【Grant-in-Aid for Scientific Research(S)】

Science and Engineering (Mathematical and physical sciences)

Title of Project : Fabrication of Heavy Fermion Superlattices

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Research Area : Mathematical and physical sciences
Keyword : Heavy fermion compound, Correlated electron systems, Superlattice

【Purpose and Background of the Research】

The Ce-based heavy fermion systems represent some of the best examples of strongly correlated electron systems. Although the research of heavy fermion physics has a long history, the investigations had been done mostly on bulk crystals which inherently possess a three-dimensional electronic structure. On the other hand, reduced dimensionality is known to enhance the thermal and quantum fluctuations as well as the mutual interaction between the electrons, which can result in novel phenomena that are not easily observed in three-dimensional systems. The purpose of this project is to fabricate thin films of Ce-based heavy fermion compounds using the molecular beam epitaxy (MBE) technique. The fine control of the deposition rate afforded by the MBE technique has enabled us to prepare superlattices formed by alternating layers of heavy fermion compounds and other normal metals. This allows us to perform an effective 'dimensional tuning' on heavy fermion systems by controlling the thicknesses of various components with atomic scale precision. The availability of these heavy fermion thin films and superlattices thus opens up a new playground for the study of strongly correlated electron physics.

【Research Methods】

This proposal seeks to integrate an STM into our MBE system, which will allow a direct, real space imaging of electronic structures. We note that the quasiparticle interference and the vortex structure imaging using the STM, which are the powerful techniques to investigate the superconducting state, have not been performed on heavy fermion systems yet – our projects are expected to lead to a conclusive determination of the superconducting gap symmetry in this class of materials.

【Expected Research Achievements and Scientific Significance】

Our projects address several topical issues of condensed matter physics. With the combination of high quality thin films and the STM, we can directly visualize the formation of the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) phase. We can also artificially introduce broken spatial inversion symmetry, which is expected to induce the so-called helical state due to the prominence of the Rashba-type spin-orbit coupling. The ability to combine the MBE and STM techniques for an in situ, real space visualization of extraordinary electronic and superconducting states in heavy fermion systems will open a new window to the study of strongly correlated electron systems.

【Publications Relevant to the Project】

- "Anomalous upper critical field in $CeCoIn_5/YbCoIn_5$ superlattices with a Rashba-type heavy fermion interface"
  S. K. Goh, Y. Mizukami, H. Shishido, D. Watanabe, S. Yasumoto, M. Shimozawa, M. Yamashita, T. Terashima, Y. Yanase, T. Shibauchi, A. I. Buzdin, and Y. Matsuda,
  Phys. Rev. Lett. **109**, 157006 (2012)
- "Extremely strong-coupling superconductivity in artificial two-dimensional Kondo lattices"
  Y. Mizukami, H. Shishido, T. Shibauchi, M. Shimozawa, S. Yasumoto, D. Watanabe, M. Yamashita, H. Ikeda, T. Terashima, H. Kontani, and Y. Matsuda,
  Nature Physics **7**, 849-853 (2011);
- "Tuning the Dimensionality of the Heavy Fermion Compound $CeIn_3$", H. Shishido, T. Shibauchi, K. Yasu, T. Kato, H. Kontani, T. Terashima, and Y. Matsuda
  Science **327**, 980-983 (2010).

【Term of Project】 FY2013-2017

【Budget Allocation】 187,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://kotai2.scphys.kyoto-u.ac.jp/index.php