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

Science and Engineering (Mathematical and physical sciences)

Title of Project：Nanoscale Helium Physics and its Applications

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Research Area：Physics, Low Temperature Physics

Keyword：Quantum Condensed Systems, Helium, Superfluidity, Nanoscience

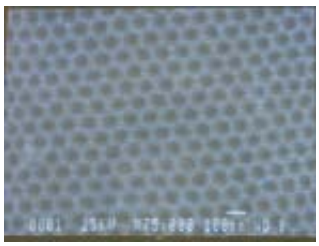
【Purpose and Background of the Research】

Superconductivity and superfluidity are not only fundamental quantum phenomena caused by "symmetry breaking", but a basis of potential applications to quantum coherent devices, such as quantum computer. In this project we study various quantum phenomena of helium (^{4}He) confined in nano-space, such as quantum phase transition and Bose glass,. This will lead to new concepts in condensed matter physics. We develop Josephson device and matter wave interferometer utilizing superfluid suppression of nanoscale helium, and apply the quantum coherent devices to other fields of science.

A new research field "Nanoscale Helium Physics" will be developed by this project.

【Research Methods】

We focus on the following four themes: (1) Study of various quantum phenomena of nanoscale He, such as quancum critical phenomena, superfluid – Bose glass transition, by thermodynamic and mechanical measurements. (2) Utilizing superfluid suppression in nanoscale He, we control superfluid flow properties in nanopore arrays formed in porous alumina. (3) Based on the porous alumina studies, we develop a superfluid Josephson junction device. (4) Finally, we develop a matter wave interferometer, which will be applied to the measurement of earth rotation and search for novel quantum interference effects.



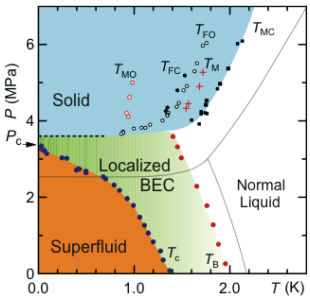
A SEM picture of nanopore array in porous alumina, which is employed in this project.

Two groups, the low temperature physics group at Keio University, and the inorganic chemistry group of Yamaguchi University, collaborate in fabricating the nanoporous structures and the helium experiment.

【Expected Research Achievements and Scientific Significance】

First, this project will reveal a variety of quantum phenomena and states in the nanoscale helium systems. Nanoscale helium will be realized as a unique model system of strongly correlated Bosons, and will provide novel notions in condensed matter physics. Secondly, nanoscale helium will open a way to develop "Helium Nanoscience", particularly by realizing superfluid Josephson devices.

Helium nanoscience is a "neutral – matter" counterpart of electronic nanoscience. Matter wave nature of superfluid helium will lead to a significant progress in other research fields such as geophysics and general relativistic physics.



Phase Diagram of ^{4}He in a nanoporous glass.

【Publications Relevant to the Project】

- K. Yamamoto, Y. Shibayama, K. Shirahama, J. Phys. Soc. Jpn. **77**, 013601 (2008) (Editors' Choice)
- K. Yamamoto, Y. Shibayama, K. Shirahama, Phys. Rev. Lett. **100**, 195301 (2008) (Editors' Suggestions).
- K. Shirahama, K. Yamamoto, Y. Shibayama, J. Phys. Soc. Jpn. **77**, 111011 (2008) (Special Topics).

【Term of Project】 FY2009 - 2013

【Budget Allocation】 168,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.phys.keio.ac.jp/guidance/labs/sirahama/sirahama-lab-jp.html