Project No.:15002 Core Institution in Japan:University of Tsukuba

JSPS Core-to-Core Program -Strategic Research Networks-
FY2008 Research Report

Project No.	15002
Research Theme	Nanoscience and Engineering in Superconductivity
Duration of Project	April 1, 2006～March 31, 2009
Core Institution in Japan	University of Tsukuba

Implementing Organizations

Country	Japan
Core Institution	University of Tsukuba
Co-Chair (name and title)	Professor Kazuo Kadowaki
Number of Cooperating Institutions	15
Cooperating Institutions	Keio University, Tohoku University, University of Tokyo, Tokyo Institute of Technology, National Institute for Materials Science, Japan Atomic Energy Agency, RIKEN, Hitachi Advanced Research Laboratory, NEC, Kyoto University, Utsunomiya University, Kyushu University, Yamagata University, Nagoya University, Tokyo University of Science

Country	EU
Core Institution	Katholieke Universiteit Leuven
Co-Chair (name and title)	Professor Victor Moshchalkov
Number of Cooperating Institutions	18
Cooperating Institutions	University of Antwerp, CNRS-CRTBT, University of Bordeaux. Research Center Julich, University of Tubingen, University of Erlangen-Nuernberg, Walther Meissner Institute, University of Naples, Leiden University, University of Twente, University of Madrid, Chalmers University of Technokogy, University de Geneve, ETH, University of Bath, University of Cambridge, Loughborough University, University College of London
Matching Fund	Yes, about 100K Euro

Country	USA
Core Institution	Argonne National Laboratory
Co-Chair (name and title)	Dr. Wai -K. Kwok
Number of Cooperating Institutions	8
Cooperating Institutions	University of Notre Dame, Northern Illinois University, Texas A & M University, The University of Chicago, University of Illinois at Chicago, University of South Carolina, University of California at Davis, University of Illinois at Urbana-Champaign
Matching Fund	yes, about 200kUS$

Result of Program Implementation

Superconducting phenomena exhibiting absolute zero resistance are extraordinary physical realization in metals, in which a macroscopic scale of quantum mechanical coherence develops as a result of strong electron-electron correlations. In order to understand the superconducting phenomena more deeply by utilizing the advanced nano-technology, quests for new superconducting phenomena associated with the quantum coherence and for superconductors with transition temperatures as high as room temperature, and researches of quantum computation, etc. will be pursued based on the fundamental materials science. Especially, two directions are newly emergent and can be considered as most important directions: the LASER operation at THz frequencies associated with the discovery of THz radiation from intrinsic Josephson junction systems in single crystalline $Bi_2Sr_2CaCu_2O_{8+\delta}$ and macroscopic quantum phenomena associated with the quantum computation or quantum information utilizing high-T_c superconductors operating at liquid Helium temperatures. With emphasis on the characteristics of the core institutions and in collaboration with core researchers internationally it is of our final goal to explore a new scientific and technological paradigm for the future scientific society in a quarter of century in advance.

We have set up international collaborative research network organization between three partners over the world (Japan, EU and USA) on Nanoscience and Engineering in Superconductivity (NES) fully utilizing nano-engineering techniques for preparing materials as well as for experimental techniques during past several years.

The following remarkable results have been obtained.

Achievements in FY2008 (Self Review)

We have made a continuous effort on the novel phenomena associated with the superconducting coherence and obtained interesting achievements being important for the applications. Newly emerging phenomena are also considered to be for the future generations. In the following we list only 4 items achieved in FY2008.

1. THz LASER radiation: In order to understand the mechanism of coherent emission of THz radiation from intrinsic Josephson junction system $Bi_2Sr_2CaCu_2O_{8+\delta}$ the directivity of the radiation has measured in the mesas with different geometrical shapes of the mesas. Then, it turns out that the electromagnetic mode is rather simple and the uniform mode is realized in the mesa both in rectangular and circular mesas.
2. Study of macroscopic quantum tunneling (MQT) phenomena using the intrinsic Josephson junction system $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$ artificially engineered into a mesoscopic size. We have found a profound extraordinary high crossover temperature T^* of the order of around 10 K, which exceeds an order of magnitude and is in favor for the quantum phase devices operating at liquid Helium temperature.
3. We were successfully able to understand the mechanism of the BEC(Bose-Einstein condensation) phenomena using the Feshbach mechanism. The condensation mechanism can be applied to superconductivity.
4. We have succeeded in growing a large single crystal of AFe_2As_2 (A=Ca, Sr, Ba)with high quality. This can be used for the study of the electronic state of these iron pnictide compounds. Certainly, this non-cuprate superconductor with T_c of over 50 K will be most interesting materials in coming years.

In addition to these scientific achievements, we organized four International Conefences this year: 1. "*the 6th International Symposium on Intrinsic Josephson Effect and Plasma Oscillation in High-T_c Superconductors*", held in Pohang University of Science and Technology, July 17th-19th, 2008, 2. "*ESF-JSPS NES International Workshop on Nanostructured Superconductors 2008: from Fundamentals to Applications*", held in Freudenstadt-Lauterbad, Germany, September 13th-19th, 3. "*CTC-NES International Mini-Workshop on THz Radiation from Intrinsic Josephson Junctions-The first one Year Anniversary of the Discovery-*", held at Ginza, Tokyo, Japan, November 23rd, 2008, and 4. "*Joint JSPS-ESF International Conference on Nanoscience and Engineering in superconductivity*", held in Tsukiji, Tokyo, Japan, March 23th-26th, 2009. The last one was the final conference for this CTC program.

Future Plan (Measures toward Achieving Research Objectives)

Within the strategic research network organizaion between Japan, EU countries and USA, we plan to extend our researches to more focussed subjects of the currently important problems: THz LASER generation using high T_c superconductor intrinsic Josephson junctions and the macroscopic quantum phenomena utilizing nanotechnology. The former one was originated from our study in 1995 in Japan on the Josephson plasma resonance so that we intend to concentrate on this problem. The latter one is important in the sense of future information technology and quantum computations. Multi-stacking high T_c intrinsic Josephson junctions are considered as a most ideal candidate for these purposes. Furthermore, development of new materials with higher T_c is also very attractive. Room temperature superconductors are desired to be a target materials as an ultimate goal of our research. The recent discovery of novel iron nictide $REFeAsO_{1-x}F_x$(RE=Rare Earth elements), AFe_2As_2(A=divalent metals), FeSe and FeTe, etc. are along with this trend. Both wide overviews of materials from point of view of Physics and Chemistry and detailed calculations based on the various models are needed for. Certainly curiosity and enthusiasm are required for the new development.