FNSNF

Schweizerischer Nationalfonds
Fonds national suisse
Swiss National Science Foundation

MaNEP Newsletter

Materials with Novel Electronic Properties

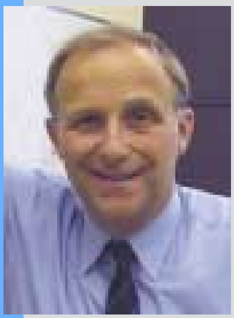
Contents :

Message of the Director
Presentation of MaNEP
Research Network & Members of the MaNEP Forum
Scientific Article - MaNEP Partner
Recent Highlights - World & MaNEP
Event

No. 1, Fall 2001

MaNEP is a National Centre of Competence in Research (NCCR) with the University of Geneva as Home Institution
The NCCR are managed by the Swiss National Science Foundation on behalf of the Federal Authorities

Message of the Director



For the scientific research in Switzerland the year 2000 was not only the entrance into a new millennium but also the establishment of a new form for organising scientific research. On December 18, 2000 the Swiss ministry for interior affairs announced the 10 first National Centres of Competence in Research (NCCR). The project « Materials with novel electronic Properties » (MaNEP) is one of the 10 selected in this first round. The University of Geneva is the Home Institution of MaNEP which is organised in a network of participating groups from major universities, institutes and industries in Switzerland. This first Newsletter is dedicated largely to the presentation of MaNEP.

According the Swiss National Science Foundation on which the NCCR depends, the basic idea behind this new research instrument is "the promotion of scientific excellence in areas of major strategic importance for Switzerland. It will promote projects at the leading edge of scientific research with a particular focus on interdisciplinary approaches as well as innovative approaches within the different disciplines". The selection of MaNEP as an NCCR is for us a remarkable stimulation, encouragement and challenge to develop an efficient and high level research programme.

In addition to the research itself the NCCR also has the mission to stimulate synergies between the participating teams, to contribute to the education of young researchers and to actively pursue knowledge transfer by establishing contacts with industry and other institutions. To this end MaNEP has established an "Information Network" and this Newsletter is one of the actions to stimulate the corresponding contacts. The Newsletter shall regularly inform on advances in our field both concerning basic research and developments towards practical applications. It is meant for a broad readership inside and outside MaNEP.

MaNEP started its activities on July 1, 2001 and I would like to take this opportunity to thank the Swiss National Science Foundation and the many people in our Research Network and at the University of Geneva who helped us in this establishing phase. My special thanks to the editorial team of this first MaNEP Newsletter.

Øystein Fischer

Presentation of MaNEP

WHAT IS MaNEP ?

MaNEP is a National Center of Competence in Research (NCCR) on Materials with Novel Electronic Properties. It is organised as a research network of collaborating partners in Switzerland.

Recently launched by the Swiss National Science Foundation, MaNEP is a long term program to promote the study of the fundamental properties of new materials, to develop techniques for their synthesis, and to prepare for their applications. The leading house is based at the University of Geneva. The Director of MaNEP is Øystein Fischer, professor at the Department of Condensed Matter Physics of the University of Geneva. The participants of the research network are from the swiss academic institutions and industries indicated on the map.

WHY MaNEP?

History shows that major advances in technology are often made possible by breakthroughs in material science. Research related to materials, and training of students in this field are essential factors in providing cutting edge leadership in the ever increasing high-tech oriented industrial competition.

Remarkable examples of new materials are the high temperature superconductors, materials showing colossal magneto-resistance, ferroelectrics, materials based on condensed carbon structures like fullerenes and nanotubes, intermetallics and organic metals. Most are a result of keystone discoveries made over the last two decades.

These materials have great potential for future applications and shall undoubtedly play an increasing role in future technology. MaNEP establishes a strong research effort in this field and promotes the training of scientists and students involved in the research programmes.

RESEARCH PROGRAMMES

MaNEP is an innovative effort guided by three visions and challenges :

- *The development of our understanding of materials with complex structures and strongly correlated electron systems.*
- *The promotion of new opportunities for experiments and applications using these materials.*
- *The creation and control of new materials, in various forms.*

To address these issues, MaNEP is based on 5 research programmes :

A. Complex oxides and other emerging materials for future electronic technologies
With device dimensions approaching the nanometer scale, oxides and other novel materials will play an important role in future electronic technology. This programme will investigate the preparation, characterisation, and physical properties of a variety of compounds with a potential for future applications.

B. Strongly interacting and low-dimensional electron systems
Many of the new phenomena observed or discovered in recent years are due to unusual interactions, to phase transitions or to the low-dimensionality of the materials. This programme aims at an understanding of the possible ground states of condensed matter in these strongly interacting electronic systems.

C. Electronic properties of high temperature superconductors
High temperature superconductivity is one of the most extraordinary discoveries of the last century. This programme aims at an understanding of the microscopic nature of this phenomenon.

D. Vortices, mesoscopics, and nanostructures
The strong spatial variations of some physical parameters and the small size of the objects considered both for practical large scale applications as well as future nanosized devices are important aspects of the new materials. This programme aims at an understanding of how meso- and nanoscopic effects influence the properties of novel electronic materials.

E. Superconducting materials for industrial applications
Applications of superconductivity are a major challenge for future innovation in energy storage, transport, as well as in high-technology electronic devices. This programme aims at developing materials for high magnetic fields and high power applications as well as for other potential applications of high temperature superconductors.

In the next pages, we present a list of the members of the MaNEP Forum with the title of their respective scientific programmes. The Forum is an assembly of all the project leaders and associates, who form the research network established within MaNEP to address all these challenges.

THE INFORMATION NETWORK

An **Information Network** has been set up with the purpose to develop contacts between the scientists of MaNEP and any other person or institution in Switzerland interested in materials with novel electronic properties.

We have the pleasure to welcome more than 20 swiss industries which have already subscribed to our information network.

Anyone who wishes to be informed of the activities of MaNEP, desires to receive the announcement of our meetings and conferences, or wants to receive our periodic reports and newsletters, shall contact the MaNEP management (see last page for the address).

MaNEP

Research Network & Mem

Superconducting and Magnetic Properties of Complex Oxides.

Prof. Ø. Fischer, University of Geneva
Director and project leader

Nanoscale Dielectrics and Mesoscopic Properties of Superconductors.

Prof. M. Büttiker, University of Geneva
Project leader

Thermodynamics and Critical Currents in Superconducting Tapes and Wires for Industrial Applications.

Prof. R. Flükiger, University of Geneva
Project leader

Electronic Transport in Novel Materials.

Dr. L. Forrò, EPFL Lausanne
Project leader

High-Resolution Photoemission of High-Temperature Superconductors and Other Low-Dimensional Correlated Systems.

Prof. G. Margaritondo, EPFL Lausanne
Project leader

Transmission and Scanning Electron Microscopy Facility for Materials with Novel Electronic Materials

Prof. Ph. Buffat, EPFL Lausanne
Project associate with Prof. J.-M. Triscone

High Tc Superconductors for a New Class of Power Electronic Devices.

Prof. M. Hasler, EPFL Lausanne
Project associate with Prof. R. Flükiger

Study of the Superconductor-Insulator Transition of Underdoped Cuprates.

Prof. P. Martinoli, University of Neuchâtel
Project leader and member of advisory board

Isotope and Pressure Effects in High-Temperature Superconductors.

Prof. A. Furrer, ETHZ Zürich & PSI Villigen
Project leader

Properties of Underdoped High Tc Superconductors.

Prof. H. Beck, University of Neuchâtel
Project associate with Prof. P. Martinoli

µSR-Spectroscopy on New Magnetic Materials.

Dr. A. Schenck, ETHZ Zürich & PSI Villigen
Project associate with Prof. A. Furrer

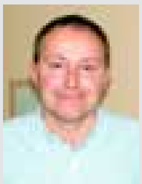
Superconductivity in Power Electrotechnology.

Dr. W. Paul, ABB
Project associate with Prof. Ø. Fischer
Member of advisory board

ers of the MaNEP Forum

Specific Heat and Thermal Conductivity of Novel Materials in Thin Film and Crystalline Form, in High Magnetic Fields and at High Pressures.

Prof. A. Junod, University of Geneva
Project leader

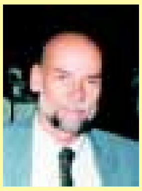


Ferroelectric Based Superlattices and Nanoscale Dielectrics.

Prof. J.-M. Triscone, University of Geneva
Deputy director and project leader

Superconductivity on the Micro-, Meso-, and Macroscopic Scale.

Prof. J.W. Blatter, ETHZ Zürich
Project leader



Synthesis of Magnetic and Conducting Nanoscopic Particles as well as their Organization into Functional Arrays.

Prof. R. Nesper, ETHZ Zürich
Project leader

Influence of Externally Controlled Parameters on the Properties of Metals with Strong Electron Interactions.

Prof. H.-R. Ott, ETHZ Zürich
Project leader and member of advisory board

Theoretical Modelling of Materials with Novel Electronic Properties.

Prof. T.M. Rice, ETHZ Zürich
Project leader and member of advisory board

Superconducting Wires for High Field NMR Applications.

Dr. D. Eckert, BRUKER
Project associate with Prof. R. Flükiger

Probing Microscopic Magnetic Properties of Novel Superconducting and Magnetic Materials with Low-Energy Muons.

Prof. H. Keller, University of Zürich
Project leader

Geometrical and Electronic Structure at and Near Surfaces of Materials with Novel Electronic Properties.

Prof. P. Aebi, University of Fribourg
Project leader

Materials for Emerging Technologies.

Dr. J.G. Bednorz, IBM Research Laboratory, Rüschlikon
Project leader

Carbon Nanostructures and the Role of Hydrogen for Novel Electronic Materials.

Prof. L. Schlapbach, University of Fribourg
Project leader

Charge Disproportionation in Low-Dimensional Systems.

Prof. D. Baeriswyl, University of Fribourg
Project associate with Prof. T.M. Rice

Scientific Article

Fault Current Limiter based on High Temperature Superconductors

M. Chen, M. Lakner, L. Donzel, J. Rhyner, W. Paul, ABB Corporate Research Ltd, Switzerland

Research Group

The global technology group ABB employes around 8'100 people in Switzerland. It serves manufacturing, process and consumer industries as well as utilities.

ABB Switzerland focuses on the development and sale of IT-assisted automation systems and solutions as well as high and medium voltage equipment.

One of the group's eight research centers is located in Switzerland in Baden-Daettwil. It employs some 165 people from over 20 countries. Two-thirds of them are scientists.

Corresponding Author:
Dr. Makan Chen
makan.chen@ch.abb.com

ABB
www.abb.com

High Temperature Superconductivity (HTS) is being explored for current limiter application because of its strong non-linear *E(j)* characteristics. ABB has recently developed a 6.4 MVA Superconducting Fault Current Limiter (SCFCL).

Introduction

Main benefit can be realised if the short circuit currents can be reduced in electrical power systems. SCFCL is ideal for such application, i.e. negligible impedance in normal operation and passive limitation of fault current through the superconducting to the normal conducting transition.

Presently the largest HTS prototypes utilise Bi-2212 ($Bi_2Sr_2CaCu_2O_{8+\delta}$) bulk material [1, 2]. Other materials being developed include YBCO films and Bi-2223 wires.

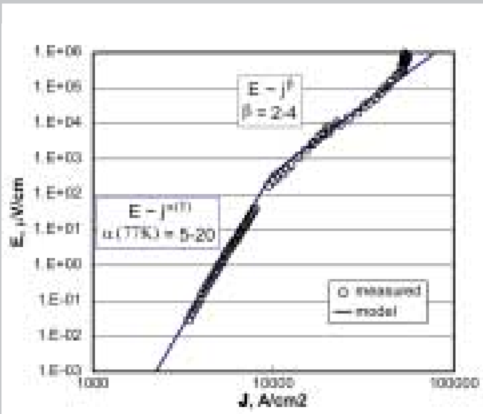


Fig.1: Measured and parameterised E(j) characteristic of Bi-2212 at 77K.

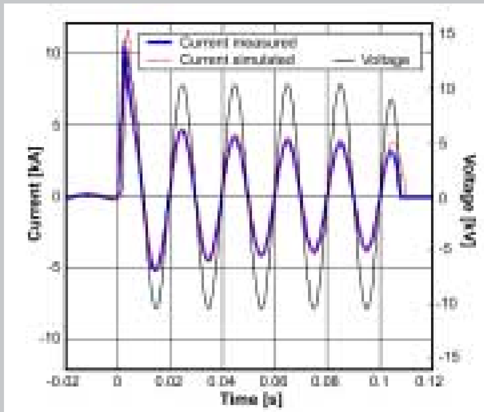


Fig.2: Short-circuit test of 6.4 MVA SCFCL based on Bi-2212.

E(j,T) characteristic of HTS

As the most critical parameter, the *E(j)* characteristic of Bi-2212 is shown in Fig. 1, where two regions with the high and low power laws correspond to the superconducting and the flux flow states, respectively. Not shown here is the normal conducting state, which appears at higher current. Such behaviour can be parametrised (Fig. 1), forming the basis for simulation.
During a fault, the current is effectively limited by the fast increase of resistance with increasing current, i.e. *j*, which also leads to warming-up and even quench of HTS.

Conductor based on Bi-2212

For resistive type SCFCL long length HTS conductor is directly connected in series to the line. Such conductor should exhibit (1) low ac-losses (2) high mechanical strength to withstand transient stresses and (3) thermal stability to avoid "hot-spots". ABB has developed a low AC-losses composite consisting of meandered Bi-2212 plates, steel as electric bypass, and fibre reinforced plastic as reinforcement, which has led to the 6.4 MVA SCFCL demonstrator.

Test and simulation of 6.4 MVA device

A resistive demonstrator rated for 800 A_{rms} has been successfully tested to 8.3 kV_{rms} (Fig. 2), corresponding to a rated power of 6.4 MVA. The single phase device limited a prospective fault current of 20 kA_{rms} to 2.7 kA_{rms} after 100 ms, in agreement with simulation.

Application outlook

SCFCL is particularly suited for applications with high prospective fault current. For example, SCFCL can (a) bring added value to existing grids, where the prospective fault current I_{pf} has reached the design value of the breakers, e.g. grid coupling [2] and (b) enable design of novel power system with high short circuit power. It is believed that niche application of SCFCL will precede large scale application which will arrive with the realisation of both low cost conductor and cost effective reliable cooling.

References

[1] W. Paul and M. Chen, IEEE Spectrum, (May 1998), 49.
[2] W. Paul, M. Chen, M. Lakner, D. Braun, W. Lanz, Physica C 354(2001), 27.

TESTING CHIPS WITH A SUPERCONDUCTING DETECTOR

A Russian-US team [1] has built a superconducting single-photon detector to control the quality of integrated circuits.

Made of ultra-thin (5 nm), very narrow (200 nm) niobium nitride strips maintained at 4.2K, the device detects the infrared or visible photon emitted when a high-speed transistor switches. The photon induces a hotspot on the micro-strip, leading to the formation of a resistive barrier in the superconducting material. The resulting voltage pulse is easily measurable. Characterized by a band-width of 20 GHz, the device exhibits a quantum efficiency of 20% for 810 nm photons and negligible dark counts. This work confirms that superconducting devices offer an unique choice for fast and ultra-sensitive optical detection because of their quantum nature and low-noise (cryogenic) operation environment.

Reference :

[1] G.N. Gol'tsman et al., Appl. Phys. Lett. 79 (2001), 705.

BOOST OF Tc IN BUCKY BALLS

A team from Bell Laboratories, University of Konstanz and ETH Zürich has reached a superconducting transition temperature (Tc) of 117 K in lattice-expanded C60 [1]. This represents the most significant increase of Tc achieved in fullerenes.

It is generally thought that superconductivity in C60-based materials is mediated by the electron-phonon interaction. In this model, Tc depends on the electronic density of states which, in fullerenes, is determined by the distance between adjacent molecules. Expanding the lattice increases the density of states, resulting in an increase of Tc. In the present experiment, the lattice expansion has been performed by intercalating chloroform and bromoform into C60 single crystals. Using a field-effect transistor geometry which has recently lead to discover superconducitvity in organic polymers [2], high densities of electrons and holes have been induced by gate-doping in the expanded fullerenes. The authors think that values of Tc higher than 150 K could be achieved if one could further increase the lattice parameter by ~ 1 %. Will the fullerenes go beyond the cuprates and become the materials with the highest Tc?

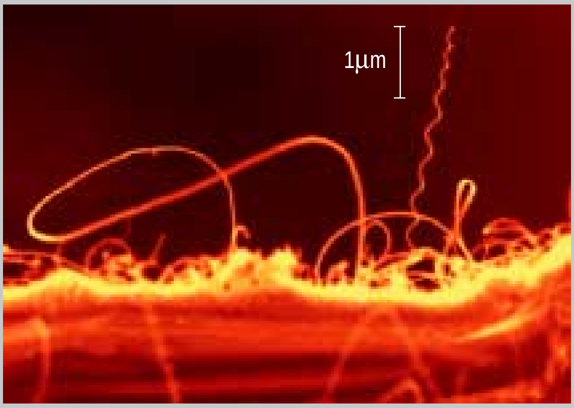
References :

[1] J. H. Schön, Ch. Kloc and B. Batlogg, Science, 30 August 2001 (10.1126/science.1064773).
[2] J. H. Schön et al., Nature 410 (2001), 563.

INTEGRATED CIRCUITS MADE OF CARBON NANOTUBES: SOON ?

A team from IBM Watson Research Laboratories has put together p- and n-type nanotube transistors to form a logic NOT gate. This spectacular achievement is a step towards more complex circuits. It opens the way to an alternative technique to silicon-based microelectronics [1].

Carbon-based transistors are orders of magnitude smaller than silicon-based ones, they are stronger than steel and chemically stable. The big challenge for the new approach is to find a way to arrange nanotube transistors to build logic circuits. IBM's breakthrough bypasses the slow process of manipulating individual nanotubes one by one, opening the way to more suitable manufacturing processes. "This is a major step forward in our pursuit to build molecular scale electronic devices" said P. Avouris, manager of IBM's Nanoscale Science Research Department [2]. The IBM team has developed a technique called "constructive destruction" to generate entire arrays of semiconducting nanotubes. Metallic nanotubes also show other surprising properties: superconductivity has been recently observed in ropes of single-wall nanotubes [3]. Besides IBM, many other groups are working worldwide on nanotube-based field effect transistors, like C. Dekker in Delft [4], C. Schönenberger in Basel [5], and others. "Bearing in mind the exceptional field emission, mechanical and electronic properties of carbon nanotubes, there is no doubt, these are strategic materials for the 21st century" says L. Forrò MaNEP project leader from the EPFL [6].



Scanning electron microscopy image of carbon nanotubes. The "multi-wall" nanotubes are 5μm in length and 20nm in diameter. Ch. Emmenegger et al., University of Fribourg, Switzerland.

References :

[1] P.G. Collins et al., Science 292 (2001), 706.
[2] IBM Research News, Yorktown Heights, N.Y., April 27, 2001.
[3] M. Kociak et al., Phys. Rev. Lett. 86 (2001), 2416.
[4] A. Bachtold et al., Science, submitted.
[5] M. Krüger et al., Appl. Phys. Lett. 63 (2001), 1291.
[6] L. Forrò and C. Schönenberger, Europhysics News 32/3 (2001), 86.

Recent Highlight - MaNEP

WILL THE MEMORY OF THE FUTURE GO FERROELECTRIC ?

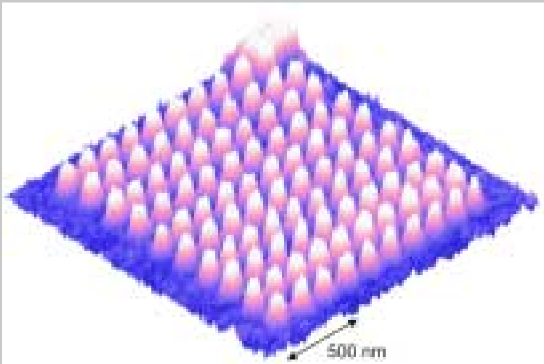
A team of the MaNEP research network from the University of Geneva has demonstrated that atomic force microscopy (AFM) can be used to precisely manipulate individual sub~50 nm ferroelectric domains in ultra high density arrays on high-quality epitaxial $Pb(Zr_{0.2}Ti_{0.8})O_3$ thin films, with writing times down to 100ns [1].

The search for novel high density storage techniques has triggered an interest in the use of AFM for nanoscopic read/ write operations in different media. An appealing approach is to locally control the polarization of ferroelectric oxides in a reversible fashion using an AFM. $Pb(Zr_{0.2}Ti_{0.8})O_3$ thin films have been recognized as a promising candidate for nonvolatile memory applications, and it has been shown that large areas control of the ferroelectric polarization is possible in this material [2]. By studying the relation between writing time and domain size, a logarithmic dependence was found for domains larger than the typical tip size, Ø ~ 40nm, suggesting an activated process similar to vortex creep in high tempe-rature superconductivity. This recent result indicates the key parameters minimizing the domain size, and suggests that information densities of at least 40Gbit/cm^2 are feasible.

References:

[1] P. Paruch, T. Tybell, and J.-M. Triscone, Appl. Phys. Lett. 79 (2001), 530.

[2] T. Tybell, C. H. Ahn, and J.-M. Triscone, Appl. Phys. Lett. 72 (1998), 1454.



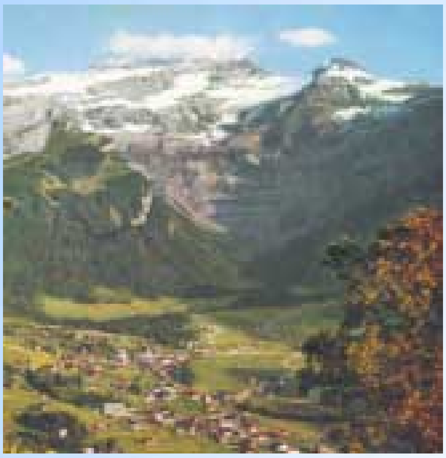
High-density array of AFM written ferroelectric domains on an epitaxial $Pb(Zr_{0.2}Ti_{0.8})O_3$ thin film.

Event

SWM01 - Les Diablerets, Switzerland

The 2001 Swiss Workshop on Materials with novel electronic properties (SWM01) is the fourth edition of a series of Swiss Workshops on Superconductivity and Novel Metals which were held every second year since 1995.

The conference takes place in Les Diablerets from October 1st to October 3rd 2001. This workshop is supported by the Swiss National Science Foundation and is organised with the purpose to promote exchange and interactions between all scientists involved in the NCCR MaNEP.



The following speakers have been invited: G. Aeppli (NEC, New-York, USA), O.K. Andersen (MPI-FKF, Stuttgart, Germany), Y. Baer (Univ. of Neuchâtel, Switzerland), B. Batlogg (ETH, Zürich, Switzerland), L. Degiorgi (ETH, Zürich, Switzerland), D. Eckert (Bruker, Fällanden, Switzerland), L. Forrò (EPFL, Lausanne, Switzerland), A. Junod (Univ. of Geneva, Switzerland), M. Lippmaa (Tokyo Inst. Technology, Japan), A. P. Malozemoff (American Superconductors, Westborough, USA), A.J. Millis (John Hopkins University, Baltimore, USA), and R. Waser (IWE2-RWTH, Aachen, Germany).

The final program, including the selection of oral and poster presentations are available on the web: **http://www.manep.ch/swm01**

MaNEP Newsletter

No. 1, Fall 2001

Cover Picture

Scanning Tunneling Microscopy image of a 40nm thick film of $SrRu_{0.37}Ti_{0.63}O_3$ grown by rf magnetron sputtering at low temperature.
The terraces are atomically flat, each observed step is one unit cell high (3.93Å).
Image scale 250x350nm.

O. Kuffer et al., University of Geneva, Switzerland.

Editorial Team:

O. Kuffer
M. Kugler
I. Maggio-Aprile
A.A. Manuel

Contact:

MaNEP Management
University of Geneva
24, Quai Ernest Ansermet
CH-1211 Geneva 4
Switzerland

Tél.: (+41 22) 702 62 24
Fax: (+41 22) 702 68 69

manep@physics.unige.ch
http://www.manep.ch