COLLABORATION AGREEMENT

REGISTRO DE CONTRATOS
TOMO 17 PAGINA 77
CONTRATO NUM. 2008-000414

Between:

. The Florida State University , represented by its collaborator, Prof. David Larbalestier
. The Pennsylvania State University, represented by its collaborators, Prof. Xiaoxing Xi and Professor Zi-Kui Liu
. The University of Wisconsin, represented by its collaborator, Professor Paul Voyles
. The Arizona State University, represented by its collaborator, Professor Nate Newman
The University of Puerto Rico-Mayagüez, represented by its collaborator, Professor Oswald Uwakweh
. The Argonne National Laboratory, represented by its collaborator, Dr Maria Iavarone
The University of Genoa, represented by its collaborator, Professor Marina Putti
The University of Naples "Federico II", represented by its collaborator, Professor Ruggero Vaglio
The CNR-INFM, represented by its collaborator, Dr.Carlo Ferdeghini

Referred as "the Parties" in the following,

Considering that:

- The above mentioned Institutions share the interest of developing the research field of superconductivity in magnesium diboride and related compounds
- The above mentioned Institutions have already collaborated in the above mentioned field, as demonstrated by various common publications (Annex 1)
- The above mentioned Institutions have a mutual interest in creating and developing an international co-operation agreement in this area, to pursue a synergistic reinforcement of their individual efforts in research and education ;

<u>The following is agreed:</u>

- to enhance the co-operation in the field of scientific research on superconductivity in magnesium diboride and related compounds , through collaboration in activities of particular scientific interest, as well through the possibility of exchange of experiences in the use of particularly complex technical and scientific equipment;
- to organise joint workshops and study programs
- to increase the exchange of researchers, post-docs and students

The details of the co-operation activities will be developed following the lines indicated in the general program (Annex 2), which forms an integral part of this document.

The Parties will fund their research activities relying on their own budgets;

The Parties will communicate to each other the results of their research and will seek to share the related information so as to encourage development of the field, consistent with the confidentiality requirements of grant or sponsored projects and in regard to Argonne National Laboratory consistent with the requirements of its Prime Contract with the U. S. Department of Energy. Where possible, results will be shared early in the discovery, preparation and publication process and held as confidential until normal presentation or publication ensues, their use in this interim being decided by a collegial agreement.

The researchers, post-docs and students who are exchanged and working in each others' laboratories will be subject to the safety and other rules governing their local Institution.

This Agreement will come into effect upon signing thereof and has a duration of five years. The request for renewal, extension and/or modification, must be submitted for the approval of the authorized officials of the Parties. Any party may terminate its involvement in this collaboration, for any reason, upon thirty days advance written notice to the other parties, to the addresses listed below, unless later amended.

Any disputes arising over interpretation and implementation of this agreement, which cannot resolved in a friendly and informal fashion, will be referred for resolution to a board of mediation consisting of one member from each disputing party signing the agreement and three other members chosen by mutual agreement.

AGREED to by the duly authorized representatives below:

Florida State University

[signature] 10/17/2007
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By: Anthony F. Rock date
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Annex 1

Relevant publications in collaboration among the participants groups:

1. "Significant enhancement of irreversibility field in clean-limit bulk MgB2", Braccini V, Cooley LD, Patnaik S, Larbalestier DC, Manfrinetti P, Palenzona A, Siri AS, APPLIED PHYSICS LETTERS 81 (24): 4577-4579 2002
2. "Very high upper critical fields in MgB2 produced by selective tuning of impurity scattering" Gurevich A, Patnaik S, Braccini V, Kim KH, Mielke C, Song X, Cooley LD, Bu SD, Kim DM, Choi JH, Belenky LJ, Giencke J, Lee MK, Tian W, Pan XQ, Siri A, Hellstrom EE, Eom CB, Larbalestier DC SUPERCONDUCTOR SCIENCE & TECHNOLOGY 17 (2): 278-286 2004
3. "Effect of disorder in MgB2 thin films," M. Iavarone, R. Di Capua, A.E. Koshelev, and W.K. Kwok, F. Chiarella, R. Vaglio, W.N. Kang, E.M. Choi, H.J. Kim, S.I. Lee, A.V. Pogrebnyakov, J.M. Redwing, and X.X. Xi, Physical Review B, 71, 214502 (2005))
4. "Characterization of off-axis MgB2 epitaxial thin films for planar junctions," M. Iavarone, G. Karapetrov, A. Menzel, V. Komanicky, H. You, W.K. Kwok, P. Orgiani, V. Ferrando, X.X. Xi, Appl. Phys. Lett. 87, 242506 (2005)
5. " Microwave intermodulation distorsion of MgB_2 thin films" , G. Lamura, A. Andreone, A.J. Purnell, L. Hao, J. Gallop, F. Chiarella, E. Di Gennaro, R. Vaglio and L. Cohen, Applied Physics Letters Vol. 82, p. 4525-9, (2003).
6. "High-field superconductivity in alloyed MgB2 thin films" ,V. Braccini, A. Gurevich, J. E. Giencke, M. C. Jewell, C. B. Eom, D. C. Larbalestier, A. Pogrebnyakov, Y. Cui, B. T. Liu, Y. F. Hu, J. M. Redwing, Qi Li, X. X. Xi, R. K. Singh, R. Gandikota, J. Kim, B. Wilkens, N. Newman, J. Rowell, B. Moeckly, V. Ferrando, C. Tarantini, D. Marré, M. Putti, C. Ferdeghini, R. Vaglio, and E. Haanappel , Physical Review B, Vol 71, 0125041-4, (2005).
7. "Magnetoresistivity as a probe of disorder in the σ and π bands of MgB2" Pallecchi, V. Ferrando, E. Galleani D'Agliano, D. Marré, M. Monni, M. Putti, C. Tarantini, F. Gatti, H. U. Aebersold, E. Lehmann, X. X. Xi, E. G. Haanappel and C. Ferdeghini, Physical Review B,72, 184512 (2005)
8. "Upper Critical Fields Up to 60 T in Dirty Magnesium Diboride Thin Films" C. Ferdeghini, V. Ferrando, C. Tarantini, E. Bellingeri, G. Grasso, A. Malagoli, D. Marrè, M. Putti, P. Manfrinetti, A. Pogrebnyakov, J. M. Redwing, X. X. Xi, R. Felici, and E. Haanappel, IEEE TRANSACTION on APPLIED SUPECONDUCTIVITY 15 (2005) 3234.
9. "Systematic study of disorder induced by neutron irradiation in MgB_2 thin films" V.Ferrando, I.Pallecchi, C.Tarantini, D.Marré, M.Putti, F.Gatti, H.U.Aebersold, E.Lehmann, E.Haanappel, I.Sheikin, X.X.Xi and C.Ferdeghini, JOURNAL OF APPLIED PHYSICS 101 043903 (2007)
10. "Characterization of neutron irradiated MgB2 thin films by Scanning Tunneling Spectroscopy" ,R. Di Capua, H.U.Aebersold , C.Ferdeghini, V. Ferrando, P. Orgiani, M.Putti, X.X. Xi and R.Vaglio, PHYSICAL REVIEW B 75 , 014515 (2007)

Annex 2

The collaboration involves US groups from 5 Universities and one National Laboratory and Italian groups from 2 Universities and one National Institute, which will be indicated in the following as:
The Penn State University (PSU)
The Arizona State University (ASU)
The Florida State University (FSU)
The University of Wisconsin,(WU)
The University of Puerto Rico-Mayaguez(PRU)
The Argonne National Laboratory (ANL)
The University of Naples "Federico II" (NU)
The University of Genoa (GU)
The CNR-INFM

Program description

1 Overview

1.1 MgB_2: a multiband superconductor with great potential for applications
In 2001, Nagamatsu et al. found that MgB_2 is a superconductor with a surprisingly high transition temperature T_c = 39 K. Soon afterwards, it was found that MgB_2 is a conventional superconductor, but unlike other conventional superconductors, it has weakly interacting multiple (σ and π) electron bands and two superconducting energy gaps. The high transition temperature makes MgB_2 very promising for electronic applications. While no reproducible Josephson junctions with stable properties have been made using high temperature superconductors, MgB_2 has great promise to replace the current workhorse, the Nb-based superconducting integrated circuits, and operate at much higher temperatures. The multiband nature of MgB_2 leads to some extraordinary properties, such as the high upper critical field H_{c2}, that far exceeds the performance of Nb-based superconductors currently used in superconductor magnets, for example in MRI systems. A cryogen-free MRI system made possible by MgB_2 will have tremendous impact on health care in the US and Europe as well as in developing countries and remote areas.

1.2 Breakthrough advances in MgB_2
High-quality materials are needed for basic and applied research of MgB_2.
The Penn State group, developed the HPCVD technique that successfully overcomes the major difficulties in the MgB_2 film deposition. The MgB_2 thin flms deposited by HPCVD are epitaxial (single-crystal-like), clean (low resistivity), and with high T_c (even higher than in the bulk MgB_2 due to strain). The quality of the HPCVD films are by far the best in the world. For high magnetic field applications, a high value of H_{c2} is critical. The H_{c2} of carbon-doped films is as high as over 60 T, and extrapolates to higher than 70 T at 0 K, a value of tremendous potential impact in magnet applications.
The Genoa group developed a technique to produce clean (low resistivity) a dense bulk materials and succeeded to introduce disorder systematically by substitution (C in sites of B, Al and Li in sites of Mg) and neutron irradiation. Moreover, the Genova group has carried out one of the major efforts in the world to fabricate high field MgB_2 conductors by a powder-in-tube (PIT) technique, and obtained very promising results, (J_c(5 K)= 10^4 A/cm^2 @13 T).

1.3 Issues and opportunities in MgB_2 research
The major issues currently facing the MgB_2 community, which also represent opportunities of future major advances, include the following: (a) manipulation of scattering rates in σ and π bands individually and in a controlled way in order to improve MgB_2 properties; (b) understanding multi-band effects on a variety of properties of MgB_2; (c) understanding new physics due to the existence of two order parameters (two energy gaps) in MgB_2; (d) fabrication of MgB_2/barrier/ MgB_2 tunnel

junctions and study the two-gap effects in them; (e) characterize microwave surface resistance and nonlinearity of MgB_2 and the two-gap effects in these properties; (f) understanding the growth mechanism of MgB_2 to achieve films of different microstructure, morphology, and orientations; (g) exploring different doping/alloying approaches to obtain high H_{c2} and high critical current; and (h) developing practical technologies for high field MgB_2 material. By forming a partnership between the strongest US and Italian groups, we will be in the strongest position in the world to tackle these issues and take advantage of all opportunities in this exciting new field.

1.4 Objectives of the project

The research objectives of this partnership are to understand the multiband effects in MgB_2using thin films of controlled degrees of doping and defects, to explore the potential for electronic devices such as Josephson junctions and microwave devices, as well as single crystals and high quality bulk materials to develop the scientific and technological foundation for high field superconductors. The uniqueness of this partnership rests on the close collaboration already established between several of these world-renowned US and Italian groups, which substantially extends the technical capabilities of each group involved. The objective of the education activities is to provide additional international research and cultural experiences to undergraduate and graduate students who will spend times in the US/Italian groups, as well as to other students, postdocs, and faculty through a range of communication technologies and research/social events. We already understand the value of these experiences since PhD students from Genoa and Naples have spent significant fractions of their PhD studies at Argonne, Penn State and Wisconsin.

2 Proposed research activities

1. HPCVD MgB_2 films of different microstructure and morphology (PSU)

Using the new HPCVD technique , large area MgB_2 thin films, multilayers and superlattices will be grown. We will study the growth mechanisms of MgB_2 films under various parameters such as substrate, temperature, growth rate, etc. The orientation, microstructure, and morphology, which are important for basic studies of multigap effects and for devices, with be systematically characterized in films made under different conditions.

2. Alloying/doping and irradiation of MgB_2 (GU, FSU, PSU, CNR-INFM)

The study of the effect of substitutions and defects on the superconducting properties of MgB_2 is crucial both to the understanding of the two-band mechanisms and to the developing of new strategies to explore higher T_c materials, and to maximize H_{c2} and $J_c(H)$ of the alloyed/doped/ disordered MgB_2 by modifying the microstructure.

3. Upper critical field and anisotropy in clean and dirty MgB_2 (FSU, ASU, GU, CNR-INFM)

The studies on these properties offer insights into the multiband effects in MgB_2, and they are important parameters for high field applications. The scientists involved in the collaboration have studied these properties extensively, utilizing the high magnetic field facilities in Toulouse and Grenoble, Talahassee. This will continue to be a focus of the investigations towards high power and high field applications of MgB_2.

4. Josephson effect in MgB_2 (ASU, NU, FSU, CNR-INFM)

The collaboration includes most prominent experts on Josephson effect in the world. The work will be addressed to achieve major advances in the fabrication of MgB_2 Josephson junctions and understanding the physics and realizing device applications in these devices.

5. Multiband effects and transport properties of MgB_2 (FSU, GU, ASU, CNR-INFM)

Normal-state resistivity, Hall effect, normal-state magnetoresistance, and electronic thermal conductivity of MgB_2 are all influenced by the multiband effects, and will be studied in films, crystals and bulk of different doping and defects.

Tunnelling into MgB_2.by low temperature STM (ANL, NU, CNR-INFM)
Both the US and Italian teams have a long history in the field of tunnelling spectroscopy in superconductors. Cryogenic scanning tunnelling microscope (down to 4K) measurements on MgB_2 will elucidate the mechanism and the role of doping in a multiband superconductor. The high resolution measurements of the two energy gaps by low temperature STM allow study of the effect of doping and clarify the role of several channels of scattering (interband scattering and intra-band scattering).

7. Electrodynamic response of MgB_2 films (PSU, NU).
Studies of the electrodynamic response of HPCVD MgB_2 films will be carried out. The low frequency measurement will be carried out using a single coil mutual inductance technique operating in the MHz region, and the high frequency measurement using resonant cavity techniques operating between 12 and 24GHz. Surface impedance and intermodulation distortion in the HPCVD films will be measured, to asses the potentiality of MgB_2 at microwave frequencies.

8. High field and high-current MgB_2 conductors (FSU, GU, PSU, CNR-INFM).
The critical current has been improved up to now, mainly by the optimization of grain boundary pinning and by the increase of the upper critical field. The introduction of suitable pinning centres could improve largely the in-field behaviour, but it seems to be a difficult task in MgB_2. A common effort in this direction could provide a significant improvement of Jc(B), making MgB2 competitive with other superconductors.
The Genova group fabricate high field MgB_2 conductors by a powder-in-tube (PIT) technique, and Penn State uses a coated conductor approach by HPCVD. In pursuing further advances, the two different approaches will learn from each other in this partnership.

9. Collaborative activities. During this partnership project, each US faculty will visit the Italian groups once for a week, to attend an annual Italian workshop on superconductivity and to conduct discussions with the Italian researchers. We will also utilize the modern telecommunication technologies to hold monthly joint group meetings among the US and Italian groups. Through the partnership, the world best MgB_2 films, by HPCVD from Penn State, become available to the Italian groups. It also brings the world-class expertise on Josephson effect, microwave characterization, PIT MgB_2 wires, etc. from Italy to the US efforts. Thus, it allows us to achieve major advances in MgB_2 research not possible without these collaborations.

3 Proposed education activities

1. Summer visit to US/Italy by undergraduate students.
Each year we will send one or more students to spend the summer in an US/Italian group. The student will have spent the previous summer in education programs in one of the US/Italian groups. During the visit, the undergraduate students will have the opportunity to visit other US/Italian groups. Arrangements for this exchange program will be described in a subsequent writing between the participating parties.

2. One-year research experience in US/ Italian groups by graduate students.
Each year we will send one or more graduate student from the US groups to spend one year in an Italian group and vice versa. The student will be chosen such that the US/Italian group provides expertise in the same area as the student's thesis subject. During the visit, the student will have the opportunity to visit other US/Italian groups and attend conferences in US/Italy. Arrangements for this exchange program will be described in a subsequent writing between the participating parties.

3. Workshops on international research experiences.

Each year upon returns of the undergraduate and graduate student to the US/Italy, we will hold a workshop, attended by other members of the US/Italian groups and invited US/Italian students/scholars. On the workshop the returning students will present their research and cultural experiences while in US/Italy.

4. A kick-off meeting will be held, possibly at the Italian Embassy in Washington, for the formal start-up of the proposed collaboration.