SYNTHESIS REPORT

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Synthesis Report

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Abstract
The CAMST Programme has established a network for the European research in magnetic recording. This has been set-up by organizing Topical meetings, General meetings, the exchange of researchers and publishing the quarterly newsletter Read/Write and a yearly distribution of a catalogue. As a result the co-operation between universities and between universities and industries has improved. Many special topical meetings and short term exchanges have been organised. As a spin-off from this prograrnme several national and new EU projects are initiated or have been started already. Bilateral projects between European recording industries and CAMST laboratories have been started already.

Introduction

Since 1989 many European Universities started to co-ordinate their research in the field of magnetic storage technologies supported by the EU. From 1989 until 1992 a Science programme with the name: Community Action Magnetic Storage Technology (CAMST) was carried out. A second activity in this are was started in 1992 as the Concerted Action Magnetic Storage Technology (or CAMST 11). The latter was officially started on October 1st 1992 in the EC BRITE/EuRam programme (BRE2.CT92.0130) for a period of 4 years as the successor of CAMST I. In comparison with CAMST I, many more laboratories were involved (25) and the budget for 4 years was very limited. In fact the money was only applicable for running the umbrella organisation. The budget was used for organizing meetings, publication of the newsletter Read/Write, administrative support, short term exchanges and the publication of the catalogue. The latter consist of descriptions of all groups, their research facilities and research programmed. No budget was available for research, consumables, equipment and paying long term visits for young and/or senior researchers. Consequently the research activities carried out in the scope of CAMST 11 are paid by "non-CAMST" sources from the participating groups (such as Universities, National Governments, other EC projects, National Research Foundations, etc.).

Technical Description

The total research programme has been divided into two main areas, one for Materials and one for Systems. Both areas have an Industrial Co-ordinator whose task it is to look after the industrial relevance of the proposed co-operation projects. The Materials Area has been subdivided into three sub-areas: Thin Films, Particulate Media and Magneto Optics. The Systems Area has been divided into three sub-areas as well: Micromagnetism, Recording and Tribology. All sub-areas are supervised by coordinators from universities. The management structure is given in fig. 1.

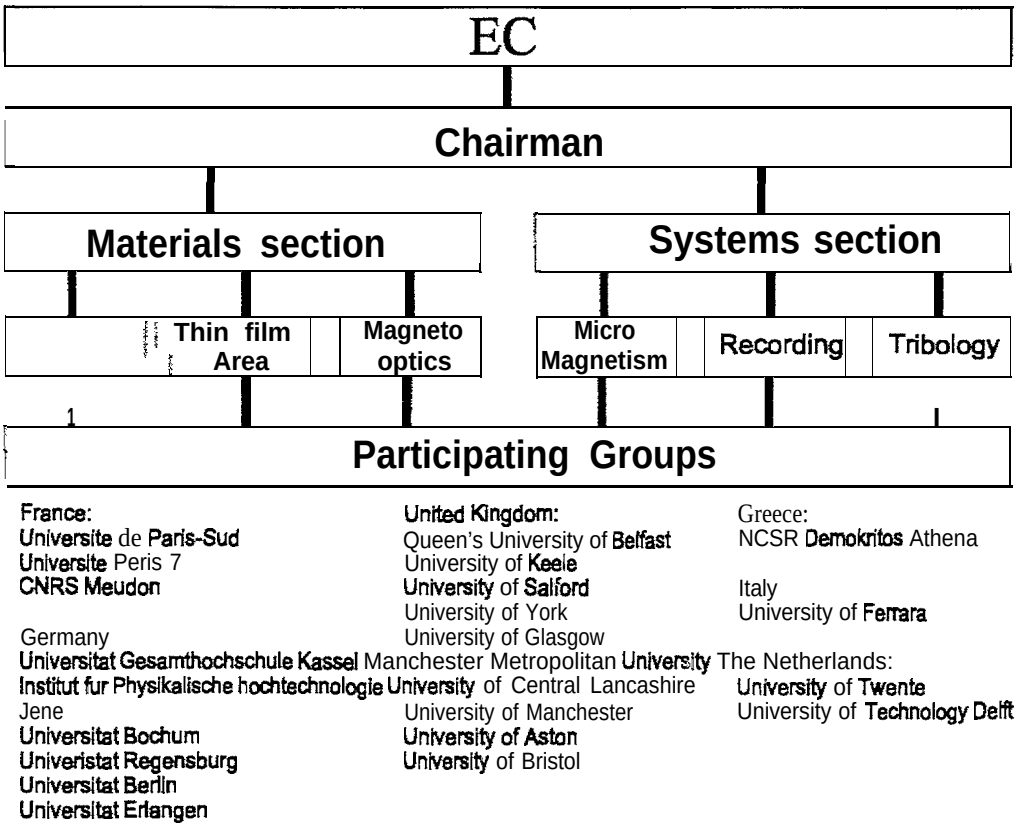

Figure 1 Management structure CAMST

The research topics of the different areas consisted of:

Particulate Media:

. Fabrication of magnetic dispersions

• Study of interaction effects and magnetisation reversal in media

. Study of the relationship between interactions and technologically important phenomena (noise, magnetisation reversal)

Thin Film:

. Enhanced bit density

. Better long term stability of stored information

. Larger signal to noise ratio for higher data rates

. Development of new recording media

. New fabrication techniques

Magneto-Optics

. Investigation of magnetic films and multilayers with strategic magneto-optical recording properties

. MO ellipsometry; application to MR magnetisation reversal studies - magnetic domain structures (MO, Lorentz and MFM) and domain wall dynamics

• High spatial resolution studies of written bits in MOR media, time resolved MO imaging

. Multilayer technology for optimisation of the MO effect - direct overwriting

. MO recording facilities

Micromagnetism

. Understanding the magnetisation process in recording media of all types

. Development of micromagnetic models of thin films, multilayers and particles

- Study of transition noise and irreversible magnetic behaviour
- Study of magnetisation reversal in single particles

Magnetic Recording

- Recording measurements of thin film harddisk media and recording tape.
- Experimental measurements on magnetic recording heads
- Theoretical development of the read/write process

Tribology

- Experimental studies on friction and wear
- Study of the elastic and plastic properties of the thin films for media application
- Advanced surface analysis for studying surface properties of the media
- Developing new measurement techniques to study the interface between head and medium.

In order to develop the co-operation between universities and industries, several means were used:

- Production of a quarterly newsletter: "Read/Write"
- Organisation of General meetings to discuss the progress of the total program
- Organisation of Topical Meetings, aimed at discussions of specific problems
- To stimulate the co-operation between the laboratories and also industry the Short Term Exchange Programme has been initiated by the Steering Committee. The participating laboratories have been invited to apply for funding and propose candidates for the exchange activities. The Steering Committee decided on applications to be funded, and on what level. Through these exchanges information and knowledge is transferred and this contributed to a wider view within the universities and industries.
- Initiation of specific targeted projects in strategic areas
- Smaller activities, like assistance with the development of applications within EC programmes and reporting to the commission

Results

First of all the research in the different areas will be discussed. Secondly the co-operation between the laboratories will be quantified. Also the spin-offs from this programme will be mentioned.

The research in the different areas

Thin film area

Magnetic thin films play a key role in magnetic and magneto-optic recording both as storage media and as active elements in recording heads. Research in the this area mainly consisted of fundamental studies on new methods for film preparation, structural and magnetic characterisation, novel magnetic materials and newly discovered phenomena in thin magnetic films and multilayers. By gaining leading positions in different fields CAMST laboratories have significantly contributed to provide the most advanced magnetic film technologies and the basic understanding of magnetic film properties as a prerequisite for European industry to successfully compete in the market for future high performance recording systems.

Particulate media area

The original project plan for the particles area envisaged that our work would concentrate in two areas concerned with particle preparation and dispersion and an assessment of the effect of interactions. Reference to the input and published work will show that the progress was followed very closely. The main conclusions are that Barium Ferrite particles are difficult to control in times of preparation and particularly orientation in media and hence this has lead to

the dominance of metal particles in the industrial sector. It is also true that metal particles enable smaller particles sizes to be used.
We also anticipated that significant collaboration with industry would occur in our area and this has been achieved.

Micromagnetic area
Within micromagnetics a number of developments have been made both in terms of theoretical rnicrornagnetics and its application to recording and head simulations. During our programme a number of important collaborations have been developed with experimental groups, especially those working on imaging measurements which represent an important test of micro magnetic calculations. The interaction between theoretical and experimental groups has been very positive in improving the understanding of magnetic materials for recording. Also important has been the interaction with groups working on recording simulations. This has enabled micromagnetic information to be fed into an understanding of the recording process. Particularly important here has been an improved understanding of the effects of intergranular exchange coupling and its relation to noise mechanisms in longitudinal thin films.

Magnetic recording area
A wide variety of theoretical and experimental work has been completed on the recording properties of thin metal film media for use in rigid disk drives and in magnetic tape. Much progress has been achieved in understanding digital recording properties by both measurement and theory and this has been underpinned by substantial programmed involving studies of magnetisation processes in the thin film media, observation of recorded patterns, and experimental measurements of record head fields. New and novel thin film head structures have been developed in one of the laboratories and elsewhere new recording systems have been designed and tested. In total this has allowed a broad coverage of a number of aspects of topics of vital importance to the development and application of the latest thin film media to advanced recording systems. Not only has this broad technological approach been of value to the development of the subject matter but it has also clearly demonstrated the importance of links between related groups of workers and it is clear that these will persist and develop to their mutual benefits in the future.

Tribology area
The concentration of activity in Tribology can be divided between the two main media types, namely hard disks and tape. The friction and wear behaviour and the lubrication regimes at the head/medium interface were investigated on commercial and model media using standard sliders. The importance of a detailed consideration of the elastic and plastic properties of the thin films investigated became obvious. Useful information on the HMI at contact was obtained using the low loads that will be typical of advanced systems. A large effort on the tribology and surface analysis of both heads and tape developed during the programme. The application of advanced physico-chemical surface analysis techniques to tape and head wear and material transfer began to reveal very important information. This effort attracting support from media manufacturers and systems designers. Advanced, integrated heads were also fabricated and applied to impact and friction and wear studies of magnetic media. the fabrication and characterisation of minituarised and integrated components for future, compact drives is an important engineering development.

Magneto-optics area

In the area of Magneto optical recording the involved teams were concerned with the preparation and characterisation of new magneto-optical media and designed magnetic film structures for magneto-optical recording (MOR). Constant targets were the improvement of the performances of MO media and MOR film structures, the increase of the density of stored information and the understanding of the thermomagnetic writing process in order to increase the signal to noise ratio in the reading procedure. Many projects have been carried out in co-operation with industrial partners.

A relative new activity in this field are patterned nanostructures in magnetic film structures which are highly promising for the third generation of MOIR media: this has been widely discussed during the Topical Meeting on "Magnetic Nanostructures" (April 1996). Also hard links were developed between University and Industrial laboratories.

Activities undertaken to promote the collaboration between universities and industries:

Newsletters

The Newsletter "Read/Write" informed on the research that has taken place in the participating laboratories by articles from different laboratories. Reports of the Short Term Exchanges and the Topical Meetings that have taken place were also included in the newsletter. Information have been given about finalised PhD reports from the laboratories involved in our programme. Also advertisements for jobs, PhD positions, postdoc vacancies were given. Furthermore it informed the CAMST members of the decisions taken by the Steering Committee.

Industrial information was given by different companies on their research or on the technology of their products. Well known scientist in the field gave their impression of the 'state of the art' in the area of storage technologies. Reviews about new books and reports about the most important international conferences have been included.

In total 16 newsletters and a special issue have been published and sent to more than 3(90 universities and industries.

***General** Meetings*

The following two days meetings have been held:

[1]. First General Meeting CAMST II, February 1993, Enschede, The Netherlands

[2]. Second General Meeting CAMST II, February 1994, Manchester, UK

[3]. Third General Meeting CAMST II, January 1995, Gif sur Yvette, France

[4]. Fourth General Meeting CAMST II, January 1996, Belfast, United Kingdom

Reports about all General Meetings have been reported in Read/Write.

Topical Meetings

In total 14 Topical Meetings (general length about two full days) have been organised by the Steering Committee:

At these topical meetings in total 342 researchers of laboratories and 48 industrials participated. Of most of the meetings an extended report has been made. A few subjexts discussed during Topical Meetings are: Advanced Hard Disk Media, Magnetic Nanostructures and Tribology.

Short Term *Exchanges*

In total 55 exchanges have taken place. A report of each exchange was published in READ/WRITE and more then 837 days have been spent on these exchanges.

Initiation of specific targeted projects in strategic areas
Many specific *samples* have been send around to various laboratories for carrying out measurements and to discuss the results together during topical or other meetings. Sometimes the samples have been prepared specially by industrial partners.
In the area of micromagnetic characterisation techniques so called CAMST *calibration sample* was made and checked by the MFM working group started during the CAMST programme.
The so-called *mobile miller* (for preparing magnetic suspensions) was developed and moved around various laboratories for preparing samples and carrying out specific characterisation studies.
At the end of the programme a list with strategic areas was made and individual laboratories have started already to discuss together with industries new initiatives for EC programmed like TMR's.

Assistance with the development of applications within appropriate EC programmes
During the programme many discussions have been made with industrial representatives during general and topical meetings. In February 1996 we agreed to make a list of the most important subjects to be carried out for the recording industry in Europe together with Universities.
The following topics have been selected for discussion with potential industrial partners:
- Advanced Hard Disk Media
- Ultra Clean Deposition
- Tape Recording
- Tribology
- Nanostructures
- Micromagnetism,
- Heads, Micromagnetism and Sensors

Some of the subjects have been already proposed, either for an EU programme or a national funding programme. Others are in preparation.

Involve European SME's in the research, by informing them of the programme through the Newsletter, and by developing activities directly aimed at the SME's.
The industrial background to manufacture magnetic storage media is that the commodity products (audio and video cassettes, floppy disks) which represent more than 80% of the industry's factory gate turnover, are at mature or very mature stages of their life cycles. The consequent over-capacity, price erosion, and competition from proliferated plants in Asia, have made survival for European SMEs in media manufacture very difficult. At the moment there are very few of them. Against this, there is a very large number of SMES engaged in activities which are ancillary to the actual manufacture, and it has been the policy of CAMST since its inception to involve these as far as possible in our activities. In general we have found that it is extremely difficult to get in contact with SME's. Moreover it was found that the few SME'S that we get contact with, want to use CAMST for trouble shooting and that is not the aim of CAMST.

Take steps aimed at follow-up activities beyond the duration of the programme,
We know that on individual basis many CAMST laboratories are involved with various European programmed. Moreover one can expect new applications in the near future.

Take responsibility for reporting to the commission.
The Steering Committee has in collaboration with the organizing body and other participants, published reports on the results of all the General and selected Topical Meetings. It has ensured

appropriate diffusion of the reports. The Steering Committee has provided the required reports made with a view to informing the Commission of the European Communities of the progress of the programme.
The Scientific and Technical results of the programme have been reported in the normal way through scientific journals and oral contributions during international conferences. The Steering Committee has ensured that CAMST and the Commission of the European Communities Brite-Euram programme are acknowledged. This has been done by the Newsletter READ/WRITE as well as presentations at different meetings.

Steering Committee Meetings
For the coordination of the CAMST programme 19 Steering Committee Meetings have taken place. Of all these meetings a report has been made.

Spin-offs
As stated above during the CAMST programme several EU projects have been submitted/started. Furthermore during the programme a substantial amount of national projects have been started. Also a number of bilateral projects between individual laboratories and industries were initiated. In order to have some kind of continuation for the CAMST programme, a world wide web site has started. We hope there will be enough funding for his project in order to keep the pages on the internet.

Conclusions
The main conclusion of this programme is that a very efficient European network has been established in the field of recording technologies. Most of the companies do know the existing of CAMST and have been involved in our activities. Many bilateral co-operation with one of the CAMST laboratories are still running.
They have showed a great interest in our activities and very often they supported us with special samples and they also co-operated in our exchange programme and with their measuring facilities. Moreover the presence of two industrial co-ordinators in our steering committee has influenced the industrial contacts a lot. Many suggestions and solutions have been given by these two colleagues.

The introduction of the *Short Term Exchanges* have established many contacts between the groups and many new activities have been reported by using tine special methods from one and another laboratory. The number of joint publications has been increased drastically. Moreover it has contributed to the educational programme of the young PhD students. It is very clear that the short term exchanges were extremely effective in facilitating discussion within CAMST groups as well as being a very effective way to promote good interactions with industry. A number of very significant collaborations and ideas have arisen from the topical meetings over the years. In our opinion this was one of the most effective areas of CAMST and one in which some future investment would be a good idea.

The *quarterly newsletter Read/Write* was not only a very good communicator between the CAMST laboratories but also between Europe and the rest of the storage technology groups in the world. Due to READ/WRITE we have made contacts with many other laboratories either from Universities or industries all over the world. Moreover finally READ/WRITE was seen as a very important communication journal about recording research and news.

The many *topical meetings in* the most relevant fields of our research have shown that it is in principle easy to contact industries around the table if one offer very interesting presentations and discussions. The reports of the meeting were very attractive also for other groups.

The *CAMST catalogue*, describing the most important points of the research of each group together with the relevant names addresses etc. etc. and which was issued each year with updated information, was a welcome help for all laboratories and industries.

The participating laboratories themselves have benefited from the CAMST programme in various manners: the input from partner labs by exchange of scientists, reports, topical meetings and many personai contacts has helped them to develop their scientific infrastructure, to introduce modern theoretical concepts and experimental techniques more easily and rapidly and to improve their expertise. In this sense it is safe to say that the collaboration within the CAMST programme has contributed to a remarkable progress in research on thin film magnetism in Europe in recent years.

Acknowledgements
The work done in the CAMST programme was only possible because a lot of people' spent a lot of effort in this programme.
First of all I would like to thank the Steering Committee for all their ideas and input on co-operation within the CAMST programme. This committee was in all ways the driving force behind the activities within CAMST.
Without the co-operation of all the different laboratories the umbrella organisation CAMST would not have been such a success. The motivation to share ideas, to share results in order to make a larger step forward was essential for the magnetic research in Europe. The contributions of the magnetic industry in Europe gave the laboratories the opportunity to collaborate with market focused research and technology.

Finally I would like to thank the European Community for the funding of this programme. Without this funding the magnetic research would not been as co-ordinated as it is at the moment.