Abstract of Presentation

Nanoscience and Engineering in Superconductivity: Emerging new concept in solid state physics from artificially engineered novel materials

Abstract :

Superconductors such as cuprate high temperature superconductors, recently discovered FeAs based superconductors and intercalated carbon superconductors, etc. are comprised of a stack of atomically thin superconducting layers. Combining this layered structure and highly developed today's nanotechnologies it is possible to modify their properties drastically and create an entirely materials. By forming the world-wide collaboration it is our objective that leads to new field of science in superconductivity based on new concept of superconductor materials science using fast developing modern nanotechnology.

A good example can be found in the new development of terahertz radiation from high temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$, which is known as a system of intrinsic Josephson junctions. The phenomena emitting strong, continuous and coherent THz radiation[1)] was discovered in 2007 as a triumph of materials science combined with nanotechnology, which enables us to fabricate micro device structures called as "mesas" for THz radiation. The 1 micron thick mesa contain approximately 760 layers and all these individual layers work as if they were coherent atoms in LASER by synchronizing the phase of the superconducting order parameter. In order to make this synchronized THz radiation, both high quality single crystals and fine nanotechnology are crucially important.

Recently, similar development is going on in various fields of science and technologies: spin tunneling phenomena between ferromagnetic materials and superconductors[2)], Dirac fermion behaviors in graphene and similar quasi-2D materials[3)], topological insulators[4)], macroscopic quantum tunneling for quantum computations, etc. All these subjects are very attractive and newly emerging field, because they involve in new concept of quantum mechanical world in actual materials. We call for world-wide collaboration to focus on these subjects and to create new direction of physics based on nanotechnology.

Another example is seen in an application of nanotechnology to superconductivity, which enables us to create artificially new superconducting materials with entirely new phenomena. For example, micro-structured superconductors have recently been known as excellent meta-materials with versatile properties controlled by number of vortices (*i.e.*, by the strength of a magnetic field)[5)]. Meta-materials give tremendous impact on

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the research field of optics and will grow in another research world and the related fields. This is another important objective of this project to be suitable for the world-wide collaboration.

Considering these points, we plan to make a preliminary group of people to carry out this plan. Three groups are considered in Japanese side: Kadowaki's group in university of Tsukuba will be based on the fundamental research of terahertz radiation from intrinsic Josephson junctions and its application to the various directions, The meta-materials is considered to be a most important direction. Dr. Kakeya's group in Kyoto university will engage in macroscopic quantum tunneling and the related phenomena for quantum computation, professor Takayanagi's group (NIMS and Tokyo university of science) will deal with quantum tunneling junction phenomena between superconductors and semiconductors/magnetic materials. They have an excellent facility for low temperature measurement below 1 K. We seek for partners who are engaging in similar subjects in the EU countries.

This research subject with emphasis on nano-technological engineering is not born today. In fact we had an international collaboration program between Japan, EU countries and USA group promoted and financially supported by JSPS (Japan Society for the Promotion of Science), ESF (European Science Fundation) and DOE (Department of Energy, the USA government), respectively for five years (2004-2008). The project was entitled as Nanoscience and Engineering in Superconductivity (NES) and is still going on only in the ESF side because of continuation of the ESF financial support. It is highly desired that this new JST program would be an excellent opportunity in order to reorganize this sort of international world-wide collaboration, if this project is accepted and approved.

References

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