbles. In 1970, he led a broad-scope magnetic recording technology project, based in several IBM research and development laboratories, that laid the technology foundation for thin film head and disk components which appeared in disk file and tape storage products in the 1980's. He has held some of the earliest patents on thin film heads and on magneto-optical recording methods.

In the mid to late 1970's, Dr. Mee worked on the Corporate Technical Committee, based at Armonk, and he later returned to San Jose to start a new joint laboratory for optical data storage. In 1983, Dr. Mee was named an IBM Fellow. He subsequently devoted some of his time to promoting storage research at Universities and collaborative research between Industry and Universities. He helped to start a number of multi-discipline University research centers and an industry-university storage consortium (NSIC). He has authored a classic book on "The Physics of Magnetic Recording" in 1963. He has more recently, edited a Magnetic Recording Handbook.

Dr. Mee became a fellow of the IEEE in 1970, and has been an active participant in the Magnetics Society since its founding.

Lubomyr T. Romankiw was awarded the 1994 IEEE Morris N. Liebmann Memorial Award with citation "For innovations in thin film fabrication processes to realize inductive and magnetoresistive thin film heads for large scale storage."

Dr. Romankiw is an IBM Fellow and Senior Manager of the Electrochemical Technology Department, Manufacturing Research, at IBM's Thomas J. Watson Research Center. He was born in the Ukraine, where he received his early education. He received the B.Sc. degree in Chemical Engineering from the University of Alberta, Edmonton, Canada (1955), and the M.Sc. and Ph.D. degrees in Metallurgy and Materials from the Massachusetts Institute of Technology (1962).

Since joining the IBM T.J. Watson Research Center in 1962, Dr. Romankiw has worked on development of fabrication processes for electronic components and devices utilizing a combination of vacuum, lithography and electrochemical processes. His most important contribution which affected the magnetic storage industry was the invention and development of the fabrication technology for inductive read-write heads and integrated inductive write magnetoresistive read thin film heads. He has managed those projects since 1968 from development through the early stages of manufacturing in the 1980's and is still closely following the projects today.

Dr. Romankiw demonstrated and pioneered the high resolution through-mask pattern plating technology as applied to

fabrication of thin-film recording heads. He also applied the plating-through-mask processes to develop processes for fabrication of x-ray lithography masks, bubble memory devices, thin film multi-chip carriers and circuitization of silicon devices. He was a co-inventor of high speed laser enhanced selective plating/etching and laser jet plating/etching. At present he and his team are pioneering the use of high-speed electrochemical micromachining of minute electronic components, and high energy density batteries. The plating systems, tools, processes, and technology which he invented are widely used today in the fabrication of magnetic and electronic components in the USA and abroad.

Dr. Romankiw holds 43 patents, has 110 published inventions, more than 100 scientific papers and four book chapters. His numerous invited lectures, worldwide at prestigious universities and conferences, on needs, potentials and the actual advances in Electrochemical Technology in Electronics, have strongly influenced the direction of electrochemical research in industry and academia.

Dr. Romankiw is a member of the Electrochemical Society, Inc. (ECS), American Electroplaters and Surface Finishers Society, International Society of Electrochemistry, the IEEE, the Schevchenko Scientific Society, Ukrainian Engineers Society, Sigma Xi and Phi Lambda Upsilon. He has received ten IBM Outstanding Invention and Outstanding Contribution awards, and 22 IBM Invention Achievement Awards. In 1984, together with R.I. VonGutfeld, Dr. Romankiw received the Research Award from ECS's Electrochemical Division. He was named IBM Fellow in 1986, member of the IBM Academy of Technology in 1987, ECS Fellow in 1990, was recipient of the 1991 AESF Scientific Achievement Award, was elected member of the Academy of Engineering Sciences of Ukraine in 1992, and was Perkin Medalist in 1993.

IEEE Magnetics Society Newsletter is published quarterly by the Magnetics Society of The Institute of Electrical and Electronics Engineers, Inc. Headquarters of the IEEE is 345 East 47th Street, New York, NY 10017-2394. $1.00 per member per year (included in Society fee) for each member of the Magnetic Society. Printed in USA. Second-class postage paid at New York, NY and at additional mailing offices. **Postmaster:** Send address changes to IEEE Magnetics Society Newsletter, IEEE, 445 Hoes Lane, Piscataway, NJ 08854-4150.

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.

Please send contributions to:

Dr. Jodie A. Christner
2G8/201-1
IBM Corporation
3605 Hwy 52 North
Rochester, MN 55901-7829
TEL: 507/253-5513
FAX: 507/253-4146
E-Mail: J.CHRISTNER@IEEE.ORG.

NEW MAGNETICS SOCIETY FELLOWS FOR 1994

Eleven members of the Magnetics Society were recently elected to the grade of IEEE Fellow. The new Fellows were recognized by Fritz Friedlaender, chair of the Awards Department of the Magnetics Society, at the Plenary Session of the 6th MMM-Intermag Conference. The new Fellows evaluated by the Magnetics Society and the contributions leading to their awards are as follows.

Gerald F. Dionne, "For contributions to the theory and development of ferrimagnetic materials and microwave ferrite devices."

David C. Jiles, "For contributions to the understanding and application of hysteresis effects in magnetic materials."

J. Douglas Lavers, "For contributions to the modeling of electrometallurgical systems and electroheat devices."

Herbert A. Leupold, "For contributions to electron beam guidance and magnetic biasing systems."

Richard D. Thornton, "For contributions to suspension and propulsion technology for magnetic levitation."

The following new Fellows are enrolled in the Magnetics Society but were evaluated by another Society: Ahmed M. El-Serafi, Raymond D. Findlay, Konrad Reicher, Sheppard J. Salon, and Thomas G. Wilson.

INTERMAG-MMM '94 *(Continued from page 1)*

Magnetic Films and Surfaces, for which which he chaired the Organizing Committee between 1975 and 1985. Prof. Barker chaired the first INTERMAG abroad in 1966 and he set up the 1972 Kyoto INTERMAG by urging our Japanese colleagues to form the Magnetism Society of Japan, which generated the necessary assurances. He was always a leader in establishing relationships between the Magnetics Society and comparable groups in Europe, Japan and China. He also wrote the first Constitution and Bylaws for the new IEEE Magnetics Group in 1967.

In 1985, he founded the Yale Center for Microelectronic Materials and Structures and recruited faculty and funds to establish its laboratories.

Prof. Barker has over 100 publications and 30 Ph.D. dissertations to his credit. He is an IEEE Fellow, a Member of the Connecticut Academy of Science and Engineering, received a Japanese Society for the Promotion of Science Visiting Professorship in 1972, an Alexander von Humboldt Senior Scientist Award in 1975, is a consultant to the Chinese Ministry of Education Key University Program, and serves in a science advisory capacity with two major corporations. He has been a guest professor and lecturer in seven countries. He received an award for Meritorious Service to Yale in April 1994 from the Yale Science and Engineering Association. However, he is most proud of a 1986 student initiated Award for Distinguished Teaching in Yale College.

Prof. Barker is the 13th 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.L. Gordon, E.W. Pugh, Y. Sakurai and W.D. Doyle.

INTERMAG-MMM '94 SESSION SUMMARIES

Session AB - Magneto-Optics

By Chair: Frances Hellman, UCSD

The talks in this session centered on efforts to develop improved magneto-optic materials, particularly in the shorter wavelength range of blue lasers. Improvements are needed in the value of the Kerr rotation angle and the perpendicular anisotropy; in addition the metallurgical stability of the most prominent material currently under consideration is poor. A number of approaches were presented, several of which tried to combine the best features of known materials by preparing and measuring or theoretically calculating properties of new alloys or multilayers. The session began with two invited talks, one on the MnBi-type alloys and recent successes in improving the properties by alloying with Sb and Pt, and the other on a partially-ordered FePt alloy which shows perpendicular anisotropy and large Kerr rotation under certain conditions. The remainder of the session consisted of contributed talks, both theoretical and experimental. Materials discussed included Co-Pt-type multilayers, MnBi-type materials, polycrystalline and single crystal garnets, various Co- and Fe-based alloys and structures, including nanocrystalline Co/EuS materials, and a theoretical discussion of Ce and U-based materials.

Session AF - Kondo, Mixed Valence, and Heavy Fermions I

By Chair: Joe D. Thompson, Los Alamos National Laboratory

Three invited and five contributed talks were presented on a range of topics related to the session title. M.B. Maple reviewed evidence for non-Fermi-liquid (NFL) behavior in $Y_{1-x}U_xPd_3$ and related correlated f-electron systems. Although the temperature dependence of electrical resistivity, magnetic susceptibility and specific heat follows power laws expected of NFL behavior in several cases, other possible explanations also should be considered, including proximity to a T=0 magnetic transition or a distribution of single-ion Kondo temperature. In a related talk, R. Osborn emphasized that the quadrupolar moment in $PrCu_2Si_2$ is quenched by crystalline electric fields, not by the multi-channel Kondo effect, and that the relatively large electronic specific heat of $PrCu_2Si_2$ derives predominantly from a low-lying CEF Schottky anomaly. However, neutron scattering data on $UCu_{3.5}Pd_{1.5}$ are consistent with a NFL interpretation. DeHaas-van Alphen studies of $CeRu_2Si_2$ and UPt_3 at fields below and above their metamagnetic transition fields were reported by S.R. Julian. Analysis of these results suggests that states near the Fermi energy are dominantly f-band like and that the f-level is not localized. X-ray magnetic scattering was used by E.D. Isaacs and coworkers to investigate the relationship between antiferromagnetic order and superconductivity in UPt_3, UPd_2Al_3 and URu_2Si_2. These experiments reveal a large suppression of the ordered moment below the superconducting transition temperature in UPt_3, demonstrating direct coupling between superconducting and antiferromagnetic order parameters; however, this is not the case in UPd_2Al_3 and URu_2Si_2. As shown by J.C. Gomez Sal, substituting 10% Y or La for Ce in $CeNi_{.8}Pt_{.2}$ alters its properties as expected from the resulting volume change. On the other hand; substitutions with magnetic Pr or Nd increase the Ce moment, contrary to expectations from the decreased cell volume. A phase transition at 0.4 K in the heavy-fermion compound YbBiPt produces partial gapping of the Fermi surface. From a detailed field and pressure study, R. Movshovich et al. propose that this transition is one to a spin density wave state which follows weak-coupling BCS behavior. Using a generalized Hubbard model, A. Kocharian suggested that at half-filling a new quantum-spin fluid state should exist in mixed valence materials. C. Sanchez-Castro presented a method for calculating the f-f ion interaction in a system in which both magnetic f and d electrons hybridize with a common conduction band and showed that correlations between d electrons, in addition to hybridization, must be taken into account in calculating the f-f interaction.

Session AR - Magnetic Sensors

By Chair: P. Ciureanu, Ecole Polytechnique, Montreal, Canada

The majority of magnetic field sensors presented at the 6th Joint MMM-Intermag Conference in Albuquerque (papers AR-01 - AR-09) may be classified in three categories:

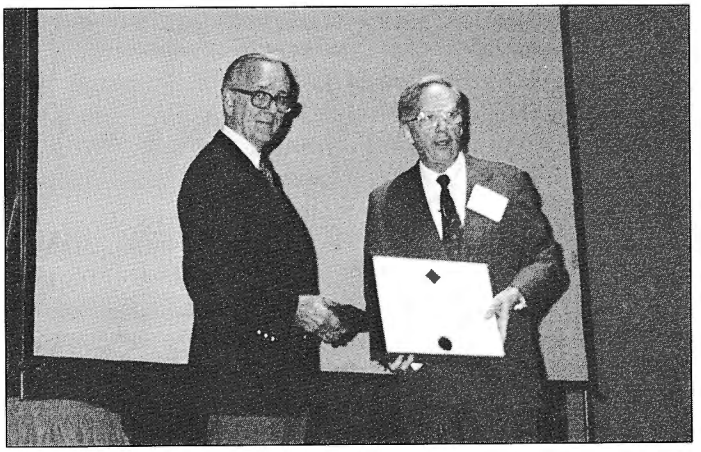
- thin film sensors based on anisotropic and giant magnetoresistive effects;
- magnetic wire sensors based on magnetoinductive and Matteucci effects;
- a micro-fiber sensor based on anisotropic magnetoresistance.

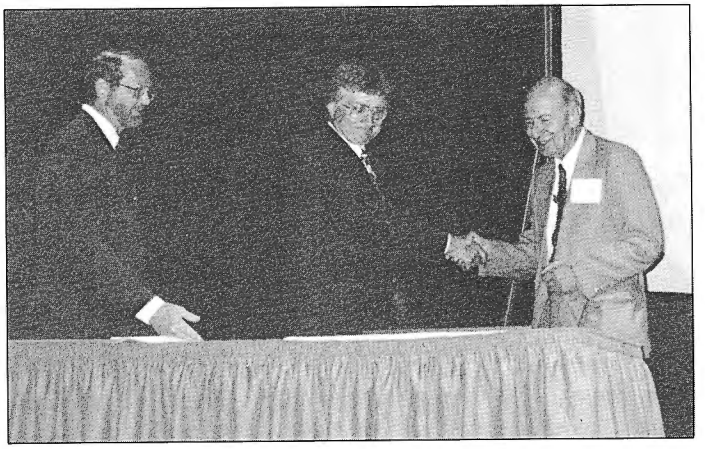
In the first category, by far the most interesting paper was that of Jim Daughton and his colleagues from Nonvolatile Electronics. They used a GMR structure consisting of 4 to 6 multilayers of Cu/CoFe/CoNiFe/CoFe/Cu. An easy axis was induced during deposition and the field to be sensed was applied in the hard axis direction. The GMR effect of this structure was 11% at room temperature and the saturation field was roughly 200 Oe. The biased bridge sensor with a linearity over 0.999 and a high sensitivity (4.5 mV/Oe) which is proposed, represents a breakthrough in sensing devices for moderate magnetic fields (50 - 150 Oe).

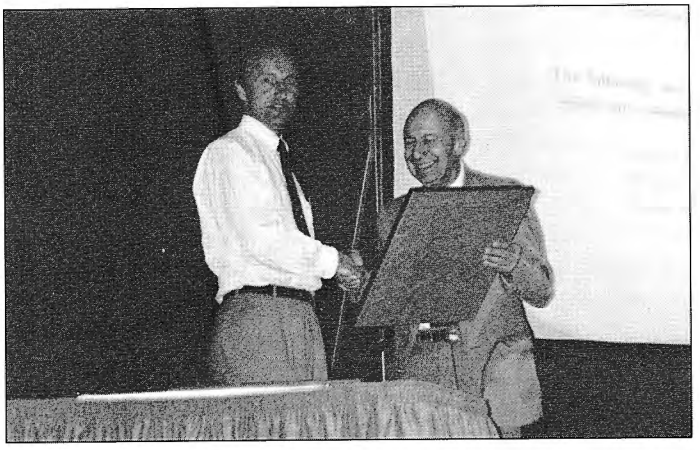
The second category is illustrated by the papers of K. Mohri and its team from Nagoya University. Their long-term work on amorphous wires was again rewarded, resulting in new sensors based on magnetoinductive effect. The sensitivity of a half bridge sensor, with each arm consisting of a 3 mm FeSiB wire travelled by a 5 mA and 100 kHz sensing current, was 1 mA/A/m, which is high enough to promote a new sensing device for weak magnetic fields. A resonant multivibrator was also constructed using a CoSiB amorphous wire. These topics were discussed in more detail at the workshop on Rapidly Quenched Magnetic Wires, organized by F. Humphrey and K. Mohri after the Conference.

Finally, an interesting sensor, based on Permalloy microfiber 15 μm in diameter obtained by rapid solidification, has proved to combine the characteristics of thin film sen-

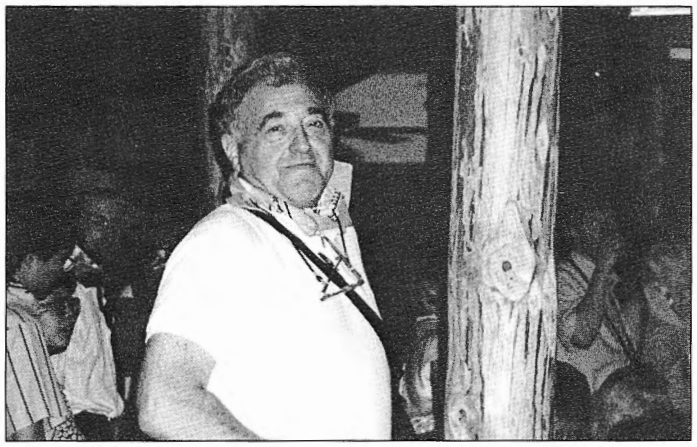
INTERMAG-MMM '94 *(Continued on page 6)*







sors (soft properties and high sensitivity) and those of wire sensors (domain structure imposed by the stress distribution quenched-in during fiber casting). This work has been presented by a Canadian team from McGill University and Ecole Polytechnique of Montreal.



Session BA - Magnetic Microscopy Symposium

By Chair: Philip Trouilloud

The first two papers showed high-quality magnetic force microscopy (MFM) images of soft magnetic samples using commercial instruments. The initial difficulty of the tip-field deforming the domain structure has been dealt with by reducing the total moment of the tip. The challenge now is how to obtain a finer understanding of tip-sample interaction and a quantitative interpretation of the images. These questions were also addressed in the Magnetic Imaging session (HA). The following paper described the first near-field Kerr optical technique for imaging in reflection. The last two papers showed impressively detailed images obtained by electron microscopy, both in transmission (coherent Foucault) and in reflection (SEMPA).

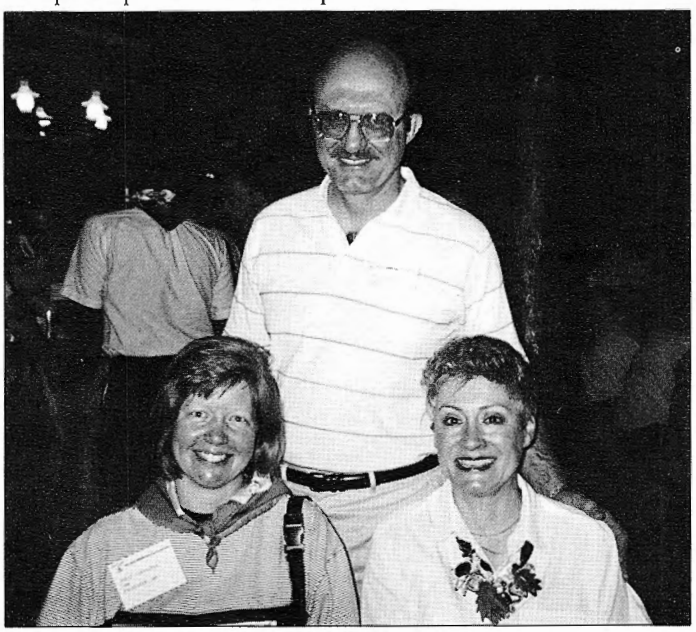
BA01 - Proksch, et al. from the Magnetic Microscopy Center at the University of Minnesota in Minneapolis used MFM to obtain quantitative data on domain wall structures. They observed both single crystals of magnetite and an epitaxially-grown, single-crystal, 0.5 micrometer thick film of iron. Simple wall models were considered, comprised of a Bloch structure in the bulk of the samples and a Neel cap at the surface. The stray field patterns from these wall structures were fitted to the MFM wall measurements with good agreement.

BA02 - Rave, et al. from the Universite' Paris-Sud and the CNRS obtained MFM images of small elements of single-layer permalloy and nanocrystaline iron-permalloy multilayers, and of bulk iron samples. In addition to the wall contrast, they also found contrast in the body of the domains. In particular, a new sub-domain contrast in the iron-permalloy multilayers was observed. If the sample magnetization is assumed frozen in place and does not respond to the tip, micromagnetic modeling of the walls ruled out the possibility of the sub-domain contrast being caused by stray fields associated with the long-range tails of the Neel walls. The "domain" contrast is understood to be due to a reversible tip-sample interaction that picks up variations in the local susceptibility of the sample to the stray field of the tip.

BA03 - Silva from CMRR at the University of California San Diego, and co-workers, presented a new method for optical imaging of magnetic domains in reflection with high spatial resolution (better than 100 nm). The sample is scanned close to a small silver particle (about 30 nm in diameter) that acts as the "aperture" for this near-field technique. Under the illumination of a laser beam, the electrons in the silver particle are driven into localized surface plasmon resonance. As a result, although the particle is sub-optical, the amount of light scattered by the particle is significant and can be picked up in dark-field mode. The localized electric fields of the scattered light couple to the sample so that magnetization orientation modulates the polarization of the light. The technique was applied to a Co/Pt sample: the effect of topographical texture on the shape of micrometer sized domains could be observed.

BA04 - Chapman of the University of Glasgow, and co-workers, introduced a novel method for magnetic imaging in a transmission electron microscope. The method, called coherent Foucault imaging, makes use of a field emission gun and phase shifting apertures made out of thin amorphous foils. The image on the microscope screen reveals the magnetic induction distribution across the specimen in the form of a magnetic interferogram. The period between the fringes is inversely proportional to the flux integrated through the thickness of the sample. For permalloy samples with a thickness of 50 nm, the period is about a tenth of a micrometer. Small permalloy elements with lateral dimensions in the micrometer range were imaged; and the flux closure patterns could be followed in detail. The fringe pattern was found to be stable, so that long term studies of a sample are possible.

BA05 - Kelley of NIST in Gaithersburg gave a detailed and impressive review of the capabilities of SEMPA (Scanning Electron Microscopy with Polarization Analysis). This is a powerful tool for high resolution studies: the spatial resolution can approach 10 nm. It can be combined with other electron microscopy techniques to gain compositional, structural and magnetic information and build a rather complete picture of a sample.



Session BB - GMR and Spin Valve Sensors for Recording

By Chair: H.S. Gill, IBM Corporation

This is the first time the program committee has had enough papers to devote a full session to Spin Valve type sensors at the INTERMAG conference. This session consisted of twelve contributed papers describing the design and materials for GMR/Spin Valve sensors.

Paper BB-01 by W. Folkerts et al. (Philips Research) discussed the application of GMR elements in Yoke Type thin film tape heads. The Spin Valve sensor consisted of $Ni_{80}Fe_{20}/Cu/Ni_{80}Fe_{20}/Fe_{50}Mn_{50}$ multilayer structure. The magnetization direction of the NiFe layer pinned by FeMn was perpendicular to that of the free NiFe layer magnetization. Hysteresis free response with a field sensitivity of 18%/(kA/m) was demonstrated. Magnetic recording heads with Digital Compact Cassette (DCC) standard were fabricated using this Spin Valve sensor in Yoke configuration. A yoke type head with a free layer permeability of 2000 to 6000 exhibited an MR coefficient of 3 to 4%.

Paper BB-02 by Chen et al. (Nonvolatile Electronics, Inc.) described design and test results for a recording sensor utilizing 40 A $Ni_{65}Fe_{15}Co_{20}$/15 A $Co_{90}Fe_{10}$/27 A Cu/15 A $Co_{90}Fe_{10}$/40 A $Ni_{65}Fe_{15}Co_{20}$ multilayer structure. This material exhibited an MR coefficient of 6%. The sense current was perpendicular to the air bearing surface. The uniaxial anisotropy was provided parallel to the air bearing surface. The uniaxial anisotropy and ferromagnetic coupling across the spacer were balanced to achieve very high permeability for the ferromagnetic films. Due to high permeability, this design exhibited 1.6 mV/um and field sensitivity of 0.7%/Oe.

Paper BB-03 by Anthony et al. (Hewlett-Packard) described magnetoresistance of symmetric spin valve structures. A spin valve configuration was described in which an unpinned ferromagnetic film was separated from exchange pinned ferromagnetic films on either side by two nonmagnetic spacers. The symmetric spin valve was shown to increase the magnetoresistance by 50% over the values of individual spin valves. The increase was attributed to a reduction of spin independent outer boundary scattering and doubling the number of spin dependent scattering interfaces.

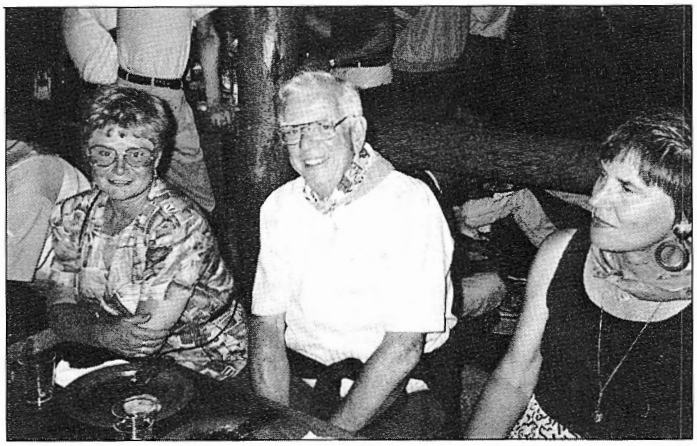
Paper BB-04 by Neil Smith (Eastman Kodak) described the micromagnetics of GMR multilayer sensors at high current densities. It was shown that at high current density (> 10^7 Amp/cm^2) the MR cefficient decreased a factor of 1.6. Half of this decrease was attributed to heating effects (temperature rise of about 100 C) and the other half to distortion of the bias point by self-fields. It was further shown that at high current density, the sensitivity increase by reducing interlayer exchange coupling may not be realizable due to self-field induced distortion of the R(H) curve.

Paper BB-05 by Cross et al. (NIST) described size and self-field effects in GMR thin film devices. The effect of the self-field produced by the applied current was separated from the thermal loss and was found to reduce the response over 32% for a current density of $1.1x10^7$ Amp/cm^2.

Paper BB-06 by Doyle et al. (Univ. of Alabama) described high frequency permeability measurements on $Ni_{76}Fe_{10}Co_{14}$/Cu GMR multilayers. The real part of the permeability was essentially flat at least up to 100 MHz with a value of 360.

Paper BB-07 by Leal et al. (INESC, Lisbon) described unshielded spin valve sensors exchange biased by thin TbCo layers. The stability of the spin valve sensor investigated as a function of track width and sensor height. It was shown that for track width/stripe height ratios greater than 4, Barkhausen noise free behavior was usually obtained and response was noiser below this ratio.

Papers BB-08,09,10,11,12 discussed GMR materials. Paper BB-11 by Kouchiyama et al. (Sony Corporation) described GMR in NiFe(5 nm)/[Ni(1.58 nm)/Fe(0.42 nm)/Cu(2.1 nm)]8/NiFe(7 nm) multilayers prepared by DC magnetron sputtering. It was shown that sandwiching the (Ni/Fe/Cu)8 multilayer with two magnetically soft NiFe layers enabled the reduction of a full width at half maximum from 16 Oe to 10.4 Oe and the increase of GMR ratio from 4.32% to 6.95%. The NiFe/(Ni/Fe/Cu)8/NiFe sensor of a practical size showed a large output, 4 times as large as the AMR sensor of the type NiFe/Al_2O_3/NiFe reported by Sony Corp. earlier.



Session BD - Novel Hard Magnets

By Chair: Jan F. Herbst, Physics Dept., GM R&D Center

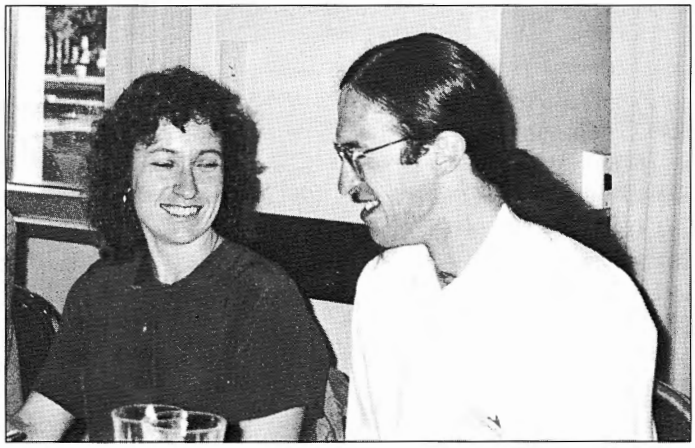
Several papers in the session involved research on the newly discovered $R_3(Fe, M)_{29}$ compounds, where R = rare earth and M = Ti, Cr, Mn, or V. This class of materials is characterized by a fascinating monoclinic crystal structure, established by Hu and Yelon and Li et al., which features two distinct R sites and fifteen different transition metal sites. As is the case for the $R(Fe, M)_{12}$ series, the structure is evidently stabilized by the M atoms since no binary R_3Fe_{29} or R_3M_{29} representative has been observed to form. The reports by Cadogan et al., Fuerst et al., and Margarian et al. indicate that the monoclinic phase exists for R = Ce, Pr, Nd, Sm, and Gd, but not for heavier rare earths. Work on interstitial modification by Cadogan et al. and Ryan et al. suggests that nitrided $Sm_3(Fe, Ti)_{29}$ may be a candidate for permanent magnet applications.

Rhombohedral (Th_2Zn_{17}-type) compounds were the subject of three contributions. Yang et al. discussed the magnetic properties of the non-stoichiometric $Sm_2Fe_{14-x}Co_xSi_2$ compounds, Al-Omari and collaborators reported a Mössbauer effect study of $Sm_2Fe_{17-x}Al_x$ materials, and Hu and Yelon

INTERMAG-MMM '94 *(Continued on page 8)*

INTERMAG-MMM '94 *(Continued from page 7)*
investigated the $Nd_2Fe_{17-x-y}Al_xSi_y$ system via neutron diffraction and magnetization measurements.

Ido and coworkers described efforts to improve the hard magnet characteristics of $SmCo_4B$ by means of iron substitution and nitrogen absorption.



Session BE - Macroscopic Quantum Tunneling/ Spin Glasses

By Chair: Eugene M. Chudnovsky, CUNY Lehman College

Interesting new experimental and theoretical results on macroscopic quantum tunneling of magnetization have been presented. David DiVincenzo of IBM - Yorktown Heights reviewed the theory of tunneling of the Neel vector in small magnetic particles, including topological effects and relevance to recent resonance experiments on ferritin. He disclosed the new data of Awschalom et al. (to be published) which show exponential dependence of the resonance frequency on the size of the ferritin core, which is in accordance with the tunneling interpretation. Anupam Garg of Northwestern University presented his theory of decoherence due to nuclear spins. Based upon this theory and his previous calculation of the power absorption, he suggested that the tunneling interpretation of the observed resonance in ferritin should be ruled out. Prabath Perera and Mick O'Shea of Kansas State reported observation of the non-thermal magnetic relaxation in Dy and Tb ferromagnetic layers with record high temperatures of the crossover from thermal to (presumably) quantum regime, 6K for Dy and 20K for Tb. They attributed their observations to quantum tunneling of domain walls.

Session BR - Kondo, Mixed Valence, and Heavy Fermions II

By Chair: Dr. Ray Osborn, Argonne National Laboratory

The field of strongly correlated electron systems, to which this session belongs, has been active for over twenty years now, and has spawned its own series of conferences such as the one to be held in Amsterdam this August. Given this maturity, it is therefore surprising that simple theoretical models can still give new insight into the behavior of strongly hybridized f-electron systems. In this session, Sheng and Cooper (BR-08) presented work in which they included exchange interactions between the band and f-electrons in addition to the hybridization contained in the conventional Anderson model. They proposed that the interplay between these two determines the nature of the f-electron ground state, with both magnetic and non-magnetic solutions possible.

The variety of observed ground states in such systems is illustrated by the extensive work of Sechovsky, Havela and co-workers (BR-01) on the uranium ternary compounds UT_2X_2 (T = transition metal, X = Sn or In). Some of these are real heavy fermions, with γ values as high as 850 mJ $mol^{-1}K^{-1}$ in U_2Pt_2In, some have more moderate mass enhancements and order antiferromagnetically while others appear to have itinerant 5f-electrons. What makes this series so interesting is the opportunity it provides to explore the conditions necessary for 5f-electron localization and magnetic order by varying the transition element ligands within an isostructural series. Their experimental results have been compared with band structure calculations and some simple patterns do emerge in spite of the wide range of properties. For example, 5f-localization increases with the filling of the transition metal bonding and anti-bonding d-bands. There is virtually no f-d hybridization predicted in the U_2Pd_2X compounds, which is the most localized of the series, whereas U_2Co_2In is predicted to be a weakly exchange-enhanced itinerant paramagnet in agreement with experiment.

Session CA - Magneto-Resistive Recording Heads

By Chair: Peter K. George, Seagate Technology

Session CA focused on Magneto-Resistive Recording Heads for low flying height and narrow-track rigid applications. Novel designs for buried sensors (CA-01), vertical recording heads (CA-02, CA-13), slanted contact designs (CA-03), exchange biased DMR designs (CA-07), and unshielded horizontal MR heads (CA-14) were presented. These papers described the geometry, fabrication techniques, and electrical characteristics of the individual designs. Several other papers concentrated on studies of exchange coupled (CA-04, CA-05) or permanent magnet biased SAL sensors (CA-10, CA-11, CA-12) with the goal of optimizing the geometry for narrow track applications. The exchange coupling aspects of MnFe (CA-09) and MnNi (CA-08) relative to head applications and ferromagnetic coupling between SAL and MR films (CA-06) in a trilayer stack were also discussed. The session closed with a modelling paper (CA-15) describing the numerical treatment of shields in a shielded MR head.

Session CB - $R_2Fe_{14}B$ Hard Magnets and Applications

By Chair: Andrew Kim, Crucible Research Center

This session contained 13 papers on $R_2Fe_{14}B$ hard magnets and applications:

C. D. Fuerst, et al., reported a massive diffusion facilitating the microstructural transformation during die upsetting. They investigated die-upset Nd-Fe-Co-B magnets from blends of dissimilar ribbons. Thermal analysis of the blended-ribbon magnets revealed that they have a single Curie temperature near that expected for a single-ribbon magnet with the same average cobalt content. This indicates inter-ribbon diffusion during hot working. L. H. Lewis, et al., reported an HREM study on the grain boundaries and the intergranular phase of die-upset RE-Fe-B magnets. The intergranular phase is amorphous and is enriched in iron; this observation is in direct opposition to that of previous reports in which the grain boundary phase is enriched in rare-earth. Further study is required to resolve this dispute. J. Wecker, et al., reported microstructural and magnetic properties of mechanically alloyed anisotropic Nd-Fe-B, and J. Bernardi, et al., reported those of sintered Nd-Fe-B-Cu-Nb magnets.

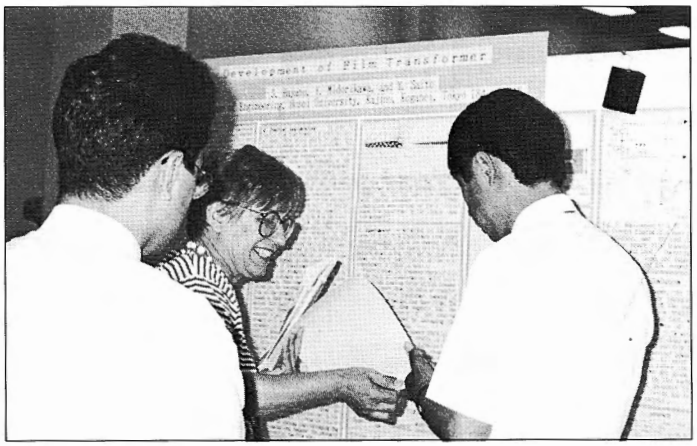
M. Leonowicz, et al., reported the high coercivity $Nd_2Fe_{14}C$ type cast magnet. The high coercivity was achieved by solid state transformation with short annealing at 850-1000°C. The additions of Cu or Ga change the properties of the intergranular phase, and affect mass transfer and kinetics of reaction. The maximum magnetic properties of 11 kOe and 5.8 KG were reported with 262°C = T_c.

M. G. Abele and H. Leupold reported the design and fabrication of uniform and high field permanent magnet assemblies.

O. Gutfleisch, et al., studied kinetics on solid HDDR processes in Nd-Fe-B type alloys by using electrical resistivity measurements. These studies suggest that the start of the disproportionation and recombination reaction depends on a critical hydrogen concentration in the matrix phase $Nd_2Fe_{14}BH_x$. G. P. Meisner, et al., studied the desorbed hydrogen-decrepitated anisotropic MQ powder. By the HD process, the instrinsic magnetic anisotropy of the $Nd_2Fe_{14}B$ phase is reduced. By hydrogen desorption at 220-250°C, the high coercivity and remanence are restored. K. E. Chang, et al., studied the absorption/desorption of hydrogen in sintered NdFeB in KOH solution by using an electrochemical method. The amount of hydrogen absorbed was proportional to the TRE content and the cathodic charging time. The anodic polarization curves indicate that the corrosion rate increases as the level of absorbed hydrogen increases.

A. Kim, et al., proposed a simple method of measuring the degree of alignment in sintered magnets by XRD. Also reported was a method of enhancing the fraction of the ideal [001] texture component in both Nd-Fe-B and Nd,Dy-Fe,Co-B magnets by doping with oxygen, which leads to a measurable increase in remanence. G. Asti, et al., applied the SPD and DMC methods to determine the orientation density of the tetragonal axis of the 2:14:1 crystallites with different degrees of grain alignment. The orientation densities obtained by both methods agreed fairly well.

B. Edwards, et al., investigated the relationship between the coercive force and the angle of the applied field of an infinite magnetic medium containing a planar defect. Their results showed that the angular dependence of the coercivity differs from the inverse cosine curve. They showed that there exists a decrease in the domain wall pinning coercivity as a function of the angle between the applied magnetic field and the anisotropy for certain ranges of parameters.



Session CC - Particulate Recording I

By Chair: J.W. Harrell, Department of Physics & Astronomy, University of Alabama

This session dealt with several important aspects of magnetic recording media, including switching characteristics, thermal stability, corrosion, dispersion and particle preparation.

Three papers dealt with chemical stability of magnetic particles. Sides et al. from Carnegie Mellon University showed that the corrosion resistance of MP media has been significantly improved. He presented results showing that the stability of the best MP media is now comparable to CrO_2. Jung et al. from the University of Arizona used flow microcalorimetry to show how a hydrophobic polymer coating reduces the uptake of H_2O by metal particles and used Mössbauer spectroscopy to study the degradation of the oxide layer. Nikles et al. of the University of Alabama demonstrated that amine quinone polymers significantly inhibit MP corrosion.

Veitch et al. from BASF showed that thermal stability depends more on the crystallite size than particle size, and

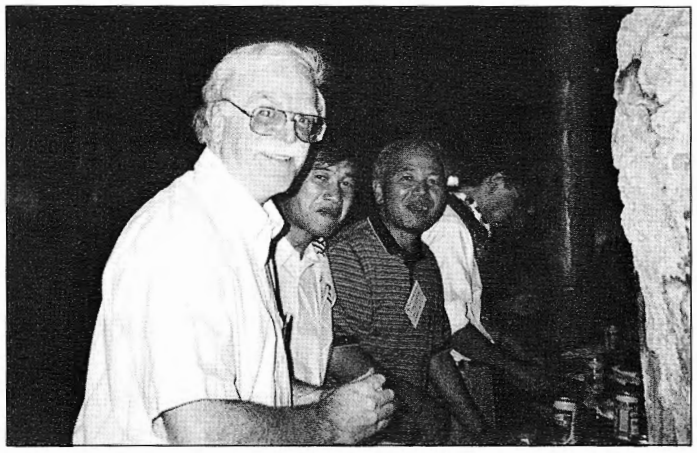
INTERMAG-MMM '94 *(Continued on page 10)*

they presented evidence that newer, smaller metal particles may have greater thermal stability than larger particles because of larger crystallite sizes in the smaller particles. Bottoni et al. of Ferrara Universita presented results showing that doping affects the time-dependent magnetic behavior of particles.

Cheng et al. of the University of Alabama demonstrated using dispersions of Co-g-Fe_2O_3 in a waterborne binder that the interaction field determined from remanence measurements was a good indicator of dispersion quality.

Four papers dealt with switching characteristics. Luo and Zhu of the University of Minnesota measured the angular dependence of switching of individual iron particles and simulated the measurements using a chain of spheres model. Yu and Harrell of the University of Alabama used FMR to measure damping constants in several media and showed that the damping constant was strongly correlated with the high speed switching time measured by Doyle and co-workers. He et al. of the University of Alabama presented numerical solutions to the Landau-Lifshitz-Gilbert equation which showed that switching in uniaxial, single-domain particles can occur well below the Stoner-Wohlfarth limit for fields with short rise times. Flanders et al. of the University of Pennsylvania and the University of Alabama presented measurements showing the effect of sequential pulses with fast rise times on switching. They observed strong reptation effects which were qualitatively explained by time-limited switching of pairs of interacting particles with different coercivities.

Suerig et al. of Aachen University of Technology described a sol-gel method of preparing hexaferrite particles.



Session CD - Magnetic Multilayer Coupling I

By Chair: Robert S. Beach, Univ. of Calif., San Diego

A wide variety of novel magnetic heterostructures was discussed in this session. Component materials included rare-earth metals, semiconductors, transition metal oxides, rare-earth garnets and metal-semiconductor hybrids.

Metal-semiconductor heterostructures hold the promise of a marriage of magnetism and semiconductor electronics. The MnAs/GaAs system reportedly exhibits very square hysteresis loops, and may find use in future semiconductor based memory elements. The uniaxial anisotropy present in this system is also observed for Fe on GaAs. This phenomenon was addressed theoretically, and is apparently due to reconstruction of the GaAs growth surface. A similar two-fold anisotropy was reported for Co/CoAl superlattices on GaAs.

Magnetic ordering temperatures are modified from the bulk in magnetite- NiO superlattices. Similar effects occur for superlattices comprised of CoO and NiCoO. In this system, changes in specific heat associated with the magnetic phase transitions were determined using a recently developed thin-film microcalorimeter.

Results on the magnetic and magneto-optical properties of garnet superlattices (YIG/BIG and YIG/EBIG) and of Tb/Fe were also reported; the magnetic properties of the latter were found to depend strongly on the structure of the Tb/Fe interfaces.

The invited paper in this session summarized results on several rare-earth superlattice systems, Ho/Y, Ho/Er, and Ho/Lu. These display extraordinarily rich magnetic phase diagrams, which are determined by epitaxial constraints and an intricate RKKY-like coupling mechanism.

Session DA - Symposium on Slow Relaxation/ Magnetic After Effect

By Chair: Dr. Kevin O'Grady, University of Wales, Bangor

This session consisted of six invited papers in a symposium format, the purpose of which was to look at the different models and experimental treatments of slow relaxation in magnetic materials. The phenomena of slow relaxation is often better known as "time dependence of magnetization" or "magnetic viscosity" and is responsible for many associated phenomena such as the sweep rate dependence of measurements of coercivity, variations in coercivities measured in the US and in Europe and elsewhere in the world where drive frequencies derived from mains electricity are different, magnetic after effect in which the magnetization of a magnetized material is found to decay with time and several other unusual effects.

The session was opened by Professor Robert Street of the University of Western Australia who wrote the original seminal work on this subject as long ago as 1949, in collaboration with Woolley. In this paper Professor Street described the development of the theories underlying magnetic viscosity and advised us that the phenomena was in fact first observed by Ewing in the late 19th century. He reviewed the work of Niel, Wohlfarth and others in developing the model which we now know as the fluctuation field model of magnetic viscosity in which a fictitious field is used to describe the thermal agitation effects that give rise to the phenomena.

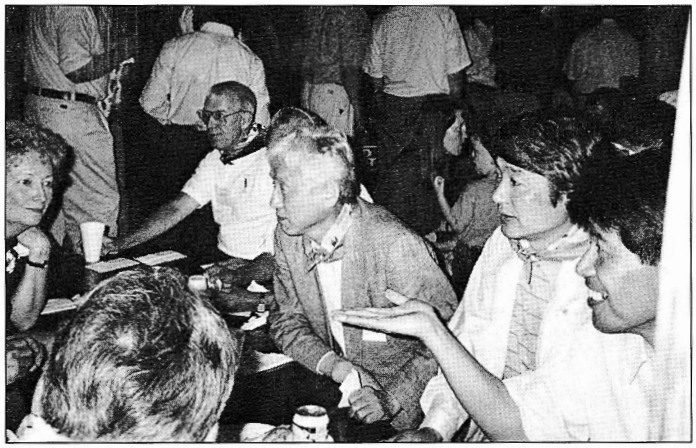
In developing this theme Professor Street showed that this fictitious fluctuation field can be derived from simple waiting time experiments in which a magnetized material is allowed to relax at a fixed field until its magnetization reaches a constant value and the experiment repeated at another fixed field fairly close to the original value, and again the time recorded. Professor Street showed that this simple analysis is capable of giving self consistent values for the fluctuation field for a wide variety of materials where the simple ln(t) law described in his original paper some 45 years ago does not apply.

The second paper in the session also derived from work in Professor Street's laboratory in Western Australia and consisted of a description of a thermo-dynamic approach to the analysis of time dependence data, based on an Equation of State model which leads to the variation of magnetization with field and time being described by a three dimensional surface in M, H and dM/dt the fluctuation field and the susceptibility of the material. This paper went on to describe how these parameters can be determined experimentally and used to define the surface which can then be used to predict for example the variation of coercivity with sweep rate.

The third paper in the session was presented by Dan Dahlberg and existing and former co-workers from the University of Minnesota and described how even for a system with a single particle size the presence of inter-particle interactions within the material can give rise to an effective distribution of energy barriers in the material and thereby lead to quasi logarhithmic time dependence. Thus it is not necessary to have disorder within the material creating the distribution of relaxation times and that they can be entirely natural just due to the nature of the material itself. This leads to a non-monatomic temperature dependence of the logararithmic decay slope and can in principal be used to derive parameters associated with the interactions in the material.

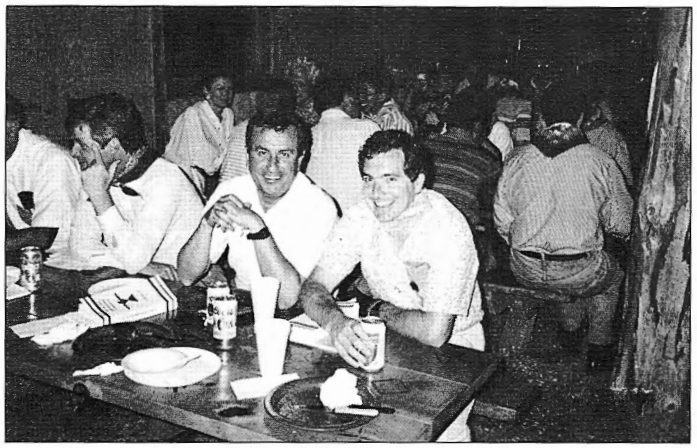
The fourth paper in the session was the first not to be concerned with the normal logarithmical or quasi logarithmic behaviour that it observed and was presented by R V Chamberlain, of Arizona State University. In this paper Professor Chamberlain developed a model that provided a physical explanation for the response of magnetic materials in terms of 'dynamically heterogeneity' which leads to non-exponential behaviour. The model included the requirement that the domains obey normal thermo-dynamic rules, e.g. extensivity, the central limit theorem, percolation theory etc., and the rate of relaxation was shown to depend upon a detailed balance of these factors. By way of example, this model was used to account for unusual data observed for EuS single crystals in which the time dependence varies anomalously. Furthermore, Professor Chamberlain reported this model accounting for Barkhausen type jumps and barrier hopping phenomena observed in single crystal whiskers of iron. The generality of the model was such that it can provide a physical explanation for observed response in paramagnets, spin glasses, ferromagnets and even high Tc superconductors.

The fifth paper from Chantrell et al. of Keele University in the UK was divided into three sections. The first section dealt with the simple model of an integral over an energy barrier distribution leading to either logarithmic or non-logarithmic time decay of magnetization.



It was shown that for the case of a wide distribution of energy barriers a single logarithmic function was generally adequate to describe the behaviour over several decades of time whereas for very narrow barrier systems a sum of ln(t) terms representing each barrier value was more appropriate. Again, this model led naturally to the concept of the fluctuation field and an experimental technique for its determination. In the second part of the paper an extension to the work described by Dahlberg was presented in which the effects of interaction fields in providing a dispersion of energy barriers was shown to be natural from a full scale computer model of the effect. As an interesting development of this, this lead to the concept of a smaller volume of reversal within the columns which initiated the effect. This implies a link between the activation volume and the micromagnetics of reversal within each grain and implies that no micromagnetic model of reversal can be complete if it neglects thermal agitation. In the final part of the work a description of an original model of a micromagnetic system complete with thermal activation was presented and the nature of the incoherent reversal resulting was described.

The final paper in the session came from the sole speaker from an industrial laboratory in the symposium and dealt with the consequences of time dependence of switching fields in magnetic recording media. This paper was presented by Mike Sharrock of 3M Digital Media Laboratory in St Paul and described in detail the effects of thermal activation on the variation of coercivity which is critical for the archival storage of data and also in terms of determining the effective coercivity in the magnetic recording write process. A simple model was developed that accounted for the time scale dependence of coercivity and was used to describe the nature of the volume within the grains that initiates reversal. It was shown that a quadratic dependence of the energy barrier on the magnetic field appears satisfactory even for switching frequencies in the range from 1 to 10 GHz and that a 3/2 power dependence is more appropriate for frequencies of 0.1GHz or less. Using this model it was shown that the switching volume agreed well with the particle volume and using this model it was shown that we will still be able to record stable data on particles an order of magnitude smaller than are currently used. In the final section of the paper, extremely elegant data from the laboratory of Bill Doyle in Tuscaloosa was used to show that the model breaks down for very fast writing times.



Session DE - X-ray Magneto-Optics

By Chair: Jim Tobin, LLNL

The X-ray Magneto-Optics session was an interesting and lively one, with nine good talks and many questions and comments. A wide range of magnetic circular dichroism experiments were discussed. This included direct magnetic structural determinations with spin polarized EXAFS and MXCD-Photoelectron diffraction, MXCD effects in x-ray resonant scattering and MXCD absorption. Much of the MXCD absorption work centered upon element specific determinations of magnetic moments and the limitations of the "sum rule" approach. A strong mixture of state-of-the-art experimental measurements and advanced theoretical modelling characterized the talks.

There were however two problems.

1. Direct competition with session DD, "Ultrathin films and overlays." Sessions DD and DE should have been sequential, not in parallel.
2. There were three "no-shows," DE-10, -11 and -12. All were by Russian authors.

Session DF - Computational Magnetics I

By Chair: Adalbert Konrad, University of Toronto, Dept. of ECE

This session on Computational Magnetics had a relaxed atmosphere, with a fair amount of interaction between the speakers and an audience of about 35 people. Due to the three papers that were not presented (DF-01, DF-10 and DF-12) there was plenty of time for questions from an attentive audience and answers by a group of enthusiastic speakers. The session had a truly international flavour. Except for the last two papers (DF-11 and DF-13), all presentations were concerned with numerical field computation for the analysis of electromagnetic devices. Highlights of the presentations are described below.

Professor T. Nakata (Okayama University, Japan) presented the finite element analysis of a magnetic solenoid actuator for a fuel injection device (DF-02). The novelty was in the employment of edge elements to solve a difficult nonlinear three-dimensional problem involving the motion of a valve.

Professor D.K. Lieu (University of California, Berkeley) presented two design techniques for the reduction of reluctance torque in permanent magnet motors (DF-03). The effectiveness of these techniques (skewing of the rotor poles and stator tooth notching) were predicted by finite element analysis and the application of the Maxwell stress tensor. Dr. Gunhee Jang (University of California) described an investigation of the influence of stator coil winding pattern on stator tooth forces in brushless dc motors with the goal of decreasing magnetically induced vibrations (DF-04).

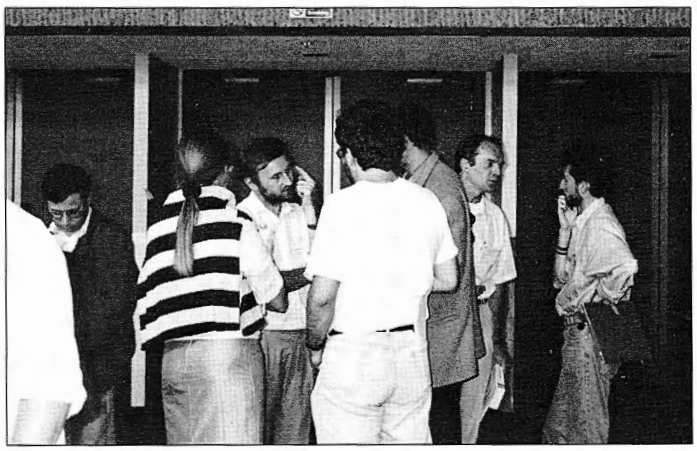
During the presentation of his paper (DF-05), Dr. S.H. Khan (City University, London, UK) stressed the importance of finite element field analysis in the computer-aided design of cylindrical linear step motors and presented field plots and the results of force calculations for a particular motor designed in Russia.

An enlightening presentation on the application of genetic algorithms for the optimization of electromagnetic device geometries (DF-06) was given by G. Fuat Uler (Florida International University. His approach was illustrated by an electric machine example in which he predicted the pole shape required to achieve a uniform magnetic flux density distribution in the pole/stator air gap.

Professor V.M. Machado (Centro de Electrotecnia da UTL, Portugal) made an interesting slide presentation on an explicit time integration iterative method for the solution of time-varying nonlinear eddy current problems (DF-07).

Dr. R. Hagel (University of Erlangen-Nurnberg, Germany) presented an induction heating application which was effectively a coupled electromagnetic/heat flow problem (DF-08). The focus of his talk was the method employed for force calculation in a moving three-dimensional shell-inductor system.

In a presentation by Ikuo Saitoh (Hitachi Ltd., Japan), a novel formulation of the three-dimensional nonlinear magnetostatic problem and its application to a magnetic recording head problem was described (DF-09).



Session EE - Preparation and Physics of Artificially Structured Magnets

By Chair: Stephan von Molnár, Center for Materials Research & Technology, Florida State University

This session was composed of four invited papers and three contributions describing a variety of methods for producing small magnetic particles and various methods for studying their structural and magnetic properties.

The first paper in the session, a collaboration between the IBM T.J. Watson Research Center at Yorktown Heights and the University of California, Santa Barbara, was presented by A.D. Kent. He described a micro-CVD technique using a STM (Scanning Tunneling Microscope) in an ultra-high vacuum environment to produce particles of nanometer-scale iron with various aspect ratios and diameters as small as 90 Å. In addition, he described a novel Hall gradiometer technique employing a 2D electron gas with which the magnetic hysteresis loops of arrays of these small magnets were measured. The sensitivity of these gradiometers is high enough to see 10^8 spins.

The second invited paper, a collaboration among three Frenchmen and one Japanese laboratory, was presented by D. Givord of the Laboratoire Louis Néel in Grenoble. These authors took advantage of the complex magnetic phase diagram of amorphous YCo_2 to produce very thin filaments of magnetic material in crystalline YCo_2 thin films by heavy ion irradiation. Diameters of these filaments could be as small as 25Å. Extensive X-ray and magnetic measurements indicate that continued irradiation caused a progressive decrease in the percentage of crystalline phase with an increase in the induced magnetic moment. Both the anisotropy and coercive fields were measured. It was concluded that the anistropy is predominantly attributable to shape anisotropy and that such contributions as magnetocrystalline bulk or surface anisotropies can essentially be neglected. The explanations for the coercivity are somewhat more complex and require the inclusion of magnetostatic interactions in some of the samples.

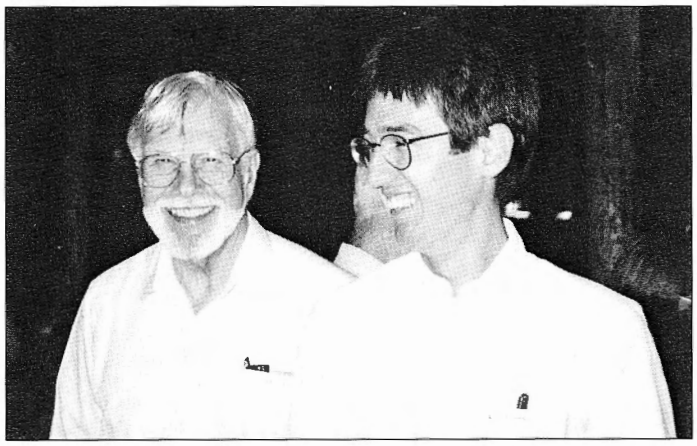
The third invited paper given by Atsushi Maeda of the SANYO Electric Company was a tour de force of MBE and photolithographic etching techniques. A variety of multilayer structures composed of rare earth and transition metal materials were summarized. The focus, however, was on ferromagnetic arrays fabricated on silicon using electron beam lithographic techniques. The starting point was 800 Å thick films of either cobalt or permalloy in various shapes and arrays with varying widths and spacings between them. Magnetic measurements were carried out to a large extent using magnetic resonance techniques, although a variey of other experimental probes were reviewed.

Perhaps one of the more imaginative techniques for producing magnetic filmentary structures was presented by Dmitry B. Rozenstein, who attended the meeting from Novgorod, Russia. Dr. Rozesnstein and his co-workers used a well-known electrochemical method for producing fine filamentary pores in silicon. Ferromagnetic filaments were then made by filling the pores with nickel. Although the Russian group is only at the beginning of their physical investigations of these materials, they have already measured the angular dependence of the ferromagnetic resonance as well as structural properties using X-ray and electron microscopic techniques.

Papers five and seven, which originated from the same laboratory at the University of Minnesota, described electron beam nanolithography and electroplating techniques to fabricate arrays of nickel pillars on silicon with remarkably uniform diameters as small as 350 Å and with varying aspect ratios. Stephen Y. Chou has hopes for these arrays as ultra-high density magnetic storage media. At present, however, the research focuses on fundamental properties of small particle arrays, their individual magnetic properties, and the influence of interactions among the particles. For example, Mark Wei used magnetic force microscopy to measure the switching fields of submicron permalloy bars. The results led to the surprising observation that the switching fields deviate dramatically from the expected monotonic increase with increasing aspect ratio. This finding is consistent with results reported by A.D. Kent in the first paper.

Paper six by several laboratories in France, including the University of Lyon and the Laboratoire Louis Néel, described a novel technique for producing small iron and nickel clusters using laser vaporization. These techniques produce remarkably small clusters with size distributions between 40 and 60 Å, and their structural and magnetic properties have been studied with various techniques, including X-ray, Rutherford backscattering, ferromagnetic resonance, and SQUID magnetization measurements. Models invoking correlated spin glasses were used to compare to the experimental magnetization. Local probes, ie. Mössbauer spectroscopy, showed that iron clusters are surrounded by a non-magnetic oxide skin and that nickel clusters have a not as yet explained reduced moment.

The session demonstrated that a sizable international community of workers is finding novel ways of producing small magnetic structures and are starting to understand their, often unexpected, magnetic properties.



Session EP - Magnetic Recording Heads: Ferrites, MIG, and Others

By Chair: Hideo Fujiwara, The University of Alabama

Fifteen papers were presented. Among them nine were concerning heads having a gap made of the material of Fe-(X)-N systems or about the materials themselves and three were concerning the sendust or sendust heads. Narrow track heads have also been a focus of the recent developments in the field of magnetic recording, and most of the heads presented were of a track width of a few microns. Application of STEM was another topic in this session.

Fe-(X)-N systems possessing high saturation induction (B_s) as well as high permeability (μ) have long been attracting attention because of their high potential of being applied to inductive heads for future high density recording. The number

INTERMAG-MMM '94 *(Continued on page 14)*

of papers concerning these systems reflects this situation. Goto, et al., Sano, et al., and Kadono, et al. have successfully applied these materials to heads in the form of almost practical uses in different styles. Naoe and Nakagawa realized *Bs* of 2.1 T with *Hc* of 0.03 Oe in the form [Fe:N/Ta:N] multilayers. Lin, et al. has investigated the dependence of the soft magnetic properties of FeTaN on the nitrogen flow rate during deposition and Kim showed how the properties of Fe-N depend on the nitrogen content. Haftek, et al. showed that nitrogen strongly affects the mechanical behavior of FeTaN films, and that a rapid and short time stress relief is associated with the nitrogen content. Gangopadhyay, et al. have made it clear that for some range of nitrogen content in FeTaN a sufficiently high permeability can be obtained with almost the same corrosion resistivity as NiFe, Narayan and Kim have investigated the mechanism of corrosion of Fe-N sputtered films compared with NiFe. Rapid thermal annealing (RTA) effects on sputtered sendust (FeAlSi) films have been investigated both by Ullah, et al. and by Daval, et al. and have been confirmed to be potentially applicable for head fabrication. Daval, et al. also utilized nitrogen for controlling the grain growth and stresses. As for the narrow track heads, Goto, et al. and Sano, et al. have confirmed the applicability of their heads to the recording of more than 250 Mb/in. Suzuki, et al. has successfully tried to fabricate a thin film head for a VCR on a substrate with its gap almost perpendicular to the substrate, making track width control easy. Ura, et al. explored the side edge effect of azimuth recording for heads of laminated sendust films with some offset at the gap. STEM was utilized by Kobayashi, et al. to be observe the domain pattern change of thin film heads by application of a write current and to confirm the correlation between the noise-after-write and the pattern change especially at a vicinity of the back-gap closure. A tomographical method by utilizing STEM to analyze the 3-D form of the head field was demonstrated by Ferrier, et al.

FB - Thin Film Recording Media II

By Chair: Kenneth E. Johnson, IBM

Several themes were present in this session. Workers from Hitachi and the University of Minnesota discussed recording results on bicrystal disks in papers FB-01 and FB-02. These disks are made using a single crystal material such as MgO or GaAs as the substrate material. These materials are chosen based on the match of the lattice parameter to the Cr underlayer. This allows an epitaxial growth of Cr. The Cobalt c-axes will grow either parallel or perpendicular to each other based on lattice matching principles. Because the substrate is single crystal, the c-axis orientations relative to the recording direction will vary as the disk rotates. A preferred orientation of the head direction being equally spaced between the two c-axes gives the best performance.

The use of multilayers in thin-film disks as a means to reduce media noise has been known for several years. Four papers presented results on this type of structure. Lal in FB-03 demonstrated that by sputtering the top layer with bias, macromagnetic properties could be tuned allowing better overwrite than in the standard structure where the two layers can at times exhibit independent coercivities separated by several hundreds of Oersteds. Ye, Lam, and Zhu (FB-08) modelled multilayer media and did recording experiments showing that track edge noise as well as on track noise is greatly reduced. Workers from AKASHIC Memories (FB-13) made bilayer structures with different thicknesses and alloys in the magnetic layers. In this way, they could alleviate PW50 and overwrite problems typically encounterd in the thicker bilayer structures. Workers from Conner measured transition shifts on keeper layered media. Such media has a layer of permalloy on the top of the hard magnetic layer and acts to increase signal output and reduce PW50 values. This study showed that transition shifts induced by the use of head bias in the write process were minimal, but in the read process they could be substantial. However, the shifts are calculable and can be handled by the channel.

E. Wu (FB-07) showed a technique for measuring the modulation noise induced by texture of media substrates. This noise, in addition to media noise, can substantially affect error rates. Fitzpatrick and co-workers (FB-06) gave an invited paper presenting a model for error rates in a thin-film disk recording system using a PRML channel. Gomez, from the University of Maryland, showed a video tape made from individual frames of an MFM analysis of a track undergoing erasure. Harrell and co-workers (FB-10) presented a new way to interpret delta-M curves. One can extract an alpha and beta parameter from the VSM measurements that relate to the mean and fluctuation field terms respectively. This results in a more physical interpretation of the media noise data relative to delta-M measurements.

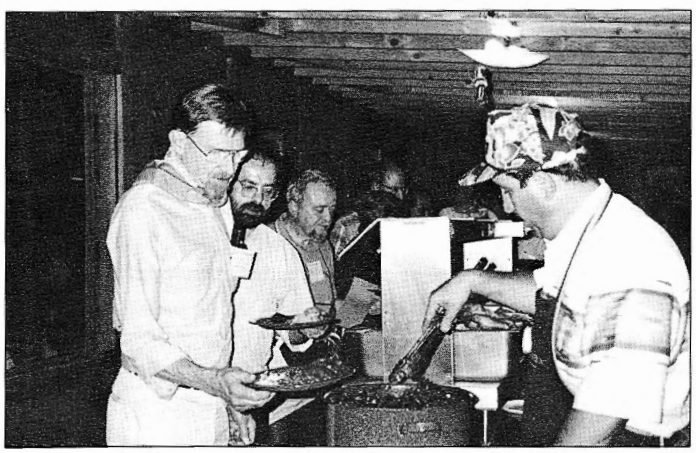
Ta containing quaternary alloys were discussed by workers from the University of Minnesota (FB-12). The addition of Ta up to 8% increases Hc. Media noise decreases with Ta and is postulated to be a result of either elemental segregation or an out of plane magnetization component present from a vertical crystallographic component in high Ta percentage films. IBM workers (FB-11) presented a method to optimize the MrT product for MR head recording. Low MrT values led to low Hc and higher noise. Higher MrT values resulted in poor resolution and overwrite. A compromise of 0.6 was the best for their system.

Session FC - Symposium on Neutron Scattering Studies of the Vortex Structures in Superconductors

By Chair: Jeffrey Lynn, NIST

This symposium consisted of five invited talks and was organized to review the recent burst of activity that has advanced our understanding of the microscopic properties of the vortex structures in superconductors, and has elucidated the underlying nature of the superconducting state in all types of superconductors. The small angle neutron scattering (SANS) technique in particular has proved to be a powerful probe of these vortex structures over wide ranges of temperature and applied magnetic field. One important question, critical to the successful use of superconductors in applications, concerns whether the vortex lattice melts into a fluid phase at elevated temperatures. The concept of melting was initially thought to be unique to the highly

anisotropic cuprate ("high T_c") superconductors, but it has recently been shown to be a universal phenomenon. Nicholas Rosov (NIST) presented detailed measurements on elemental niobium, where a transition from a vortex crystalline lattice to a flux fluid was observed. The orientation of the lattice was still controlled by the underlying crystalline lattice, and hence this vortex phase is best described as a correlated (or hexatic) flux fluid rather than as an isotropic liquid. A melting transition was also reported by Mohana Yethiraj (ORNL) for the high T_c superconductor $Bi_2Sr_2CaCu_2O_{8+x}$, where the vortex scattering is only observed for very small fields and relatively low temperatures. One of the interesting observations for this material is that there is an anomalous increase in the scattering intensity at low temperatures, which may be related to the underlying mechanism for superconductivity in this highly anisotropic material. The nature of the vortex lattice in the high T_c $YBa_2Cu_3O_7$ system was the subject of Bernhard Keimer's (Princeton) talk, where the vortex lattice is found to be distorted from the usual triangular configuration. For applied fields near the *c*-axis direction the vortex lattice is pinned by the twin planes, while for large angles with respect to the *c*-axis the orientation is thought to be controlled by the Fermi surface and superconducting gap anisotropy. Peter Gammel (Bell Labs) reported on the vortex structure observed in hexagonal $NbSe_2$, which material has the advantage that the full (H,T) phase diagram of this anisotropic system is experimentally accessible. The flux lattice is found to be pinned by the crystalline anisotropy, in contrast to expectations based on anisotropic London theory, and can be clearly affected by the introduction of transport currents in ways that are in contrast to theoretical expectations. The nature of the vortex lattice and its relation to the superconducting order parameter in UPt_3 was the subject of the talk by Rafael Kleiman (Bell Labs). This "heavy fermion" superconductor is thought to have an unconventional d-wave pairing state, and the measurements could be used to determine both the London penetration depth λ and the superconducting coherence length ξ. The effective mass anisotropy could also be determined, and directly related to the anisotropy of the Fermi surface and superconducting gap anisotropy. Overall the symposium demonstrated the power and elegance of applying SANS to this class of problem.



Session FF - Ferrites and Soft Materials

By Chair: Sungho Jin, AT&T Bell Labs

In Session FF on Ferrites and Soft Materials, a total of eight papers were presented (3 on ferrites, 2 on Fe-Si alloys, 2 on metallic thin films, and 1 on nitride films).

Van Dover et al. (FF-01) discussed epitaxially oriented thin ferrite films of (Ni,Zn)-, (Mn,Zn)- and other ferrites. Optimized deposition conditions produced high quality films with low anisotropy, high saturation and permeability suitable for high frequency applications. In Ramesh et al.'s paper (FF-03), the effects of heat treatment atmosphere on the microstructure and magnetic properties of polycrystalline Mn-Zn ferrite samples were described. Hsu et al. (FF-04) added sintering aids to the Ni-Cu-Zn ferrites to lower the densification temperature and make the co-firing with Ag easier. These ferrites may be useful for inductors and multilayer ferrite applications. Jerome et al.'s paper (FF-05) discussed the correlation between the soft magnetic and structural properties of sputtered Ni-Fe permalloy films. The nature of the buffer layer between the film and the Si (100) substrate has a significant effect on local anisotropy and magnetic properties, e.g., a Ta buffer gives rise to an order of magnitude lower Hc than a Cr buffer layer. Van de Riet et al. (FF-06) presented a paper on new soft magnetic thin films of Fe-Gd-N. The films are heat treated to exhibit a nanocrystalline microstructure. Hiramoto et al. (FF-07) described their results on FeAlSi-based multilayer films with FeAlSiO oxide interlayers. The layer structure exhibits high saturation and permeability. Abdellaoui et al. (FF-08) utilized a ball milling technique to prepare a Fe-33%Si type crystalline disordered solid solution mixed with amorphous phase, and studied its structure and magnetic properties. Basso, et al. (FF-10) discussed the dynamic Preisach model for interpretation of power losses in a rapidly quenched Si-Fe alloy. The relationship between processing, microstructure, and soft magnetic properties of the alloy was studied.

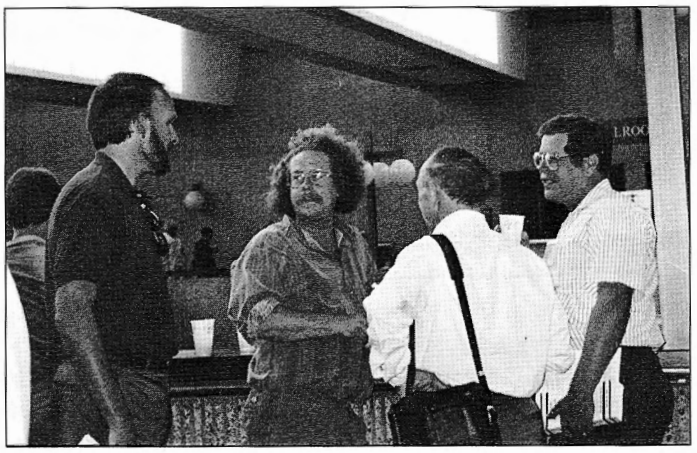
FP - Recording Modeling and Phenomena I

By Chair: R. D. Gomez, University of Maryland at College Park

The topics presented in this session can be categorized into three major areas namely: noise characterization, remanence, and performance assessments in magnetic recording systems. The origins of noise in the system were analyzed in FP-04 on the basis of a physically-based model which incorporated the contributions from a standard head. The model predicted experimentally observed noise sources labeled "repeatable" and "nonrepeatable" and, in the case of repeatable noise, shows promise in their statistical characterization. The characterization of the nonrepeatable noise attributable to medium irregularities, however, remains an open problem. An attempt to understand their contribution was presented in FB-05 where a series of dibits having some intended separation were written and variations in the transition spacings at different locations were measured. Variations as much as 70 nm bewteen transitions were observed and were ascribed to the irregularities in the medium microstructure. Still on the issue of noise, a novel way to characterize noise in tape systems was discussed in FP-01. This model

 (Continued on page 16)

is based on the premise that magnetic microstructures can be treated as a dynamical system, and can thus be analyzed by calculating the phase space trajectories of the time series. Using commonly used tools in nonlinear dynamics, the model predicted that noise are not random but are instead chaotic. FP-10 described a practical recipe for measuring transition jitter in thin film longitudinal media. In this procedure, contributions from various noise sources such as write-clock jitter, spindle speed precision, system noise, etc. were eliminated; making the technique reach an acceptable accuracy for diagnosis of high density recording. On the topic of remanence, FP-02 showed an approach to overcome the inability of Preisach hysteresis and Stoner-Wohlfarth models alone to predict positive delta-M curves associated with positive interparticle interactions. Such interactions are well known to exist in Ba ferrite media. The key is to account for the interaction dependence on the magnetization by using a so-called moving or positive feedback model in a self-consistent computation. In FP-03 the angular dependence of the remanence magnetization in tapes has been reported. The data suggests that a combined Lorentzian and Gaussian distribution of the easy axis of the particles may be used and that the high field selects the nearer of the two directions along the easy axis for each particle. As far as system performance is concerned, the model described in FP-08 predicted that a saturable magnetic keeper layer in longitudinal media yields significant improvement over conventional thin film media. Isolated pulses calculated from the model showed that the keeper introduces improvement of 55% increase in peak amplitude, 46% reduction in the half-width, pulse shape asymmetry and eliminates undershoots from the pole edges. Along the same line, FP-07 modeled the relationship between the overwrite characteristics in perpendicular recording media on the basis of transition shifts. The paper concludes that the overwrite is not governed by the residual background magnetization but is influenced more by the transition shift at sufficiently high fields. As a result, a bilayered head which suppresses the transition shift also improves the overwrite characteristics. In FP-06, a practical and simple statistical model was presented to predict the threshold error rate as a function of tracking position by taking into account missing and extra bits separately. The model predictions are in excellent agreement with the experimental data. Finally, FP-09 calculated the response of a thin-film recording head based on the knowledge of the 3 dimensional magnetic field distribution of the media. Without resorting to the reciprocity relation, the pickup voltage was calculated at different positions along the track by solving Maxwell equations in Fourier series representation. The model correctly predicted some experimentally observed fine structures in the head response function and the parameters obtained in the fitting process compared favorably with the experimental values.



FR - Hard Magnets II

By Chair: Herbert A. Leupold

This session concerned the physics, fabrication and improvement of hard permanent magnets as well as the exploitation of such materials in magnetic devices. Of the twenty-two papers presented, fourteen were materials oriented (FR 22 and FR 1-13) and eight concerned applications to magnetic devices. (FR 14-21).

Papers 1-3 and 5, 11, 13 dealt with improvements of NdFeB properties through novel fabricational procedures, 5, and through control of grain growth by hydrogenation, 1, 2. Paper 3 described how bonded NFeB magnets of densities up to 98% of the theoretical maximum can be obtained through rotary forging of raw specimens to which PTFE has been added as a lubricant and binder. Paper 5 showed the salutary effect of tungsten doping upon coercivity and thermal stability in NdDyFeCB magnets. Paper 11 showed how flux stability in sintered NdFeB magnets can be consolidated by direct Joule heating. Paper 13 discussed how thermopower measurements were used to separate the effects of the different scattering mechanisms in RFeB compounds.

Papers 4 and 12 concerned systems of the Sm_2Co_{17} type. Paper 4 showed the effects of casting parameters and processing conditions on the microstructure and magnetic properties of sintered magnets, while 12 describes Mössbauer studies of SmCoC compounds that show how addition of small amounts of Ga, to these systems enhances thermal stability and axis anisotropy.

Papers 6-10 were on miscellaneous topics: magnetic properties of the compounds $RCO_{10}MO_2$, 6; anisotropic magnetic powder of PrFeB cast alloy, 7; magnetic hardening by crystallization of amorphous precursors through very fast heating, 8; anisotropy phase diagrams of YCo_4B-based compounds, 9; a theoretical discussion of magnetic viscosity and coercivity models, 10; and effects of additives on the properties of sheet Sr-Ba ferrite magnets, 22.

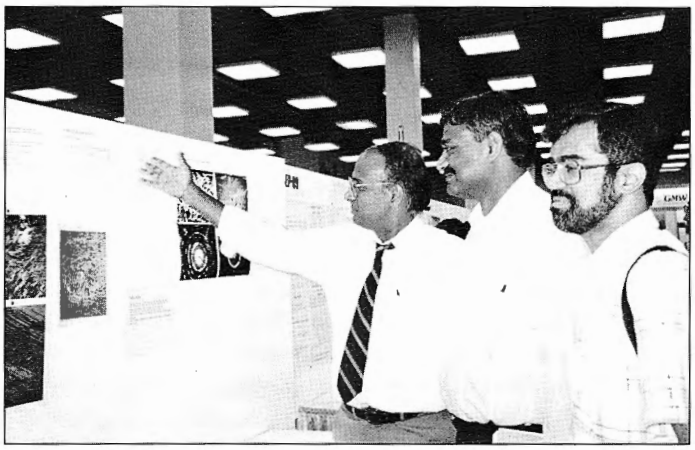
Of the applications papers, FR-14 investigates how field uniformity can be maintained in cylindrical magnetic structures even when they have finite length and are open at both ends as in MRI magnets. Fr-15 describes the geometries of closed spheroidal structures designed to afford maintenance of field uniformity when access holes must be drilled through the walls at specified locations. Paper 16 describes simplification of the construction of the structures of paper FR-15 from uniformly magnetized slabs of magnetic material.

Paper 17 and 18 describes methods of magnetic coupling for devices in which direct mechanical contact between certain parts is undesirable. They are especially applicable to measuring devices such as gas meters where frictional forces must be kept to a minimum for accuracy over a wide

range of measurement.

Paper 19 shows a method of accurate determination of PM synchronous motor parameters by digital torque angle measurements.

Papers 20 and 21 describe the theory of novel passive dI/dt limiters. The former describes a three material passive limiter and the latter the extended magnet used in that limiter.



FS - Spin Waves and Other Excitations

By Chair: Dr. Chester Alexander

The papers in session FS were a mix of theoretical and experimental descriptions of work on spin waves in ferromagnetic and superconducting materials. Four different papers in this session dealt with scattering of electromagnetic waves; (1) from spin fluctuations in non-saturated magnetic films (FS4), (2) from magnons in NdCuO (FS14), (3) from spin waves in MnF_2 (FS8), and (4) from magnons in FeSi films (FS15). There were four papers dealing with spin wave theory: (1,2) of self-localized surface spin waves (FS3, FS5), (3) of spin wave dispersion in Ni (FS9), and (4) of amplification and dispersion of spin waves in a ferrite-superconductor material (FS6). Paper FS12 was a presentation of experimental and theoretical studies of magnetostatic waves created by non-uniform magnetic fields in ferrite films, while paper FS7 reported the first observation of magnetostatic surface wave solitons in dipolar regimes. Peterman and Wigen described the control of chaotic oscillations produced in YIG films during high-power FMR experiments (FS10), and Garifullin, Goryunov and Khaliullin described how electron paramagnetic resonance studies of Er^{3+} were used to demonstrate long-range exchange interactions in the superconductor LaEr (FS11).

GA - Symposium on Tape Heads and Systems

By Chair: Thomas J. Beaulieu

This session consisted of five invited papers, of which only four were actually presented:

GA-01: Mark Jursich of Seagate discussed "Effects of Biasing Methods on the Performance of MR Tape Heads." He compared data for SAL and shunt biasing for single-ended and center-tapped operation. The SAL showed enhanced sensitivity and bias uniformity, but did suffer a bit in the center-tapped mode. No longitudinal stabilization was used.

GA-02: David Seagle of IBM discussed the "Design and Performance of a QIC-500 Thin-Film MR Tape Head," a joint effort between IBM and HDL to market a head for the 255 and 500 MB QIC application. Considerable technical data was presented on design, performance, durability, as well as various noise contributors to the overall signal-to-noise ratio. The head is SAL biased, and a proprietary pole-tip material is used for durability reasons.

GA-03: Hiroyuki Ohmori of Sony presented "A Thin-Film Head for HD-VCRs," describing a novel evolution of the well-known TSS head to a smaller, more magnetically efficient inductive head design for VHS, using a thin-film deposited coil to achieve the size reduction. Despite somewhat low Sendust permeability, this head was able to maintain flat output signal to 4 MHz for the single- layer core, and 12 MHz for the 3-layer core. Overwrite was good, and cross-talk for the double azimuth head was better than 30 dB when the gap-gap separation exceeded 350 microns.

GA-04: Peter Brew of Applied Magnetics presented a paper on "Thin- Film MR Tape Heads for QIC Tape Drive Applications: Current Trends and Future Directions." This paper was primarily a discussion of the many factors affecting the design of successful QIC tape heads, such things as backwards compatability, drive interchange, as well as numerous contributors which affect head-tape separation. Some time was devoted to discussing performance results for the 3010 and 3020 QIC heads (255 and 500 MB cartridges), operating at 22 and 44 kfci. A merged, SAL biased head was shown. It was stated that the move to separate read and write gaps, in the merged head, allows for independent optimization of the write and read functions.

GA-05: This paper by Fred Jeffers of Kodak was withdrawn.

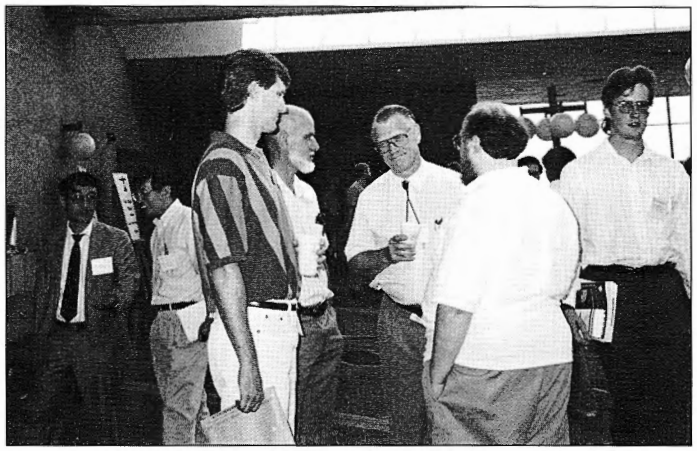
GC - Giant Magnetoresistance in Compounds

By Chair: R. Bruce van Dover

While a magnetic field has only a weak effect on the resistivity of most metals, there are some compounds in which the effect is dramatic. T. Kasuya (Tohoku Univ.) surveyed mechanisms leading to large magnetoresistances in materials with 4f electrons, emphasizing the role of critical scattering. He also pointed out the role of defect states, for example in $Eu_{.99}Gd_{.01}Se$. V. Sechovsky (Charles Univ., Prague) emphasized two general mechanisms that can lead

 (Continued on page 18)

to large magnetoresistance: suppression of spin fluctuations in band metamagnets (e.g., $RECo_2$) and the effect of changes in spin periodicity in conventional metamagnets (e.g., the layered compound UNiGa). He pointed out that the latter effect does not depend on the 2D layered structure, as qualitatively similar behavior is observed in UNiGe which has 1D chains. He also suggested that practical uses might be found for materials like FeRh, which has a ferromagnetic/antiferromagnetic transition somewhat above room temperature. R. von Helmholt (Siemens) and S. Jin (AT&T-Bell Labs) described recent measurements of $LaMnO_3$ thin films doped with alkaline earths. von Helmholt described the magnetic phase diagram, and reported the existance of a spin-glass-like regime in samples with Cu doping on the magnetic site. Jin reported values of $\Delta\rho/\rho$ as high as 1300 at 77K in a field of 60 kOe, and $\Delta\rho/\rho$ = 4.6% at room temperature and 1 kOe. Both speakers suggested that doped $LaMnO_3$ might be useful for some technological applications (though probably not for MR read-head sensors). H. Sato (Tokyo Metropolitan Univ, Tokyo) characterized giant magnetoresistance behavior in thin-film multilayers, emphasizing the need to collect data using a wide range of techniques (Hall effect, thermal conductivity, and thermoelectric power) in order to elucidate the mechanisms involved. The ultimate goal is to develop a continuous perspective that encompasses GMR in thin film multilayers and GMR in compounds.



GF - Magnetostriction I

By Chair: James R. Cullen, NSWC - White Oak (MD)

All of the papers of this session were devoted either to piezomagnetics, i.e., the development of strain under an applied magnetic field, or to the effect of stress on magnetic and elastic properties of magnetostrictive materials. Of the thirteen papers delivered, more than half were devoted to studies of the magnetoelastic properties of high-strain, rare-earth-iron alloys and compounds. There were reports of the performances of amorphous $(Tb,Dy)_xFe_{100-x}$ alloys as actuator devices; in particular a-$Tb_{40}Fe_{60}$ materials used in a bimorph cantelever device with a-$Sm_{35}F_{65}$ produced 500μm deflections at 1 kOe applied field (GF01, Honda et al.; see also Quandt, GF04). Interestingly, the Tb-DyFe amorphous films showed higher low-field magnetostriction, indicative of lower magnetic anisotropy, than Tb-Fe films. (See papers GF04, Quandt and GF05, Grundy et al.)

There were three papers which addressed, theoretically, the problem of non-uniform states of strain arising from magnetostriction. GF-03, (Arrott and Lee) discussed this in relation to magnetic domains in Fe whiskers; GF-08 (James and Kinderleher) presented a theory of structural domains in Terfenol D while GF-10 (de Simone) discussed the more general problem of strain microstructure in magnetic materials.

The effect that internal stress can have on the elastic and magnetic properties of highly magnetostrictive materials was illustrated by the paper of Clark et al. (GF07) on the elastic modulus of rare earth-iron eutectic alloys and Teter et al. (GF14) on the spiral-to-ferromagnet transition in Dy,Fe eutectic alloys.

Terfenol and terfenol-related compounds remain a popular topic; paper GF13 (T. Kobayashi, et al.) reports measurements of λ_{111} and λ_{100} in (Tb_xDy_{1-x}) $(Fe_{1-y}Mn_y)_{1.95}$. The λ_{100} constant increases with Mn content, a result which seems to reinforce the notion that only in (TbDy)Fe_2 Laves phase compounds is λ_{100} anomalously small.

A novel means of studying magnetostrictive processes in wires using STM (Scanning Tunneling Microscopy) was reported in GF02 (Costa, et al.). Results were correlated with magnetization measurements on the same samples.

Finally, we mention paper GF11 (Lim, et al.) which reported on the increasing magnetostriction of melt-spin ribbons of Dy-Fe-B with increasing Dy content.

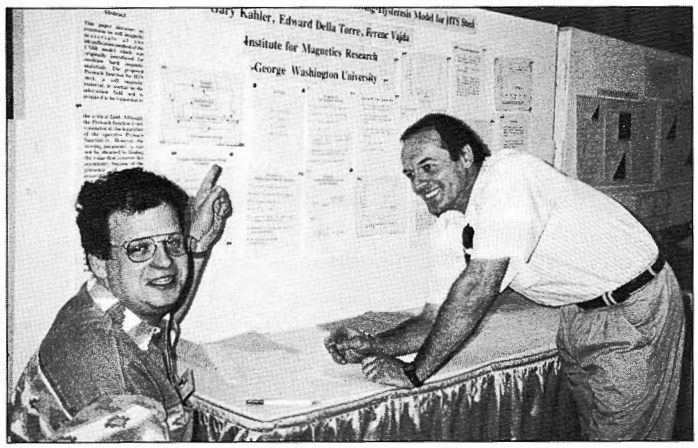
GP - Thin Film Recording Media III

By Chair: E. M. T. Velu, Carnegie Mellon Univ., ECE Dept., Pittsburgh, PA

In session GP, twenty one papers were presented on thin film recording media. Four of them were on perpendicular recording and the rest dealt with longitudinal recording media. Eight papers were on cobalt based alloy media, eight were on oxide media and one was about disk lubricant. Recent interest has been focused on developing media with multi-gigabit per square inch recording density. This demands thinner media (<30 nm) with higher coercivity (>2000 Oe) and near zero intergranular exchange interaction with a smooth surface and (head media) interface conducive for near contact recording. Many papers presented in this session address some aspects of this interest. A fairly new subject is the study of high coercivity rare earth transition metal alloy films. Three papers describing magnetic proper-

ties and microstructures of SmCo/X (X=Cr, V, Ti, & Cu) and SmFeN/Cr thin films were presented. Presence of nanocrystals of 2 to 5 nm in size well separated by columnar voids with a maximum coercivity of 4200 Oe for SmCo/Cr and 6000 Oe for SmFeN/Cr films were reported. A lot of interest was also shown in the high coercivity barium ferrite thin film media. Linear density (D_{50}), media noise, PW_{50} and SNR comparable to conventional cobalt alloy media were reported for barium ferrite media. Interesting microstructures showing in-plane and perpendicular magnetic anisotropy developed by laser annealing and post sputtering heat treatment were presented. There were also papers dealing with Cr seggregation in CoCr films and structure and texture changes in CoCr and CoNi thin films.

In perpendicular recording, improved sputtering methods for CoCr films and other alloy systems such as CoPt-O and Pd/Co multilayers were presented for high density recording. A linear density of 145 kfci with a large read back pulse amplitude for narrow track (12μin) was reported for Pd/Co multilayer media.



HD - Magnetic Multilayer Coupling III

By Chair: Alison Chaiken

Session HD, entitled "Magnetic Multilayer Coupling III," was remarkably lively and well-attended given that it occurred at the close of the conference. The principal theme of the session was non-Heisenberg interlayer exchange coupling in multilayers. The term "non-Heisenberg" refers to coupling that is not proportional to the cosine of the angle between adjacent magnetic moments. This unusual coupling results in a magnetic ground state where moments on adjacent ferromagnetic layers in a multilayer are neither parallel nor anti-parallel, but somewhere in-between.

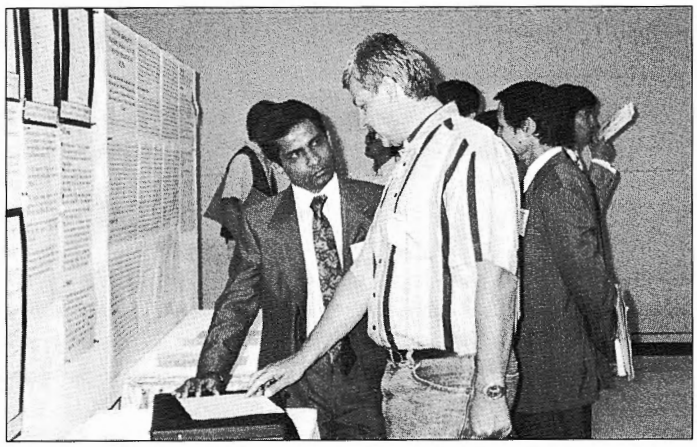
Talk HD-01 was presented by Mark Filipkowski of Naval Research Lab. He reported anomalous ferromagnetic resonance and magnetization measurements on FeCo/Mn/FeCo trilayers, and explained them with a newly minted theory by John Slonczewski of IBM Yorktown Heights. The second speaker was Ivan Schuller of UCSD, who put forward the idea that dipole coupling in multilayers with correlated roughness may give some non-Heisenberg contributions.

The third paper was an invited paper by John Anker of Missouri University Research Reactor. John's talk compared x-ray and neutron diffraction data, and established that "non-collinear" coupling is a rather common phenomena in magnetic multilayers. HD-04 was presented by Z. Tun of Chalk River, who demonstrated the existence of antiferromagnetic interlayer coupling in Co/Re multilayers.

HD-05 and HD-06 both treated the dependence of interlayer exchange coupling on the thickness of the ferromagnetic layer in multilayers. This same issue was also extensively discussed in the other sessions on magnetic multilayer coupling. HD-05 was a ferromagnetic resonance study presented by L. Zhou of Ohio State University, while HD-06 was a magneto-optic study of wedge samples presented by Pascal Bloemen of Eindhoven University of Technology.

HD-07 was presented by X. Meng of McGill University, who studied the effect of propagating roughness in NiCo/Cu multilayers using magnetization and magneto-optic methods. The final paper, HD-08, was presented by Jacques Miltat of Universite Paris-Sud. Prof. Miltat showed Kerr images of NiFe and Co films in a spin-valve, and showed that the domain patterns of films in the trilayer structure were significantly more complex than those of similarly prepared single films.

The topic of magnetic multilayer coupling (particularly non-Heisenberg contributions, dependence on ferromagnetic layers thickness, and across insulating spacer layers) was hotly debated in several sessions of the conference. We look forward to learning more next spring in San Antonio.



HQ - Soft Materials and Applications

By Chair: Craig A. Grimes

There was a great variety of topics in this session, ranging from new magnetic alloys to finite element analyses.

D.H.L. Ng, C.C.H. Lo and P. Gaunt used two models to determine the effect of bowed domain walls on the magnetic viscosity, which was then correlated with the coercive force. Y.S. Cho, Y.B. Kim, C.S. Kim, K.H. Lee, and T.K. Kim reported on the magnetic properties of (Fe,Co)-B-Al-Nb alloys with ultrafine grain structure. The soft magnetic properties lie between those of Metglas 2605S-3A and Metglas 2714A. They found an increase in the soft magnetic properties with annealing, the effect of which is reduced with increasing Nb content.

H. Tsujimoto, T. Kamei, and M. Yachida reported on the properties of a thin film transformer composed of a patterned CoNbZr thin film. The resonant frequency of the transformer changed in response to an applied bias cur-

INTERMAG-MMM '94 *(Continued on page 20)*

INTERMAG-MMM '94 *(Continued from page 19)*
rent, allowing for the possibility of a controllable band-pass filter in the GHz region. T. Yanada, T. Matsuda, O. Ichinokura, and T. Jinzenji, reported on the origin and control of electrical surge noise in tranformers. Their suggested method to reduce noise was to use the leakage inductance and stray capacitance of the transformer to make a filter. Y.T. Huang, W.B. Shu, and C.J. Chen reported on a finite element model able to design rotary transformers as a function of permeability of the core materials, and dimensions of the air gap.

D.H.L. Ng, C.C.H. Lo, S.C. Cheng, and J.P. Jakubovics presented their paper on the use of magnetoacoustic emission to determine the permeance of a given magnetic sample. For a fixed permeability, the thickness of the sample could be determined; for a fixed thickness, the permeability of the sample could be determined. M. Goktepe and T. Meydan reported on the possibility of using a toroid as a force transducer. For a toroid with linear BH characteristics, displacement of the loop could be correlated with applied force. The sensitivity of the toroid decreased with annealing of the specimen.

ENGINEERING EMPLOYMENT GUIDES AVAILABLE

As part of its employment assistance efforts for members, IEEE-USA has reprinted both editions of its popular two-volume *Employment Guide for Engineers and Scientists*. Subtitled "A Practical Job Hunter's Manual," the Guide covers all aspect of finding or changing employment.

One edition is written specifically for engineers and scientists who have employment experience. Containing information on salaries and solid advice on conducting a job search, this edition also provides assistance in writing resumes, working with employment services, networking with colleagues and friends, interviewing, evaluating the compensation package, coping with job loss, and knowing your legal rights in the employment process.

An alternate edition is written for students and contains basic information about how to conduct a job search. Special features include a list of the 50 most-asked questions during a job interview. The companion volume to both editions is a *Directory of Employers of Engineers*. Listing hundreds of companies by state, the *Directory* includes telephone numbers and contact persons.

IEEE-USA provides complimentary copies of the *Guide* to unemployed U.S. members above student grade. Put your request in writing, including your member number, and mail it to the IEEE-USA Office in Washington, D.C. These publications are also sold through IEEE's Service Center at a cost of $14.95 to members and $19.95 to nonmembers, plus tax and shipping, for either edition. To order, call (800) 678-IEEE and request IEEE Catalog No. UH0186-7 for the experienced engineer edition or UH0188-3 for the student edition.

ADDRESS UPDATES FOR '94 DISTINGUISHED LECTURERS

The Magnetics Society has selected three outstanding individuals to be the Distinguished Lecturers for 1994. They are James Daughton, who will talk on the phenomenon of giant magnetoresistance, Isaak Mayergoyz, who will talk on hysteresis modeling and Roger Wood, who will discuss signal processing in magnetic recording systems. In order to arrange for a talk by them for a Magnetics Society Chapter contact them directly.

Both James Daughton and Roger Wood have address updates since the January printing of the Newsletter and the fliers. Corrected addresses are given below.

James Daughton
Nonvolatile Electronics, Inc. (NVE)
11409 Valley View Road
Eden Prairie, MN 55344-3617
Tel: 612 829-9217
Fax: 612 829-9241

Isaak Mayergoyz
Electrical Engineering Department
University of Maryland
College Park, MD 20742
Tel: 301 405-3657
Fax: 301 314-9281
E-mail: isaak@eng.umd.edu

Roger Wood
IBM Corporation
P01/0282
5600 Cottle Road
San Jose, CA 95193-0001
Tel: 408 256-4131
Fax: 408 256-2653
E-mail: wood@sjevm13.vnet.ibm.com

IEEE FELLOW NOMINATIONS

The Fellow Nominating Subcommittee of the Magnetics Society has established a "clearing house" for nominations for the IEEE Fellow Awards.

If you intend to nominate a Magnetics Society member for this award, please let me know about it. Hopefully, this information will avoid duplication of effort and will prevent worthy candidates from being overlooked.

Fellow Nominating Subcommittee
% Richy Josephs
Innovative Instrumentation Inc.
220 Limestone Lane
Willow Grove, PA 19090

215-659-6719 (office)
215-646-3272 (factory voice/fax)

NEW IEEE-USA SERVICE PUTS ENGINEERING JOB OPENINGS ON THE INFORMATION SUPERHIGHWAY

WASHINGTON, Aug. 3 — Beginning this month, the U.S. Infobahn becomes a road connecting engineers with job opportunities all across the nation. The United States Activities division of The Institute of Electrical and Electronics Engineers Inc. (IEEE-USA) announced today an innovative electronic job-listing service designed to give IEEE members access to up-to-date information on employment openings.

For a nominal handling fee, employers of engineers and placement services can list job openings on the Internet via regional or national autoresponse files posted by IEEE-USA — which are accessible at no cost by IEEE members.

IEEE-USA's Employment Assistance Committee developed the new service to assist record numbers of unemployed members as well as those seeking career advancement. According to IEEE-USA Chairman Jean Eason, "A recent Institute survey revealed that 75 percent of our U.S. members either have access to the Internet, or will be connected within one year. We believe the information superhighway can be a very effective medium to increase job-seekers' opportunities without imposing an additional financial burden on them."

The service is designed for easy use by both employees and job-seekers. Employers, placement agencies and recruiters simply submit a form — which can be obtained and returned via diskette, fax or mail — listing specifics for each opening, along with a nominal handling fee of $10 per listing for employers, and $15 for placement services and recruiters. IEEE-USA will process and post listings on the Internet, by state, in any of six regional autoresponse files. A seventh file will include nationwide and outside the United States.

To gain access, job-seekers send an e-mail message to designated Internet addresses, and the requested files will automatically return to the individuals' e-mail addresses. Job listings will be continuously updated, and remain posted for 30 days, unless specified otherwise by the employer.

The following auto-response files have been established: for Region 1, info.ieeeusa.jobs.r01@ieee.org; for Region 2, info.ieeeusa.jobs.r02@ieee.org; for Region 3, info.ieeeusa.jobs.r03@ieee.org; for Region 4, info.ieeeusa.jobs.r04@ieee.org; for Region 5, info.ieeeusa.jobs.r05@ieee.org; for Region 6, info.ieeeusa.jobs.r06@ieee.org; and for nationwide and outside the United States, info.ieeeusa.jobs.other@ieee.org. IEEE members who do not have Internet access can obtain files through their local Section officers, PACE representatives or Student Branch officers.

For more information on the new service, or for employer job-listing forms, contact William R. Anderson of IEEE-USA at 1828 L Street, NW, Suite 1202, Washington, DC 20036, 202-785-0017 (telephone), 202-785-0835 (fax), or w.anderson@ieee.org (e-mail).

IEEE-USA INTRODUCES NEW CAREER MAINTENANCE SERVICES

WASHINGTON, June 15 — With engineering unemployment near an all-time high, the United States Activities division of The Institute of Electrical and Electronics Engineers Inc. (IEEE-USA) has introduced a series of new career maintenance services for U.S. members: a job referral agency, an alliance of consultants' networks, and a special services discount.

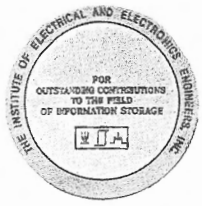
IEEE-USA has contracted with JOB BANK USA to offer an inexpensive job referral service that provides a state-of-the-art, computerized resume data base with a large, national client base of employers. To join, an IEEE member submits a one-page enrollment form and up to two current resumes, creating an individual electronic career record. When JOB BANK USA receives employment openings, its computer identifies qualified applicants, who are then informed of available positions. If applicants are interested in the openings, their resumes are forwarded directly to the employers.

The service includes maintenance of the personalized career record for one year, a quarterly newsletter, a toll-free telephone number for updates to the record, and unlimited referrals to JOB BANK USA clients. For information and costs, members can call 800-296-1872 and indicate IEEE affiliation.

Further, a newly-formed Alliance of IEEE Consultants' Networks (AICN) will coordinate the development of IEEE's rapidly growing local consultants' networks. Networks serve their primarily self-employed members with speakers, newsletters, membership directories and client referral services. At the national level, AICN will establish a data base of IEEE consultant-members, develop tutorials, publish a newsletter, and produce standards and guidelines for legal documents related to self-employment. Interested members can contact AICN through IEEE-USA at 202-785-0017 to request a copy of "How to Start A Local Consultants' Network," the list of local networks, and the membership list of AICN's national coordinating committee.

In addition, all IEEE members are now eligible for a 10-percent discount on most services at Kinko's, including computer rental, resume creation, typesetting, fax and printing. The newly-expanded discount was originally negotiated by IEEE-USA's Employment Assistance Committee for unemployed members. To receive the discount, members must show their IEEE membership cards. Members can telephone 800-743-COPY for Kinko's locations.

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

NEW IEEE-USA BOOKLET EXPOSES FLAWS IN U.S. PENSION SYSTEM

WASHINGTON, Aug. 3 — A new publication by the United States Activities division of The Institute of Electrical and Electronics Engineers Inc. (IEEE-USA) describes several major flaws in the U.S. voluntary private pension system. *Six Threats to Your Retirement Income Security,* the latest edition of IEEE-USA's Professional Guidelines series, seeks to educate Institute members about important pension policy issues and involve them in IEEE-USA's continuing efforts to promote pension reform legislation.

In addition to presenting an overview of the U.S. private pension system, the booklet outlines the following threats to retirement security: limited coverage and failure to vest; integration of private benefits with Social Security; lack of portability from defined benefit plans; underfunded and overfunded plan terminations; early retirement; and insurance company insolvencies.

IEEE-USA will distribute the publication to Members of Congress and other national groups. Institute members and others can obtain a copy by contacting Marilyn Sumpter of IEEE-USA at 202-785-0017 (phone), 202-785-0835 (fax), or ieeeusa@ieee.org (e-mail).

IEEE UNITED STATES ACTIVITIES 1995 EXECUTIVE FELLOWSHIPS CALL FOR APPLICATIONS

NOTICE: IEEE-USA and its U.S. Competitiveness Committee seek candidates for one-year Executive Fellowships beginning in January 1995. Executive Fellows will assist the Under Secretary of Commerce for Technology in the U.S. Department of Commerce's Technology Administration. The Under Secretary will determine the Fellows' specific responsibilities.

PURPOSE: The program, supported in part by the Alfred P. Sloan Foundation, seeks to make practical contributions to U.S. competitiveness. The Executive Fellows provide a resource of industrial experience and scientific and technical knowledge to key government policymakers, and help to broaden the perspectives of both the professional and governmental communities on the value of such interaction.

CRITERIA: Applicants must demonstrate the following:

- U.S. citizenship, and IEEE membership at Member Grade or higher for at least four years;
- Technical competence and senior management experience in industrial R&D, electronics, manufacturing technologies or related fields;
- Strong interest and experience in applying technical knowledge to the formulation of policies that enhance U.S. technological competitiveness; and
- A history of service to the profession.

STIPEND: The Executive Fellowship will provide a stipend of $24,000 for living and moving expenses during the fellowship tenn. Fellows, or their employers, will be responsible for salaries and all other expenses.

APPLICATION: For further information and application forms, contact Chris J. Brantley at 202-785-0017 (telephone), 202-785-0835 (fax) or c.brantley@ieee.org (e-mail); or write to the Secretary, Executive Fellowship Program, IEEE United States Activities, 1828 L Street, NW, Suite 1202, Washington, DC 20036-5104.

Application Deadline: October 3, 1994

BOOK REVIEW

Applied Magnetism, ***edited by Richard Gerber, C.D. Wright, and G. Asti (Kluwer Academic Publishers, The Netherlands, 1994).***

Reviewed by Ami Berkowitz
Physics Department and
Center for Magnetic Recording Research
University of California, San Diego

NATO Advanced Study Institutes (NATO-ASI) generally offer splendid opportunities to soak up sun and scientific lore in proportions determined by the participants. The book under review is the product of a course entitled **Applied Magnetism** held in Erice, Sicily, Italy in July, 1992 as a NATO-ASI. If the course was as good as this book, the attendees were fortunate, indeed. The general subject of applied magnetism has never been covered so completely, nor as well. There are ten chapters whose titles and authors are as follows:

The Physics of Magnetic Recording - H. Neal Bertram
Magnetic Information Storage - Mark H. Kryder
The Magnetic Properties of Fine Particles - R.W. Chantrell and K. O'Grady
Magnetic Separation - Richard Gerber
Domains and Domain Walls in Soft Magnetic Materials, Mostly - J. Miltat
Permanent Magnets - G. Asti and M. Solzi
Magnetoresistance - D.J. Mopps
Thin Film Magneto-optics - P.H. Lissberger
Microwave and Optical Magnetics - Daniel C. Stancil
A Scientific Basis for Computational Magnetics - Peter P. Silvester

The authors of the chapters have all made significant contributions to their respective topics. The focus of each chapter is the current status of the field. However, in each case the subject is developed with sufficient depth to make a newcomer comfortable. The chapters are uniformly well written, bibliographies are very adequate, and there is a very useful index. Applied magnetism is one of the powerhouses of modern technology and this volume is the best introduction available to this field.

A volume like this was sorely needed, and I think future revised editions should be considered. If this happens, I have two suggestions. Firstly, it would be useful to have a discussion of amorphous materials in particular, and more on soft magnetic materials in general (e.g. ferrites). Secondly, perhaps a dozen pages or so on general magnetic principles could be incorporated. An ideal place would be in Bertram's chapter. These comments, however, only suggest how to make an excellent book even better. It is a pleasure to recommend this volume to anyone entering or already working in applied magnetism.

PHILADELPHIA PERMANENT MAGNETS MEETING

By Professor Bryen E. Lorenz

The annual, day long gathering of the Philadelphia Permanent Magnets Meeting (PPMM '94) was held on May 26 and hosted by the University of Pennsylvania. PPMM '94 was cosponsored by the Magnetics Chapter of the Philadelphia Section of IEEE, along with YBM Technologies of Hatboro, Pennsylvania. The meeting was broken down into a morning session chaired by Dr. Charles Graham of the University of Pennsylvania and an afternoon session chaired by Dr. Bryen Lorenz of Widener University.

Port Wheeler, of Wheeler Associates (Elizabethtown, KY), began the meeting with an overview of the research and development outlook for permanent magnetic materials and applications worldwide. S.G. Sankar, of Advanced Materials Corporation (Pittsburgh, PA), covered several new advances in his talk, "Permanent Magnet Materials and their Applications." This theme continued in the afternoon with two talks, the first entitled "Recent Developments in Novel Permanent Magnet Materials," given by George Hadjipanayis, of the University of Delaware, and the second entitled, "Increasing Maximum Energy Product in Permanent Magnets," presented by Bao-Min Ma, of Rhône-Poulenc Corporation (Cranbury, NJ). Dale Ostergaard, of Swanson Analysis Systems, rounded out the afternoon with a discussion covering "Finite-Element Analysis of Magnetic Fields using the ANSYS Program."

Several dozen individuals attended the meeting representing a broad mix of suppliers, manufacturers and academics from the local area. This marks the third time that this event has been held, with plans for the next meeting already underway. The organizers of PPMM '94 would like to give special thanks to YBM Technologies for their generous financial and clerical support.

IEEE-USA ANNOUNCES NEW JOB REFERRAL SERVICE

In conjunction with one of the nation's premier employment data base companies, IEEE United States Activities (IEEE-USA) is introducing a new, inexpensive job referral service for members and their families. JOB BANK USA's Career Advancement Service combines a state-of-the-art computerized data base with a large, national client base of employers.

To join, members submit a one-page enrollment form and up to two current resumes, creating a personalized electronic career record. When JOB BANK USA receives employment openings, its computer identifies qualified applicants; then the Service telephones to inform them of the available position. If applicants are interested in the opening, their resumes are forwarded directly to the employer.

The Career Advancement Service includes maintenance of the personalized career record for one year, a newsletter, a toll-free telephone number for updates and changes to the record, and unlimited referrals to JOB BANK USA clients. For more information and costs, call (800) 296-1872 and indicate IEEE affiliation.

IEEE MAGNETICS SOCIETY NEWSLETTER CONFERENCE CALENDAR

SEPTEMBER 11-15, 1994

13th International Workshop on Rare-Earth Magnets and their Applications and 8th International Symposium on Magnetic Anisotropy and Coercivity in Rare Earth-Transition Metal Alloys

I. R. Harris, School of Metallurgy and Materials, The University of Birmingham, Edgbaston, Birmingham B15 2TT, UK,
TEL: (44) 21 414 5165, FAX: (44) 21 471 2207

OCTOBER 20-21, 1994

1st IEEE Workshop on Environmentally Conscious Manufacturing for the Electronics Industry
IBM, T.J. Watson Research Center
Yorktown Heights, NY, USA

Jeff Gelorme, IBM, T.J. Watson Research Center, P.O. Box 218 (16-204), Yorktown Heights, NY 10598, TEL: 914 945-3430, FAX: 914 945-4013

OCTOBER 24-25, 1994

Soft Ferrite Users Conference
Chicago, IL.

Magnetics Materials Producers Association, 11 S. LaSalle Street #400, Chicago, IL 60603, TEL: 312 201-0101, FAX: 312 201-0214

APRIL 18-21, 1995

INTERMAG 95
San Antonio, TX.

Diane Suiters, Courtesy Associates, 655 15th Street NW, Suite 300, Washington, DC 20005, TEL: 202 639-5088, FAX: 202 347-6109

JULY 17-19, 1995

6th International Conference on Magnetic Recording Media, (MRM)
Oxford, UK.

MRM 1995, The Institute of Physics 47 Belgrave Square,
London SW1X8QX, UK, TEL: +44 71 235 6111, FAX: +44 71 823 1051,
E-Mail: IOPCONF@ULCC.AC.UK

SEPTEMBER 17-20, 1995

International Symposium on Non-Linear Electromagnetic Systems (ISEM)
Cardiff, Wales, UK.

ISEM 95 Secretariat, Cardiff School of Engineering,
University of Wales College of Cardiff, P.O. Box 917, Newport Road,
Cardiff CF2 1XH Wales, UK, TEL: +44-222-874070,
FAX: +44-222-874420