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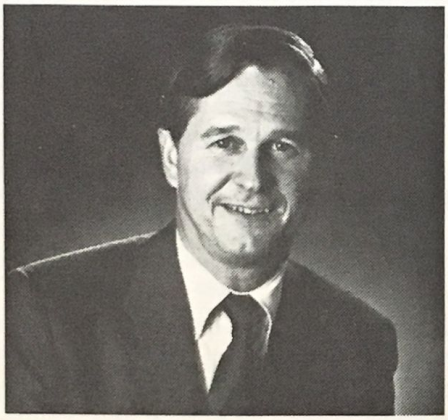
CRAIG PERLOV, EDITOR

Magnetic Technology in Japan

R. M. White



R. M. White

In 1983 the Office of Science and Technology Policy (OSTP) encouraged the Commerce Department to establish a Japanese Technology Evaluation Center (JTEC) to provide a shared public understanding of Japanese research and technology; to advise Federal decision makers on possible cooperative research programs; and to provide information in support of private industrial research and development. This program is now being managed by the National Sciences Foundation. To implement its mission JTEC carries out studies of topics suggested by its participating agencies such as DOC, DOE, NASA, etc. Such a study has recently been carried out on Advanced Computing. This study included all aspects of computing *including* data storage. The panel consisted of six members who spent one week in Japan last November visiting various institutions. Robert M. White represented the data storage component of this study. The panel's observations were presented at a workshop at the National Sciences Foundation on December 8. The following is the "Overview" from R. White's contribution to the JTEC report.

(continued on Page 2)

1989 MMM CONFERENCE

Boston, Massachusetts

November 28 - December 1, 1989

The 34th annual conference on Magnetism and Magnetic Materials (MMM) was held in Boston last month. The chairman's conference summary was not prepared at the Newsletter press time, but the session summaries are included in this issue. There were forty-eight sessions including symposia on Magnetic Aspects of High Temperature Superconductivity, Dilute Magnetic Semiconductors, Computational Magnetics from First Principles, New Facilities and Techniques in Magnetism and Magnetic Coupling Through Chromium.

(Session Summaries begin on Page 5)

JAPAN (continued)

OVERVIEW

If one steps back and looks at the recording activities in Japan one observes several things. First of all, most of the industrial research appears to be focused on near-to-medium term issues. One exception is NTT which has a photon-echo storage project which is indeed a long-range concept (I noticed they recently published a Phys. Rev. Letter on this work.) In the U.S. we see more adventurous research such as the holographic storage at MCC, or the attempts to exploit the high resolution of scanning tunneling microscopy. NEC continues to pursue the Bloch line memory, which has revolutionary potential. But I view this as an extension of magnetic bubble technology. An interesting indication of the scientific vitality in the U.S. is the development of the technique known as SEMPA, which stands for Scanning Electron Microscopy with spin Polarization Analysis. The U.S. National Institute for Standards and Technology (NIST) has done a great deal towards making this technique practical. Electron miscroscopy provides one with sub micron resolution. The spin polarization enables one to measure the magnetization with the same resolution. Since recording wave lengths are already in the submicron range such a technique should prove invaluable for understanding the recording process. Yet, except for Hitachi, there are no SEMPA instruments in the companies I visited. However, except for IBM, no U.S. companies possess this capability either. But it does exist at the following universities: MIT, Stanford/IBM, CMU, U. of Minnesota (Honeywell/CDC)

There are very few universities in Japan that offer training in the field of recording. When asked about how their technologists are trained, most said that it is done "on the job" by the company.

In fact, many of the "researchers" do not have PhDs. The American graduate research university is an engine with enormous potential. One only has to look at what it did for biotechnology. It is certainly not being effectively utilized to support the U.S. recording industry.

Another observation is the fact that all the Japanese companies that offer storage devices are (1) vertically integrated, (Fig. 1) and (2) have substantial research efforts (50 to 100 people) that encompass all the options (Fig. 2).

	Futjitsu	Hitachi	NEC	Sony	Matsushita	Toshiba
Disk Drives	X	X	X	X	X	X
Tape Drives	X	X	X	X	X	X
Disks	X	X	X	X	X	X
Tapes				X	X	X
Heads	X	X	TF MIG	TF	X	X
M-O Drives	X	X	X	X	X	
M-O Media	X	X	X	X	X	
Lasers		X	X	X	X	

Figure 1

	Futjitsu	Hitachi	NEC	Sony	Matsushita	NTT
Metallic Media	X	X	X	X	X	X
Barium Ferrite		X		X	X	
M-O Media	X	X	X	X	X	X
Phase Change		X	X		X	X
MR Heads	X	X	X	X	X	
Tri-bology	X	X	X	X	X	X
Air Bearings	X	X	X	X	X	X
Coding	X	X	X		X	X
VerticalRecording	X	X	X	X	X	X
SEMPA		X				
STM		X	X		X	

Figure 2

The IEEE Magnetics Society Newsletter is published quarterly by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017. The objective of the Newsletter is to publicize activities, conferences, workshops, and other information of interest to the membership of the Society and technical people in the general area of applied magnetics. Copy is solicited from the S-Mag membership, organizers of conferences, officers of the Society and local chapters, and other individuals or organizations with potentially relevant material. Copy should be sent to Dr. C. M. Perlov, Hewlett-Packard Labs, MS-2U, P.O. Box 10490, Palo Alto, CA 94303.

One of the aspects of vertical integration that struck me was the ability of each company to prototype systems in order to evaluate the components. Take Fujitsu's "Hero" drive, for example. It's not clear whether there's a real market for this "optical RAMAC", but they have a drive that's beta-test quality. In the U.S. we have excellent university research efforts in magnetic modelling, tribology, encoding, thin films, etc. And, as we mentioned above, we have numerous venture-capital-funded component sources. But we have no mechanism for integrating these technologies into real systems. IBM is the only organization with this capability. This observation would suggest that the U.S. recording industry consider complimenting one of its university recording centers with the capability to prototype complete systems. This might be done in conjunction with an advanced manufacturing engineering program, which some universities are beginning to consider.

In comparison to Japan, only a few U.S. system companies are vertically integrated (Fig. 3) in recording. Ordinarily, vertical integration becomes finacially advantageous when one's volumes exceed some level. One can then reinvest the savings in new technology, further enhancing one's technical edge. Vertical integration also has the potential of being more efficient. U.S. component suppliers, for example, complain of being misled by drive manufacturers who "multiple-order". Such practices are more easily controlled by vertical integration. If one has access to a strong vendor base then one can compete with vertical integration. However, the U.S. component suppliers are neither numerous or healthy.

	IBM	AT&T	DEC	Unisys	HP
Disk Drives	X		X	X	X
Tape Drives	X		X	X	X
Disks	X		X	X	X
Tapes				X	
Heads	X		X	X	
M-O Drives	X				
M-O Media	X				
Lasers					

Figure 3

In terms of covering alternative options, I found the Japanese *all* preparing for the eventual transition to perpendicular recording in rigid disk systems. They are seriously targeting flying heights below 0.1 micron. Most U.S. manufacturers regard perpendicular recording as too long range. As we mentioned above, U.S. drive manufacturers tend to rely on head and media suppliers for their components. There are very few sources of perpendicular media or heads in the U.S. Most of the major Japanese drive companies are developing in house expertise with perpendicular CoCr films.

Another "option" under development by nearly all the Japanese companies I visited is reversible optical storage. This is generally magneto optic, although Matsushita is no longer the only one looking at phase change media. Hitachi, for example, claims to have found a fast crystallizing material suitable for single beam overwrite. Again, vertical integration assures these efforts with their own state-of-the-art solid state lasers. Optical storage has been a long time coming. Part of the reason for this has been the lack of standards. As a result, one of the advantages of optical storage, its removable media, becomes a disadvantage. However, once magneto optical systems achieve data rates and access times comparable to magnetic systems the fact that they are not plagued by the low flying height requirement will make them very attractive. The level of U.S. effort in this technology is woefully inadequate, considering its potential.

To summarize, I feel that the U.S. recording industry will find it increasingly difficult to compete in the next one, and certainly two, generations of products. The failure to make significant R&D investment now will mean less familiarity with the technology later, increasing the likelihood of design errors. Unless U.S. companies take a longer term view and improve their utilization of the university research community I predict that the Japanese will eventually dominate data storage devices. The existing university recording efforts, in order to survive will be tempted to admit Japanese sponsors who have demonstrated that they are effective at transferring technology. The result will be that the research community will receive strong, long term support, the consumer will receive high performance storage, but the U.S. will have lost another high technology industry segment.

EUROPEAN COOPERATIVE FOR MAGNETIC STORAGE RESEARCH

Roy Chantrell

Last April, a European research program called "Community Action on Magnetic Storage Technology" (CAMST) was started. This is a cooperative research effort in which 17 European University laboratories investigate magnetic and magneto-optic recording. The activities of CAMST include the exchange of young scientists between laboratories, joint research projects and several meetings.

CAMST is a project supported by the European Community through the Stimulation Exercise (now termed Science) program. The Science program is in a sense a recognition of the fact that Europe has a pool of scientists whose efforts are somewhat dissipated by lack of communication. What is at stake according to the Science program is a 'European scientific action space' in which academic research can develop in parallel with, and in support of, industrial research and development program, is a framework for the establishment of collaborative research projects, by means of:

- Provision of salaries for young scientists,
- Support for travel and exchange of personnel,
- Provision of capital equipment.

Because of its origins the CAMST program places the highest priority on collaboration, the majority of the funding being used in support of exchanges and salaries for young scientists. The project is structured so that many young scientists for whom funding is provided will carry out Ph.D. programs based in more than one laboratory. This, and the accent on communications, of which READ/WRITE forms a part, is expected to promote the coordination of the future European research effort.

It is not enough, however, to support academic research in isolation. Much of the proposed research has been formulated with industrial needs in mind, and it is expected that the project will evolve in consultation with industry. The positive contributions from industrial participants at the first general meeting in Regensburg give rise to the hope that the consultive process will considerably enhance the prospects for the CAMST project.

At the heart of CAMST is a research project which we believe to be challenging and stimulating. No doubt the form of the project will change with experience, but the present involvement of laboratories having proven expertise in a wide range of areas, coupled with the expected addition of further participants during the course of the research, leads to the confident prediction that CAMST can make a significant contribution to research in magnetic recording. It is not unreasonable to anticipate a very exciting three years!

CALL FOR MAGNETICS SOCIETY ACHIEVEMENT AWARD

The Magnetics Society honors one of its most outstanding members each year for his or her scientific, technical or service contributions to the Society. The award consists of a prize of $2,000 and a diploma to be presented at the Intermag Conference.

Past award winners: Fred Luborsky, 1981; Herb Storm, 1982; Harold Lord, 1984; Joe Suozzi, 1985; Fritz Friedlaender 1986; Andrew Bobeck, 1987; Floyd Humphrey, 1988; and Paul Biringer, 1989.

Nominations are invited for the 1990 award to be presented at the Brighton Intermag Conference in April 1990. Any member of the Magnetics Society may nominate a candidate. The nomination should be accompanied by a curriculum vitae and a statement of the candidate's contributions. Nominations should be sent before February 10, 1990 to:

Dr. Fred E. Luborsky
Chairman, Achievement Awards Comm.
G. E. Corporate R&D
P.O. Box 8
K-1, 1C36
Schenectady, NY 12301

SESSION SUMMARIES

Session AA
Magneto-Optic-Optic Recording
Martin Chen

Thirteen papers (one invited) were presented in this session. Direct overwrite of rare earth-transition metal (RE-TM) media received most attention; it being the subject of the invited talk and six contributed papers. Three papers dealt with non-RE-TM media: Co/Pt and Co/Pd multilayers, and garnets. The remaining three papers were about various studies of RE-TM media.

C.J. Lin (IBM) reviewed considerations behind single-layer direct overwrite media and exchange-coupled multilayer direct overwrite media. While single-layer media have simplicity, practical performance levels have only been achieved with multilayers. The limits of coil-power consumption and field switching speed in bias-field modulation direct overwrite were also discussed in this invited talk. T. Fukami et al (Mitsubishi Electric) demonstrated direct overwrite in exchange-coupled media in which the initializing magnet is replaced by a permanently magnetized layer. The permanent layer is separated from the reference and the memory layers by a switching layer, resulting in a quad layer disk structure. This is an exciting new development which significantly simplifies drive design, albeit at the expense of a more complex disk. Direct overwrite results using single layer films were presented by three groups. T. Shimizu et al (IBM) showed disk-level, direct overwrite results on TM-rich RE-TM films. S. Hashimoto et al (Fujitsu) studied erasing on a disk using high frequency pulses instead of a continuous beam. Their method simplifies direct overwrite using a two-beam optical head. T. Nihara et al (Hitachi) obtained interesting, but unexplained, non-monotonic dependence of domain size on writing energy for coupon samples of $Tb_{24}Fe_{65}Co_{11}$ films. The result can potentially be exploited for direct overwrite. It is readily apparent that these single-layer direct overwrite approaches are still far from being practical. T.W. McDaniel and M.R. Madison (IBM) compared experimental and modelling results on noise under recording conditions of insufficient bias field, as might be encountered during field modulation direct overwrite.

S. Hashimoto, Y. Ochiai and K. Aso (Sony) studied Co/Pt and Co/Pd multilayers and reported that for total film thickness below 200 400Å, square Kerr loops with $\theta_k \gtrsim < 0.25°$ are obtained (resulting in 53dB CNR). M. Alex et al (Fujitsu) reported that $Ce_xD_{y3-x}Ga_yFe_{5-y}O_{12}$ films have suitable MO properties for recording using (near IR) diode lasers. They found a very sensitive dependence of T_{comp} of the film to the background pressure of the deposition system. Suzuki et al (IBM) compared crystallization of Bi-substituted garnet films through rapid, post-deposition thermal annealing and through in-situ annealing during deposition. Rapid thermal annealing was found to yield better MO properties.

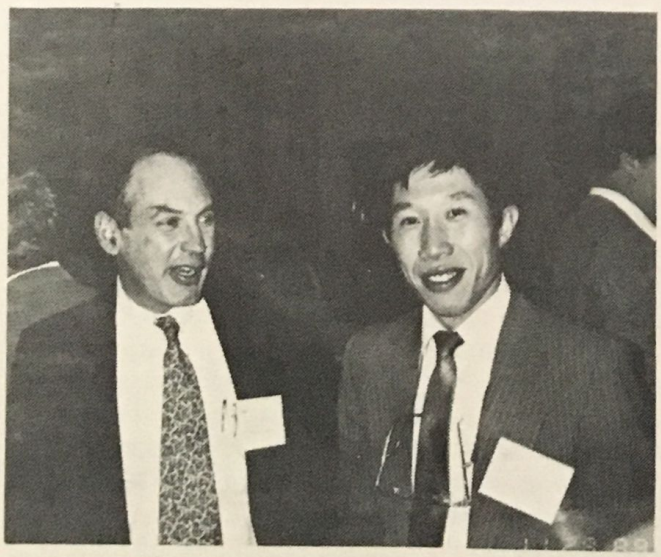
M. Aeschlimann et al (ETH Honggerberg) investigated the kinetics of domain formation by detecting the spin polarization of photo electrons released by 16ns-long, excimer laser writing pulse. Depending on whether the sample is held above or below its compensation temperature, different switching speeds were observed. The result is interpreted as being caused by a difference between the lattice and the spin temperatures. W.A. Challener and S.L. Grove (3M) measured the MO properties of a range of TbFeCo alloys and concluded that the Tb contribution to the MO activity is about 5%. Some inadequacies of the mean field model were noted. C.M. Perlov, E. Della Torre and H. Birecki (HP) contrasted modelling of the writing process using the cell and the bubble models. They noted that while both models can produce comparable results, the cell model fails if cooperative spin-flip is important and the bubble model is not suitable when a complex domain pattern is formed.

Session AC
Magnetism of Small Particles
Ami E. Berkowitz

This lively session consisted of an interesting mix of theoretical and experimental papers that reflected increasing activity in this field. A range of preparation techniques were represented: Linderoth and Morup (01) described the preparation of amorphous FeB particles by borohydride reduction. Borohydride reduction was also used by Nafis et al (03) to synthesize FeNiB particles. The influence of Ni was discussed. Papaefthymiou et al (07) prepared Fe particles by evaporation of Fe under Ar. These particles had an Fe_3O_4 coating which appeared to be superparamagnetic at room temperature. At temperatures below the Fe_3O_4 blocking temperature, a large H_c was attributed to interaction of the Fe core with the Fe_3O_4. Shull et al (08) described composites of Fe in silica gel prepared by polymerization. Depending on treatment with H_2 or O_2, a wide range of compositions and properties were obtained. Linderoth and Morup (10) reduced Fe^{2+} in a sodium amalgam. Mossbauer

data showed a (surprising) influence of Hg on the Fe atoms at the surfaces of the Fe particles produced. Arajs et al (11) prepared Co particles in a wide range of sizes by precipitation from solution. Yiping et al (12) also prepared Co particles, but used Li to reduce Co halide solutions. In all these papers, a rich variety of properties were shown to depend on size, composition, homogeneity, etc. Yamaguchi et al (09) discussed linear chain clusters produced by drying in an applied field water based ferrofluids to which PVA was added. Magnetic and optical polarization measurements reflected the symmetry of these chains. Kreuger et al (02) reported on small angle neutron scattering from the 400-500 Å cubic magnetite particles found in bacteria. A puzzling result was the evidence for dynamic spin correlation lengths of 50 Å.

A variety of theoretical problems were discussed. Chen and Fredkin (04) demonstrated how the continuous variation of magnetization for fields in excess of the critical field for curling depends on the ratio of particle size to the classical domain wall thickness. Dean et al (05) discussed the remanent magnetization developed in an assembly of single domain particles on applying and decreasing an a.c. field. The importance of the existence of three unequal axes for this gyroremanent behavior was stressed. Lin et al (06) described their calculations of the behavior of nano-dimensional groups of Fe, Ni, and Co atoms. Klik and Gunther (13) calculated thermal relaxation in particles starting with a Fokker-Planck relation for the magnetization orientation distribution.



Session AD
Superconductivity
J. D. Thompson

Fifteen talks on aspects of magnetic behavior in high temperature superconductors and related Cuo_2 layer compounds were presented in Session AD. Approximately two-thirds of these addressed questions of copper or rare earth magnetism in $YBa_2Cu_3O_7$, $ErBa_2Cu_3O_7$, La_2CuO_4, Nd_2CuO_4 and $Sr_2CuO_2Cl_2$ compounds through Mossbauer spectroscopy, neutron scattering and magnetization measurements; whereas, the remainder were concerned with the static and dynamic responses of the flux line lattice in high temperature superconductors. Just a few highlights of this session include: the observation by Saitovitch et al that Fe may segregate to twin boundaries in Y123 under certain annealing conditions; Ar annealing raises T_c by 5-7 K in Fe doped Bi 2212 (Tang et al); the report by Lynn et al that a 2D Ising model accurately predicts the Er order parameteer variation in Er123 below $T_N \simeq 0.6$ K; the finding by Filipkowski and Budnick of a bulk spin glass transitiion in vacuum annealed $La_{1.98}Sr_{0.02}CuO_4$; an ordered copper moment of $0.49\mu_B$ (Loong et al); and the observation by Flippen and Askew of a strong frequency dependence to the magnetic irreversbility line in BiSrCaCuO crystals that is absent in YBaCuO crystals.

Session AP
Hard Magnets I
Frederick E. Pinkerton

Poster session AP on Hard Magnets comprised papers on a variety of topics: intrinsic magnetic properties of hard magnetic phases, properties of magnets fabricated by melt-spinning or sintering, and theoretical and experimental studies of domain wall pinning. Reflecting the continued scientific and technological interest in Nd-Fe-B magnets, the majority of the papers were on $R_2Fe_{14}B$ materials. These were complemented by several papers on other magnet materials.

One of the most intriguing papers was that of Otani et al. They reported evidence that some preferential alignment can be obtained in melt-spun Nd-Co-B ribbons when amorphous ribbons are annealed in the presence of a magnetic field. Unlike Nd-Fe-B, the Curie temperature of Nd-Co-B is above its crystallization temperature, providing a mechanism for magnetic alignment during crystal-

lization. Unfortunately, Nd-Co-B is planar rather than axial at the crystallization temperature. In another paper on melt-spun material, Brett et al reported successfully compacting Nd-Fe-B ribbons by rotary forging, and obtained some alignment via this process.

Three related papers dealt with domain wall pinning. Hadjipanayis made direct TEM observations of wall pinning in $Sm(Co,Ni)_5$ melt-spun alloys, while a strong pinning theory for $Sm(CoNi)_{2.5}$ was given in a poster by Chen and Gaunt. Weak pinning in FeCu alloy was discussed in a poster of Ng and Gaunt.

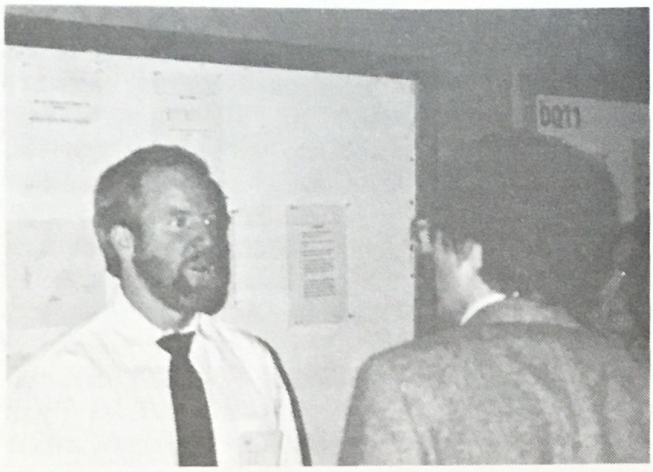
The relationship between degree of alignment and remanence in sintered Nd-Fe-B magnets was explored in a paper by Kawai et al, who found that the remanence agrees well with that predicted from the alignment as measured by x-ray intensity data. Otani et al discussed the origin of the low temperature Barkhausen jumps observed in sintered Nd-Fe-B and Sm-Co magnets. Mazany and Dickens successfully protected magnets from salt corrosion by applying an anticorrosion coating. Mossbauer spectroscopy on sintered Nd-Fe- B magnets was used by Diao et al to try to extract preferential site occupation by Mo and W substituents. High remanence hard ferrites were fabricated by Evans and Thompson by using high purity starting materials.

Four papers focused on intrinsic magnetic properties. Spin reorientation transitions were studied using ac susceptibility measurements in $Er_{1.5}Nd_{0.5}Fe_{14-x}M_xB$ (M=A1, Co) by Malik et al, while NMR was used by Jedryka et al to study the canting angle and local anisotropy in $Nd_2(Co,Fe)_{14}B$ in the low temperature conical moment state. Crystallographic and magnetic data on R-Fe-carbides were presented in a poster by Feng and Wen-wang. Czjzek et al employed Yb Mossbauer to derive crystal and exchange field parameters for Yb_2Fe_{17}.

Session CB
Transport and Uncoupled Films
C. J. S. Moodera

The session on Transport and Uncoupled Films (CB) started well with an invited paper on noise measurements and its sensitivity to studies on the dynamics of weak spontaneous symmetry breaking in magnetic thin films, with examples on $\sim 10^{-13} Cm^3$ size Cr films. Noise measurement near and below T_N in Cr film and its relation to Q-domain fluctuations was presented and discussed. In the remaining session consisting of 11 contributed papers, there were two more papers on the epitaxial Cr films. One dealt with the change in T_N as a function of film thickness by resistivity measurement for Cr[100] on LiF[110] films. It was observed that T_N decreased with film thickness, which was attributed to stress in the films. The other paper on Cr concentrated on the film structure study as a function of substrate temperature and film thickness. On glass substrates Cr grew as either (110) or (200) orientation, depending on T_{sub} or thickness.

Magnetotransport studies on Fe-Cr-Fe sandwich (lightly pointed out as 'solid state Stern-Gerlach experiment') showed discontinuity in magnetization and also magnetoresistance (MR) as a function of the applied fields, besides displaying large MR. A crossed polarization geometry model was used to explain their data. As a function of film thickness and aspect ratio H_c, H_{sat} and MR were studied in polycrystalline NiCo alloy films. Large anisotropic MR was observed in amorphous compound films of U with Sb and Mn, which have large spin-orbit coupling. There were four papers on multi-layered systems–two on Cu/Ni and another two on Ti/Co and Co/W. In a Cu/Ni system prepared by electrochemical deposition, magnetization relaxation was observed to be sample dependent. In sputter-deposited Cu/Ni, X- ray data indicated interlayer mixing below about 14Å for ΔÅ. For thicker films (e.g., 30/30), satellite structure was evident; Curie temperature was seen in addition to a peak in M vs. T (reminiscent of spin glass behavior) at a temperature T_p which was layer thickness dependent. This was attributed to the important role of interlayer mixing even in thicker films. On the other hand, no superlattice peaks were observed in the Ti/Co system. The absence of a net magnetic moment for Co<20 Å at 300 K was attributed to a nomagnetic interface layer of thickness about 22Å. Brillouin light scattering was also measured for this system. In the Co/W system by 5Å of superlattice structure was observed showing no interfacial diffusion, and by 10 Å Co net μ was observed at 300 K. Spin polarized inverse photoemission was used to study the band structure of a monolayer of Fe on W. Efforts at measuring the electron spin polarization by tunneling in the half-metallic ferromagnetic (HMF) system, NiMnSb (which is theoretically predicted to show 100% polarization of the conduction electrons), for the first time was also reported. However, this work on HMF thin films is still in its initial stages.



Session CP
Superconductivity
Jeffrey Lynn

Session CP was a poster session on Superconductivity. It contained 27 presentations in a wide variety of subjects, which makes a summary such as this difficult to compose and by necessity somewhat arbitrary. Generally, the papers fell into three areas: (1) Sample Preparation Techniques and Superconducting Properties (2) Magnetic Ordering in Superconductors (3) Experimental Techniques.

In the first category, laser ablation is the preferred technique to produce the highest quality films. For the YBCO system, films with critical current densities of $\simeq 4.10^7$ A/Cm^2 were reported. STM measurements were also reported on Tφ-x and Bi-based high T_c crystals. This tunneling data revealed a gap for the Tφ system of $\Delta \sim$ 19meV, with $2\Delta/kT_c \sim 4^c$, which is close to the BCS value. Several papers reported measurements of the anisotropy of the normal state and superconducting properties of these high T_c materials, and of irreversibility and flux flow behavior in the superconducting state.

The second general area of interest concerned the magnetic ordering and interactions in superconductors. For the high T_c materials, the Cu spin ordering was studied in both the $La_{2-x}Sr_xCuO_4$ and $\mathfrak{R}\ Ba_2Cu_3O_{6+x}$ ($\mathfrak{R}^c$=x rare earth element) by specific heat, Mossbauer, μ SR and NMR. One system of particular interest was $Y_{1-y}Pr_yBa_2Cu_3O_{6+x}$, which is the only 123 material where the rare earth strongly influences the superconducting properties. The Pr is thought to be in a mixed-valent state, and orders magnetically at low temperatures (~ 17K). Measurements were also reported on "conventional" superconductor systems. One system consisted of multilayers of Nb and Cr, where the resistivity and T_c were found to be influenced by the layering when the Nb thickness became smaller than the mean free path. Observation of the magneto- optical Kerr effect was also reported for the Chevrel phase system $EuM\Theta_6S_8$.

Finally, the technique of magnetically modulated microwave absorption was presented, and compared to SQUID magnetization measurements. Both techniques couple to the superconducting state, but in different ways, yielding information which is potentially complimentary.

Session DC
Particulate and Perpendicular
Recording Media
M. P. Sharrock

This session was devoted to recent advances in particulate and thin-film recording media, and illustrated some of the concerns common to both of them.

Y. Nakatani et al presented, in two companion papers, computer simulations of magnetic reversal processes in cubic, elongated, and hexagonal plate-shaped particles. The reversal mechanism was very dependent on particle thickness in the platelets. The cubic and elongated particles showed two-stage reversal processes.

Schabes and Bertram also described a study of magnetic reversal; their work was concerned with the coercivity enhancement due to surface-doped cobalt in acicular iron oxides.

J. H. Hsu et al discussed the use of molybdenum to prevent the degradation of -Fe O particles at elevated temperatures and so to aid in the processing of these materials.

A. E. Berkowitz et al presented an experimental study of anisotropy field and coercivity as functions of temperature in a variety of recording particles. The principal results were that the cobalt- surface-treated iron oxides show a multiaxial anisotropy at low temperatures and that iron particles appear to have superparamagnetic components at room temperature.

Parker and Berkowitz gave anisotropy field distribution derived from magnetic measurements in recording particles. These were used to calculate coercivity values, which gave better agreement with experimental values than would be obtained with coercivities calculated from average anisotropy fields.

R. H. Victora presented calculations of exchange parameters and dead-layer thickness in barium ferrite and explored the consequences of various

alternative Co and Ti dopant sites and of various crystallographic surface layers.

Shao and Alexander showed that electron spin resonance of free radicals can be successfully used to measure magnetic fields inside coatings of magnetic particles.

P. Mayo et al presented results of Monte Carlo calculations on the interactions of magnetic platelets. The results showed probable positions of particles with respect to each other and predicted the enhancement of stacking by an applied magnetic field.

Chagnon and Keirstead described the use of an organometallic surface agent to control the inter-particle interactions in barium ferrite dispersions.

J. E. Snyder et al described studies of saturation magnetization in sputtered CoCr films as a function of substrate temperature. A theoretical model for interpreting the results in terms of Cr segregation and diffusion was presented.

A novel thin-film recording medium, of CoPtB(0) composition, was described by K. Hayashi et al. Higher coercivities and magnetization densities than those of CoCr films were claimed.

J. Skorjanec et al and E. D. Dahlberg investigated the effects of film thickness and of the presence of a magnetically soft "keeper" layer on magnetization decay in CoCr films.

S. Akiyama et al discussed the making of well-oriented CoCr films on thermoplastic substrates, without exceeding the temperature tolerance of the substrate, by "facing-targets" sputtering.

C.-R. Chang discussed a three-dimensional particulate model of magnetic reversal in CoCr films, and used it to predict the effects of varying the size of the inter-column gaps in the film and also to compute minor hysteresis loops.

D. Lottis et al explained the quasi-logarithmic magnetization decays with time seen in CoCr films by means of a model that uses a varying internal field rather than a distribution of activation energies.

Session ED
Superconductivity and Applied Magnetism
Roger F. Hoyt

Session ED on Thursday morning featured a variety of papers concerned with recent work in the areas of Superconductivity and Applied Magnetism. Average attendance during the course of the session was 40, with 3M conference participants rotating in and out between talks to hear specific papers in which they had interest.

The first set of papers dealt with the high T_c $YBa_2Cu_3O_7$ superconductors, with FE substitution for Cu atoms. Paper ED-01 described studies which indicated that the Fe atoms primarily occupy the Cu(1) sites and could be transferred to Cu(2) sites through heat treatment and annealing. This change was observed in the Mossbauer spectrum and the resultant changes in the depression of T_c and the orthorhombic to tetragonal transition measured. The lowering of T_c with the transfer of Fe to Cu(2) sites was interpreted as due to disorder and magnetic scattering effects. Paper ED-02 examined the hysteresis losses of the hi T_c compounds, primarily from the point of view of applications to power distribution. Previous DC hysteresis curves indicated that large losses can be expected in these materials. The paper presented results which indicated that even larger losses are seen in AC application, and that substitution of Fe for Cu slightly reduced the AC losses, but increased the DC losses. These differences were interpreted as being due to other factors than eddy current effects, perhaps flux creep or crystal structure behavior.

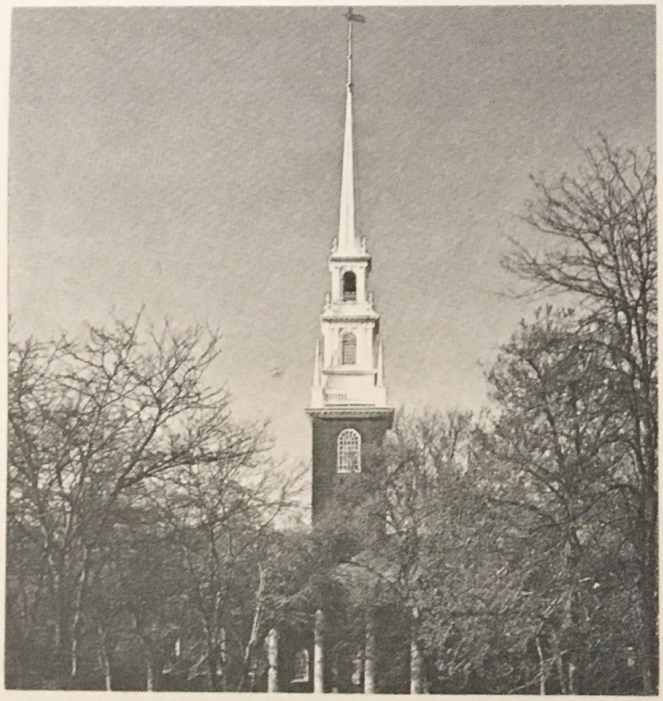
Paper ED-04 addressed the anistropy in the microwave resistance of Y $Ba_2Cu_3O_7$-8 in the normal and superconducting state. The measured resistance and the temperature and magnetic field dependencies were discussed in terms of the two-fluid model.

A very interesting paper, ED-05, by Mayergoyz and Keim, discussed a well known critical state model due to Bean which is used to describe the magnetic hystersis of type II "hard" super-conductors. It was shown that this model is a particular case of the Preisach model used to describe magnetic hysteresis in ferromagnets. This then allows the use of the Preisach model for describing superconducting hysteresis and application to hysteretic losses occurring in the use of super-conducting magnets.

There were next several papers presented in the session which dealt with improvements in instrumentation for magnets. P. J. Flanders presented in paper ED-06 a design for a novel force gradient magnetometer. Instead of the usual force balance, a cantilevered piezoelectric element was used to sense the magnetic force on a sample in the applied field gradient. The design allowed for high sensitivity and could accommodate a wide range of sample sizes and temperature ranges. Papers ED-08 and ED-09 focused on techniques for study of Barkhausen noise. Paper ED-08 by Jiles and Hariharan discussed incorporating a multichannel analyzer into a system for measure-

ments of Barkhausen activities in Damascus Steel. Paper ED-09 by Swartzendruber et al of NIST discussed detailed measurements of Barkhausen noise or Fe and Ni films. The differences in the spectral distributions as a function of film thickness were discussed. The relation between the noise frequency and amplitude were discussed, and found to be different between the pure metal samples and those of Fe-Si. Paper ED-10 presented a technique by which magnetostriction in amorphous wires could be measured. The technique used an AC current in the sample wire in the presence of an applied DC field.

The application of tensile stress creates an anisotiopy field in the sample. The applied dc and ac fields, along with the anisotropy field (from the stress) results in small angle magnetization rotation, and second harmonic generation in a sampling coil. By balancing the 2nd harmonic generation with the bias field in the presence or absence of stress, the anisotropy and hence the magnetostriction can be inferred. Finally, paper ED-12, by Cross and Goldfarb of NIST, Boulder presented a paper on the use of a toroid magnetometer for Hi-T_c superconductors. This allowed precise measurement of magnetization curves of the sample without correcting for demagnetization factors. This was used to study inter-granular coupling effects as a function of fields and temperature.



The final three papers of the session were concerned with novel applications of magnetism in chemistry and mechanical effects. Papers ED-13 and ED-14, by Chagnon discussed use of magnetic colloids in chemical reactions, magneto-viscous damping, to achieve higher product yields, more rapid separation times and their effects in optimizing loudspeaker design. Paper ED-15 by Ueno showed experimental work on the effects of very high magnetic field gradients on combustion flames. Field gradients as high as 200 T/m were capable of extinguishing candle flames completely, an effect he attributes being due to the magnetic force on the paramagnetic O_2 molecules. Theoretical and Modelling calculations of the effects were presented by Ueno in the poster session, paper GQ-18.

Session EP
Spin Waves, Magnetostatic Waves
Nick E. Buris

Sixteen papers were scheduled for presentation in the Spin Wave and Magnetostatic Wave Session. Unfortunately, only ten of these were finally presented. The floor was shared equally between spin wave and magnetostatic wave papers.

Q. Xia and P.S. Riseborough discussed spin wave anomalies of an antiferromagnet with a small Dzyaloshinski-Moriya component in its exchange interaction when bias field and anisotropy are of comparable magnitude.

K. Ravindran and J.E. Drumheller told us all about the ac susceptibility of Tetramethylammonium Copper Chloride at various field values.

N-N Chen and M.G. Cottam explained how impurity layers in Heisenberg ferromagnets may result in localized spin waves at the impurity layer and the free surface of the ferromagnet. They also explained how the magnetization depends on temperature in different layers of the ferromagnet.

V.S. Viswanath and G. Muller showed us how the recursion method can be programmed to yield several properties of time-correlation functions and their spectral densities.

J-M Liu and G. Muler discussed the classical spin dynamics at very large temperatures ($T \to \infty$). They also discussed how the nonlinear time evolution of a system of a finite number of spins becomes linear as the number of spins becomes larger and larger.

H. Chen, P. DeGasperis and R. Marcelli applied Stancil's theory of magnetostatic wave loss to the analysis of the Q-factor of straight resonators.

N. Buris explained the effects of cubic anisotropy and loss on magnetostatic surface waves in layered [111] YIG films.

S. Hanna presented an experimental work on surface acoustic and magnetostatic wave Bragg diffraction.

K. Sun and C. Vittoria discussed the steerability of a magnetostatic wave in a YIG double layer when the orientations of the magnetization of each layer differ.

Finally, Z. Huikang, C. Thibaudeau and A. Caille examined the magnetostatic surface and volume wave modes of antiferromagnets with perpendicular unaxial anisotropy.

Session EQ
Ferrites and Resonances
William Wilber

The thirteen papers presented in the Ferrites and Resonances session can be organized into three categories: material synthesis; magnetic resonance and spin waves; and ferrite permeability. In the material synthesis category, one paper described a process for synthesizing ultrafine particles of $ZnFe_20_4$. An average crystallite size of 19 nm was achieved and the ferrite could be sintered to 99.4% of theoretical density. In a second paper, the substitution of GeO_2 for ZnO in the preparation of Mn-Zn ferrite was shown to promote discontinuous grain growth and to reduce the lattice parameter. A third paper discussed the deposition of Ni-Zn films by spin-spray plating and their applicability for microwave device use.

The largest fraction of papers in this session dealt with magnetic resonance and spin waves. Barium ferrite was the material of interest for two presentations in this poster session. The first was a theoretical calculation of the spin-wave spectrum based on the sublattice magnetizations; the resultant acoustic spin-wave stiffness constant was one-half the value for YIG. In the second Ba-ferrite paper, the measured FMR linewidth was found to be surprisingly frequency independent and was explained in terms of a time-dependent scattering process. Similarly, linewidths for various YIG films were studied from 1-20 GHz and found to be essentially frequency independent up to 12 GHz, although linewidth maxima at lower frequencies appeared with the addition of Pb. FMR and VSM measurements of a YIG/GGG/YIG thin-film structure provided information on the magnetization and anisotropy of the two YIG layers. FMR measurements on single-crystal garnet and Y-hexaferrite, using a slot- coplanar device, showed a linewidth that scaled with frequency.

Several papers reported the use of magnetic resonance to study materials other than ferrimagnets. Thin films of MnF_2 provided the first observation of standing spin waves in an antiferromagnet. Perpendicular and parallel FMR measurements were used to quantify the magnetic profile of permalloy films modified by surface oxidation. Thin permalloy films were characterized also in terms of their microwave loss at 10 GHz by use of the effective linewidth technique. An effective linewidth of 27 Oe was found for fields far away from FMR.

The initial permeability of a ferrite as a function of frequency was the topic of two presentations. First, the permeability for arbitrarily shaped domains with parallel magnetizations was calculated and shown to agree with experimental data on demagnetized ferrites. Second, it was shown that a chosen value of permeability at some frequency between 100 MHz and 1 GHz can be engineered by selecting the appropriate static field and modified YIG composition.

Session FA
Computational Magnetics
From First Principles

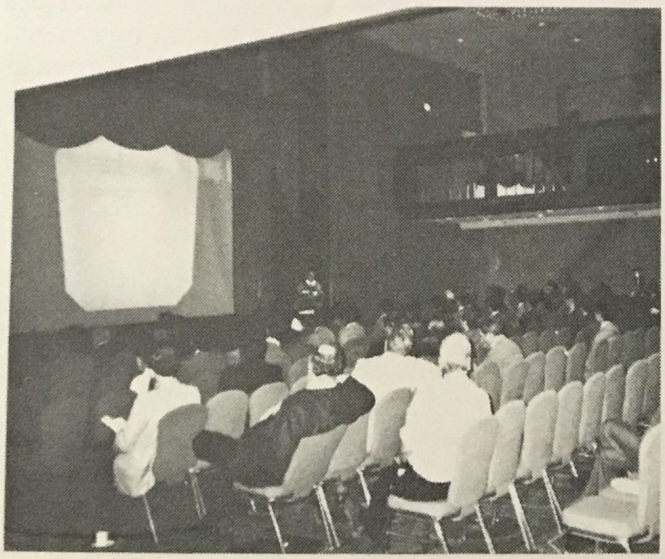
This session was devoted to fundamental aspects of magnetic theory. Two papers discussed atomic models of exchange interactions (FA-01) and magnetoresistance (FA-5). Three papers discussed macroscopic micromagnetic processes in thin metallic recording media (FA-02, FA-03), Magneto-optic materials (FA-03), and Fine particles (FA-04).

In FA-01 Watson remarked that key papers in exchange interactions were presented at the 1952 magnetism conference and recommended, in particular, the Van Vleck article. Berger in FA-05 gave a very physical and illuminating presentation of the calculation of magnetoresistance coefficients in ferromagnetic alloys. He showed how the variation of 3d wavefunction amplitudes between the constituents leads to a maximum MR coefficient at a concentration dependent on the amplitude ratio.

In FA-02 McFadyen and Beardsley presented DPC images of thin metallic polycrystalline films utilized in magnetic recording. A series of pictures of magnetic structure was presented representing various remanence states along the major loop. As the magnetization was decreased from saturation,

nucleation of reversed domains occurred at repeatable sites. As the magnetization decreased further a somewhat regular domain pattern was formed. The domain walls contained vortices. Analysis showed that the average vortex spacing reached 1-2 μ. Theoretical analysis was in good correspondence with the experimental images. Mansuripur and Giles (FA-03) discussed the use of a connection machine for the computation of hysteresis in recording films. They utilized a 256 x 256 array with 500 Å hexagonal discretization representing the grains and were able to encompass sufficient size to show the variety of wall patterns in the demagnetized state in agreement with McFadyen et al. The connection machine was also utilized to simulate the dynamic growth of reversed domains in the magneto-optic recording process. In this case a continuous medium was discretized by 10 Å elements. It was interesting to observe the motion of Bloch lines around the reverse magnetization closure walls as these domains expanded.

In FA-04 Fredkin and Koehler showed results from simulation of micromagnetic processes in fine particles. The particles discussed were generally large with respect to the exchange length so that multidomain structures occurred at or near remanence. Their method involves energy minimization similar to an FEM procedure with tetrahedral discretization. They showed results modeling media with curved boundaries. In particular, from comparisons with analytic solutions (curling in a sphere) they argued that care must be taken in evaluating the exchange energy when discretization does not follow an orthogonal (cubic) system.



Session FC
Spin Chains
Jill C. Bonner

On the theory side, this session contained a hefty dose of spin chains of higher spin (1, 3/2, 2) and rather prominently featured the Haldane conjecture. Gomez-Santos introduced a variational approach, similar to the rather successful Hartree-Fock method of Bulaevskii. This was applied to the S-1/2 XYZ chain as a best case, and then to the S=1/2 qualitative features predicted by Haldane were reproduced. In an invited paper, Steiner discussed the current status of neutron scattering experiments in the experimental Haldane system C_5NiCl_3, concluding that some specific features were not yet understood. He came to a similar conclusion for the case of experimental studies on the soliton-bearing 1D S-1 ferromagnetic chain, $CsNiF_3$. Lin described an interesting and apparently quite powerful method for studying finite chains, consisting of a quantum real-space RG method combined with direct chain diagonalizaton. He obtained results for chains of spin 1, 3/2, and 2 larger than any obtained previously, and estimated the ground state energy in the thermodynamic limit in each case. Application to the S-1 biquadratic chain was contemplated. Bonner presented a brief account of a controversy as to whether the biquadratic chain had an energy excitation gap, resolved in the affirmative by a recent exact solution for ground state and gap. Finite-size effects in the spectral excitations and the T=O magnetization curve were presented. Bonner also discussed the problem of logarithmic corrections, which slow the convergence of numerical methods near an essential singularity. This problem is ubiquitous for quantum spin chains of higher spin. Using methods of conformal field theory, an expression has been derived which gives a quantitative estimate of deviations from the true, limiting exponent values expected to be observed in numerically obtained results from finite systems.

In an invited paper dealing with experimental measurements on the S=1/2 ferromagnetic linear chain systems CHAB and CHAC, Kopinga also presented theoretical results for the behavior of spin-1/2 linear chain derived from a Trotter formula approach and extended to the case of magentic fields. Good results were obtained for the thermodynamic properties, which in turn showed very good agreement with experiment. Convergence was disappointing for the case of correlation functions, however. A second theoretical approach

inspired by experimental work in CHAB was presented by Lemmens. Using a variational approach, he was able to separate the elementary excitations of an easy-plane linear ferromagnet with symmetry-breaking field into classical solitons and quantum spin waves. A group from Florence concluded that linear chains in which trivalent rare earth ions and organic radicals alternate in space is best described in a two-spin up, two-spin down ground state model, governed by next-nearest-neighbor interactions. Finally, Williams, working in the group of Landee, discussed properties of the low-dimensional Ising-like ferromagnet system FeTAC, demonstrating a 1D to 2D crossover in the magnetic properties.

Session FD
Nonlinear Dynamics and Chaos
P. E. Wigen

This session included a wide variety of nonlinear phenomena, but suffered significantly from the withdrawal of four papers as the authors were unable to attend.

On the topic of chaos, Dr. Savage reported in an invited paper on an unusual system in which the Young's modulus varies significantly with the magnitude of a magnetic field. By applying an oscillating field, a magnetostatic ribbon was driven in and out of the gravitational regime, and auto-oscillations, bifurcations, and intermittent bursting on routes to chaos were observed.

Professor Rezende reviewed his extensive data in parallel and perpendicular pumped YIG including auto-oscillation threshold fields, amplitudes and frequencies as a function of sample dimension, shape, spin wave relaxations rate and wavevector. He reported that the data are in disagreement with predictions and that a good model is still needed to explain the routes to chaos in YIG spheres.

Mr. McMichael reviewed the data and a model associated with the nonlinear dynamics in the main magneto-exchange branch of YIG films at perpendicular resonance. "Fingers" in the auto-oscillation versus magnetic field plane were observed that were associated with the individual magnetostatic modes in the film. Having no degenerate short wavelength spinwave modes, the model predicted the auto-oscillation frequency and power levels to within 10% of experimental values.

Dr. Carroll reported observations in YIG films at low frequencies between 2 and 4 GHz. In the chaotic regime, a fractal dimension of 2.9 was reported for volume modes and 2.6 for surface modes. Lyapunov exponents of about 10^5 bits/sec were reported for both modes in the chaotic state.

Mr. Srivastava considered the integrability condition for a pair of exchange-coupled quantum spins interacting via a biaxial exchange and single-site anisotropy energy. The integrable cases were investigated and using a novel approach then the authors were able to demonstrate the evolution of level repulsion in nonintegral models whose distribution of spacings is used as an indicator of quantum chaos.

In two papers involving nonlinear but nonchaotic behavior, Dr. Cross reported on a study to use microwaves and Brillouin scattering to make direct observations of predicted flips in the spinwave angle for the unstable modes. Using low frequencies, the overlap of FMR and subsidiary absorption were observed to give very low minimum thresholds and a new prediction of a flip in the azimuthal spinwave angle in the overlap region was predicted and observed.

Finally, Prof. Soohoo reported the use of a resonance technique in a Permalloy film to investigate the discrete changes in the rf absorption as domain wall generation and discontinuous displacements occur. Tens of "threshold fields" were observed in the switching process giving a new technique that allows a detailed investigation of the microscopic behavior of the switching process.

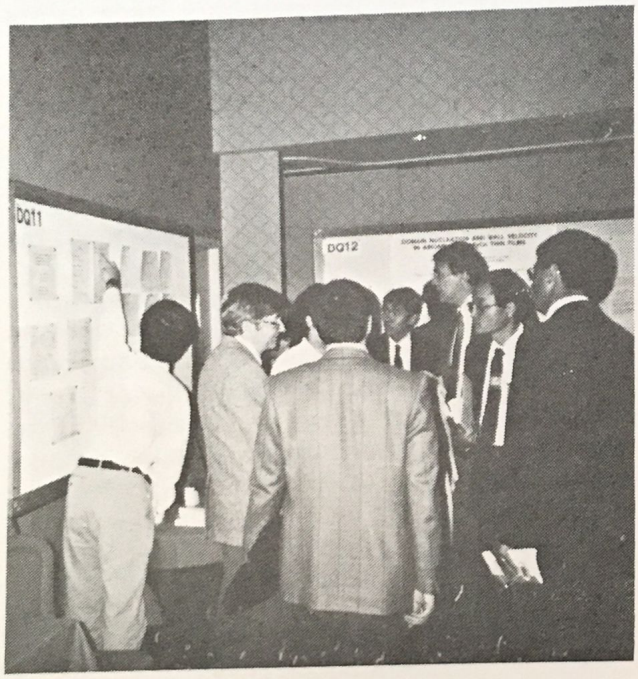
Session GC
Two Dimensional Magnetism
Gene Dresselhaus

The session consisted of an initial invited talk by A. Auerbach on some new theoretical techniques to treat quantum Heisenberg models, 11 contributed talks, and a rescheduled invited talk by the Russian group from Leningrad on the experimental evidence for spin soliton formation in propagation in thin magnetic films which was presented by Dr. Carl Patton.

The 11 contributed talks were approximately evenly divided between theory and experiment. The scheduling had the theory talks first on the program and the experimental talks came at the end of the session. About half of all the talks dealt with the magnetic aspects of the new high temperature oxide superconductor materials. Two of the theory talks addressed the solutions of the 2D quantum antiferromagnet.

The experimental talks were related to magnetic phase transitions in thin films, and various layered compounds including graphite intercalation com-

pounds, $BiCuO_4$, and $CuSb_2O_6$. The experimental realization of 2D models (often calculated by Monte Carlo) is now quite convincing and in some cases agrees very well with theoretical models. The paper by the Argonne group on an experimental realization of the ferromagnetic Ising model was a good example of where MBE technology can produce very interesting science.



Session GD
Random Anisotropy and Amorphous Magnets
J. R. Cullen

The papers in this session were divided into two categories; those dealing with magnetic systems dominated by random anisotropy and those whose subjects were amorphous ferromagnets in which random exchange modifies the ferromagnetic behavior. Among the former there were both experimental and theoretical papers. These included two invited papers. In one, the rotational dynamics of amorphous $Dy_xGd_{1-x}Ni$ alloys were probed in an innovative way. The authors (Barbara, Dieny and Filippi) rotated a disk-like sample about its symmetry axis while simultaneously measuring the two in-plane components of the magnetization. The steady state response could be interpreted in terms of a magnetization fixed with respect to the sample and one fixed with respect to a static in-plane field. Since these alloys fall in the sub-category of large anisotropy to exchange ratio, the authors picture the delay in forming and reforming of the magnetization as being due to a distribution of lifetimes caused by rough domain walls attempting to follow the motion of the sample with respect to the applied field. The results invite an extension of the theory of random-axis alloys to include dynamical effects.

The second invited paper, by M.S. O'Shea, reported on magnetization measurements of rare-earth iron, cobalt and nickel films. It was pointed out that it is possible to observe two temperature-driven transitions, at least in some Er-containing alloys; the upper transition presumably from paramagnetic to ferromagnetic, while the low-temperature transition was assumed to signal the onset of a spin-glass state.

Among the many interesting contributed papers, perhaps the most intriguing was that by Fisch and Harris, GD04, who find that there exits a phase transition in the $D\rightarrow\infty$ version of the random axis model, in the x-y case. This surprising result does not contradict our understanding of phase transitions because, as the authors point out, the long-range correlations which lead to the transition are not correlations in the ferromagnetic order, which are necessarily short-range for $D\rightarrow\infty$. Since the computations of the correlations were confined to the high-temperature regime, precisely what type of order, or the nature of the low-temperature phase, could not be determined.

M. Sostarich (GD09) was able to modify the generalized Slater-Pauling curve of Moruzzi et al to incorporate the sensitivity of the number of s-p electrons to variation in M concentration for Fe-Co-M, Fe-Ni-M (M = metalloid) alloys. By so doing, he was able to demonstrate the tendency for the M = B rich alloys to behave as weak itinerant ferromagnets, in contrast to P-rich alloys, for which the Fe moment remains strong.

Finally, mention should be made of paper GD07 (Lu and Chien) who studied vapor quendred $Fe_{x-}W_{1-x}$ alloys over the whole composition range. Over the middle of that range, i.e. for $.3<x<.7$ the alloys are amorphous, and no moment was detected to 5K. Why does W, which forms in the BCC structure as does Fe, have such a deleterious effect on Fe magnetism in the amorphous phase?

Session GP
Magnetochemistry
Gary C. DeFotis

Chagnon and Hamilton presented a poster showing how magnetic separations for biological molecules can be achieved using polymer-coated superparamagnetic particles (more effective than larger, bare magnetic particles) capable of binding selectively to biomolecules. Ueno and coworkers presented three posters in the magnetobiology/-magnetophysiology area. One dealt with magnetic field patterns from multiple dipole configurations in an inhomogeneous volume conductor, as a model for the head. Magneto-encephalograms are found to be insensitive to changes in distances between dipoles. Another found that localized stimulation of the brain and spinal cord, correlating with effects in the limbs, could be achieved using a pair of opposing pulsed magnetic fields produced by a suitable coil arrangement. A third presented evidence that no adverse effects could be detected in tadpoles hatched from embryos that had been exposed for as long as six (eight) hours to fields as high as 6.34 (5.4) Tesla.

Batllo et al presented a poster showing how the 750 K dissociation of diamagnetic O_2^{2-} (originating from traces of water captured in the crystal growth process) into paramagnetic O^- in high purity single crystal MgO can be detected by magnetic susceptibility measurements. Janssen et al applied EPR at much higher than usual fields and frequencies to study lower dimensional magnetism in single crystal TEA $(TCNQ)_2$. Some unusual structure was observed. Murty, Rao and coworkers used zero-field NMR to study metal support interactions in several cobalt catalysts for syngas conversion. The spectrum for Co-TiO_2 is unique, and suggests a strong structural modification or electron exchange interaction between cobalt and titania.

Hatfield and colleagues exhibited two posters. In one, on the calculation of spin Hamiltonian parameters via the cluster approach, perhaps the most interesting result was the uncovering of a relationship between superexchange bridge geometry and exchange interaction rather different from that found earlier by Hatfield et al for Cl and Br bridged dimer and chain systems. In the other, on the magnetic properties of a sulfur-bridged iron dimer, a surprisingly strong antiferromagnetic exchange was found, occurring via an unsymmetrical unit with two short and two long Fe-S distances.

Bellesis, Simizu and Friedberg presented an interesting poster on magnetic ordering in certain Ho^{3+} systems. Interionic interactions are dipolar, with magnetic ordering at 0.23 K. Nuclear and electronic degrees of freedom, manifesting themselves here in comparable energy ranges, are found to be independent (from analysis of specific heat data) due to the Ising character of the non-Kramers ground doublet. These may be the first good examples of such behavior, predicted previously by Mattis and Wolf.

Carlin and coworkers presented four posters. One reported susceptibility data for a copper system behaving as a 2D Heisenberg antiferromagnet. Another examined some Gd and Yb systems in which three bridging bromide ions couple the rare earth ions diametrically. In contrast to most rare earth compounds, where dipolar interactions dominate, magnetic superexchange is of main importance here. The magnetochemistry of tetrahaloferrate ions was examined in a third poster. Substitution of different halides at two different sites in the structure is a variation than can be played on these systems. Canted antiferromagnetism is observed, and attributed to antisymmetric exchange. A fourth poster presented results on some, relatively rare, Cr^{3+} superexchange coupled systems, one of which behaves as a linear chain antiferromagnet.

DeFotis et al presented two posters. One dealt with $MnCl_2H_2O$, a previously unexamined hydrate with magnetic behavior distinctly different from that of the anhydrous material or the higher hydrates. It is a quasi-1D Heisenberg antiferromagnet, ordering at 2.16 K due to an interchain exchange interaction about 3% as strong as the intrachain exchange. The other dealt with $Mn(SCN)_2(i\text{-}C_3H_7OH)_2$, also a quasi-1D Heisenberg antiferromagnet. Significant anisotropy was observed in the single crystal susceptibility. Unusual polynuclear SCN^- bridges mediate the superexchange interaction in this system.

Session GQ
Hyperfine Fields, Quasicrystals, Small Particles
Lydon J. Swartzendruber

Session GQ was a poster session concerned with hyperfine fields, quasicrystals, and small particles.

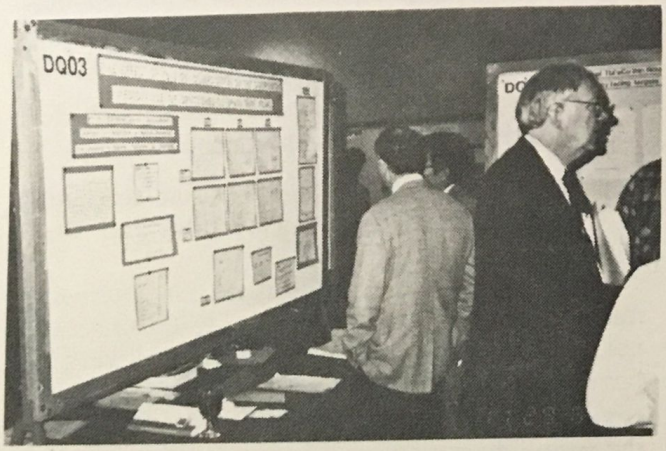
This session illustrated that the interesting magnetic properties of rapidly solidified alloys with quasiperiodic structures continues to draw attention (and controversy), with six posters devoted to this topic. These materials appear to have magnetic critical temperatures which are quite high, 100 K to above 400 K, even though the average moments

are very low, 0.1 Bohr magneton or less. Some joint work on electronic and nuclear specific heats was performed at the Laboratoire de Physique des Solides in Orsay and the CECM/CNRS in Vitry, France. Results were interpreted as showing that 30% of the Mn sites carry a saturated moment in a high field (7 T) whereas only 1 or 2 percent of the Mn are involved in a spin glass state at zero magnetic field, and as being consistent with a picture in which a sp-d resonant effect produces a pseudo-gap important to the stability of the quasiperiodic structure.

Measurements of the magnetic properties and $^{88}_{Y}$ NMR in $Dy_xY_{1-x}Fe_2$ by Alves and colleagues at the Centro Brasileiro de Pesquisas Fisica in Rio de Janeiro showed that Dy behaves in a qualitatively different way than Tb or Ho when substituting for Y. This different behavior was explained as arising from a much larger domain wall pinning when Dy is added.

Small particle work of considerable variety was presented, including studies on nanometer size particles generated by iron atoms clustering in cold pentane (Kansas State University) and measurements of layered films of submicron Fe_30_4 (Clarkson University, Potsdam and University of Alabama-Huntsville).

Many groups are currently studying hyperfine fields in high temperature superconductors and related compounds to help discover clues to the mechanisms responsible for superconductivity. Measurements of the ^{63}Cu NQR in CuO was presented by workers from Pavia and Milano (Italy). Just as in oxygen deficient BYCO it was found that one-dimensional spin correlations are present above T_N, while at lower temperatures the spin dynamics crosses over to a three-dimensional character.



Session HB
Magnetic Imaging
Dan Pierce

The session on magnetic imaging got off to an excellent start with an invited talk by Dr. Mike Scheinfein of the National Institute of Standards and Technology on the observation of magnetic microstructure using scanning electron microscopy with polarization analysis (SEMPA). Images of the full vector magnetization were displayed for Fe and Co single crystals, a Co based metallic glass, and some permalloy structures. Bloch walls were found to turn over into Neel walls at the surface. Neel walls in opposite directions were found to be offset from one another and to meet at a singularity which was also imaged. Images of written bits on two hard disk media showed how the quality of the bits at the microscopic level correlates with the measured readback noise. Scheinfein compared results of magnetic simulations using an energy minimization scheme with the SEMPA measurements and used the calculations to understand trends in the measurements and to infer magnetization distributions in the bulk. Such calculations were used to explain variations in apparent domain wall width from TEM Lorentz measurements in Fe. Also, a simulation of a magnetic force microscope with an Fe tip and a permalloy surface showed how the tip/sample interaction can perturb the sample magnetic structure.

Peter Grutter from the University of Basel and John Mamin from IBM Almaden research center reported on imaging with magnetic force microscopy (MFM). Grutter claimed 10 nm spatial resolution in a measurement of a FeNdB hard magnetic material. Mamin described a force microscope wherein the cantilever motion was detected with an interferometer. He had tried several tip materials and studied the tips with Lorentz microscopy to determine that the last 20 μm or so of the tip is a single domain. Resolution better than 100 nm was achieved with tungsten tips coated with 50 nm of CoPtCr. Striking images of transitions written with a recording head in a longitudinal medium (in plane magnetization) and in a perpendicular medium (out of plane magnetization) were obtained with the MFM. The MFM revealed detail within the magnetic transitions and side- writing effects. The MFM was also used to study the erase band created during overwrite under various conditions. The technique provides a high contrast image of

the magnetic field above the surface of the specimen. It is applicable in air, and can even measure through a coating such as a lubricant on the surface.

On a different lingth scale, Chris Gudeman of IBM Almaden Research spoke of mapping the anisotropy field and easy axis orientation over a 2 inch x 2 inch area. He described using the longitudinal magneto-optic Kerr effect as an effective "torque magnetometer". The Kerr effect monitors the direction of magnetization as the applied field is rotated in the plane of the film. Approximately 300 locations can be measured in about 10 min.

Session HE
Ferrimagnets
J. E. Greedan

This oral session was well attended considering the Friday afternoon time slot. Attendees were not limited to inorganic chemists but included experimentalists and theorists from the physics community as well. The session began with an invited paper by Marc Drillon (Strasbourg) who outlined the recent developments in his group concerning both the molecular engineering of novel magnetic systems, especially one dimensional ferrimagnets, and the theoretical modeling of their thermodynamic properties. Many of the contributed papers from E. Coronado (Valencia), D. Beltran (Valencia), F. Palacio (Zaragoza) and R. L. Carlin (Illinois-Chicago) provided further novel examples of 1-D ferrimagnetic materials and confirmed the theoretical models. The means by which the ferrimagnetic correlations were achieved was varied and often quite subtle. Examples were CoNi(EDTA), $6H_2O$ and other compounds with different alternating transition metal ions in chains but the effect was also seen in zig zag polymeric chains of Co(II) where g-tensor anisotropy alternating from site-to-site was the root cause. Much debate ensued regarding whether this latter case represented a true ferrimagnetic system. Heterometallic trimers and tetramers such as those obtainable from Keggin-type heteropolytungstates were also featured.

THE PROCEEDINGS OF THE IEEE ON ELECTROMAGNETICS

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ANNUAL CONFERENCE MAGNETISM AND MAGNETIC MATERIALS

The Thirty-Fifth Annual Conference on Magnetism and Magnetic Materials will be held at the Town and County Hotel, San Diego, California. The Conference annually brings together scientists and engineers interested in recent developments in all branches of fundamental and applied magnetism. Emphasis is traditionally placed on experimental and theoretical research in magnetism, the properties and synthesis of new magnetic materials and advances in magnetic technology. The program will consist of invited and contributed papers. Selection of contributed papers is based on abstracts whose submission deadline is 16 May 1990. An Abstract Booklet will be available in advance of the Conference from the American Institute of Physics for a fee of $15.00. Registrants will receive this booklet at the Conference. Proceedings will be published in the Journal of Applied Physics.

Individuals who are not on the Conference mailing list may obtain Conference information and details concerning the preparation of abstracts in the prescribed format by writing Dr. John T. Scott, American Institute of Physics, 335 East 45th Street, New York, New York 10017 or Diane Suiters, Courtesy Associates, 655 15th Street N.W., Suite 300, Washington, D.C. 20005.

This topical conference is sponsored jointly by the American Institute of Physics and the Magnetics Society of the IEEE in cooperation with the

American Physical Society, the Office of Naval Research, the Metallurgical Society of the AIME, the American Society for Testing and Materials and the American Ceramic Society. The meeting will be open to all persons subject to a registration fee of approximately $200 (marked reduction for students).

CONFERENCE ANNOUNCEMENT

The Fourth Biennial IEEE Conference on Electromagnetic Field Computation will be held October 22-24, 1990 at the Westbury Hotel, Toronto, Canada. The three-day conference is being sponsored by Region 7 and the Toronto Section of the IEEE, in cooperation with the IEEE Antennas & Propagation, Magnetics and Microwave Theory & Techniques Societies. The conference will provide a forum for Engineers and Numerical Analysts having interests in low and high frequency computational electromagnetics to discuss common issues relating to numerical and analytical techniques for 2D and 3D problems and applications; parallel computing for e.m. field analysis; CAE and visualization; automatic mesh generation; verification and validation of field analysis codes. Parallel sessions will be kept to a minimum. Information concerning this conference can be obtained from:

CEFC '90 Conference Secretariat
Department of Electrical Engineering
University of Toronto
Toronto, CANADA M5S 1A4

Prospective authors are invited to submit a two-page digest by April 16, 1990 to the Conference Secretariat.

INTERMAG 1990

Intermag 1990 will be held at the Metropole Hotel in Brighton, England, April 17-20, 1990. This week follows Easter, allowing delegates to visit some of the many places of interest in the UK. Brighton is a seaside town 60 miles south of London. It was the first seaside resort in the world and was made famous by the Prince Regent in the 18th century. There are many interesting buildings to explore, including the Royal pavilion and the older shopping areas known as 'The Lanes'. A full spouses' social program will be available with visits to interesting places in Sussex.

The scientific program has now been finalized after an overwhelming number of digests were received. Intermag 1990 promises to be a very full and exciting meeting with high quality contributions in all current areas of interest in magnetics. Should you require further information please contact the Conference Coordinator:

Davina Houseago
Intermag '90
c/o ITEL
Brighton Polytechnic
Brighton, BN2 4GJ, United Kingdom
Telephone: 273 670400

11th INTERNATIONAL WORKSHOP RARE EARTH MAGNETS

The Eleventh International Workshop on Rare Earth Magnets and Their Applications will be held at the Carnegie Mellon University, Mellon Institute, Pittsburgh, PA October 21-24, 1990. A satellite Symposium on Anisotropy and Coercivity will be held October 25, 1990. For further information, please contact:

S. G. Sankar, Chairman
11th Int'l. Workshop Rare Earth Magnets
Carnegie Mellon University, Mellon Inst.
4400 Fifth Avenue
Pittsburgh, PA 15213
(412) 268-5649, FAX 412 268-3101

CONFERENCE CALENDAR

Image Storage and Retrieval Technologies, February 11-16, 1990, Marriott Hotel, Santa Clara, CA. Contact H-P David Shieh, IBM T. J. Watson Research Center, P.O. Box 218, Yorktown Height, NY 10598.

INTERMAG 1990 Conference, April 17-20, 1990 Metropole Hotel, Brighton, UK. See page 18 for further information.

8th International Conference on Video, Audio and Data Recording, April 23-26, 1990, Birmingham, UK. For information contact Conference Services, IEEE, Savoy Place, London, WC2R OBL, Telephone 01-240-1871 x222.

The 4th Biennial IEEE Conference on Electromagnetic Field Computation will be held at the Westbury Hotel, Toronto, Canada, October 22-24, 1990. See page 18 for further information.

11th International Workshop on Rare-Earth Magnets & Their Applications, October 21-24, 1990, and 6th International Symposium on Magnetic Anisotropy & Coercivity in Rare-Earth-Transition Metal Alloys, October 25, 1990 are to be held at Carnegie Mellon University, Pittsburgh, PA. For further information see page 18.

35th Magnetism and Magnetic Materials Conference, October 29-November 1, 1990 Town and Country Hotel, San Diego, CA. See page 17 for further information.

IEEE MAGNETICS SOCIETY NEWSLETTER
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