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

Integrated Science and Innovative Science (New multidisciplinary fields)

Title of Project : The evolution of the positronium beam science using the technique of photodetachment of the positronium negative ion

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Research Area : New multidisciplinary fields
Keyword : Electron・positron

【Purpose and Background of the Research】

The hydrogen atom is a bound state of an electron and a proton. The electron can also bind to a positron, the anti-particle of the electron, to form positronium. Positronium is the lightest "atom" although it self-annihilates into γ-rays with a lifetime of 125ps or 142ns. It has been proposed that an energy tunable beam of positronium will be a powerful tool in investigation of material surfaces. However, the production of a beam with sufficient intensity and appropriate energy range has been difficult to realize. The only beam of positronium produced thus far has been using charge exchange between positrons and gas molecules in the energy range below 400 eV.

In recent years, we have found that the positronium negative ion, a bound state of two electrons and a positron, is emitted efficiently from alkali metal coated tungsten surfaces when bombarded with slow positrons. Since it has a negative charge, the ion can be easily accelerated with an electric field. We have also succeeded in the observation of the photodetachment of the ion. Using this technique, we can produce a positronium beam with the required energies.

Our goal in the present work is the production of an energy tunable positronium beam using these techniques and the development of hitherto unrealized new fields of beam studies. The positronium beam is expected to have a high quality and high intensity.

【Research Methods】

In order to photodetach the positronium negative ion, which has short lifetime (479ps), it must be irradiated with high power pulsed YAG laser light. Two pulsed slow positron beam lines will be used to synchronize with the pulsed laser light. One is the linac based beam, which can be obtained at the Slow Positron Facility in the High Energy Accelerator Organization (KEK). The other is a pulsed slow positron beam using a positron trap. Positrons from the β^+ decay of a ^{22}Na positron source are trapped using a magnetic field and electric fields and extracted as a pulsed beam. The trap based positron beam is compact and can be used even in small laboratories of universities.

【Expected Research Achievements and Scientific Significance】

Since positronium has negative affinity for most materials, the beam will demonstrate its power for the analysis of topmost layers of solids. Furthermore, the beam is not influenced by the charge up of surfaces even if it is incident on insulators. In the present work, we will develop new technologies for the analysis of the topmost layers. In particular, we will establish the technology for the diffraction of scattering positronium at grazing angle incidence from insulators.

We will also endeavor to achieve the basic characterization of the positronium atom and the positronium negative ion, which have not been elucidated completely.

【Publications Relevant to the Project】

・Y. Nagashima, T. Hakodate, A. Miyamoto and K. Michishio, New J. Phys. 10 (2008) 123029.
・H. Terabe, K. Michishio, T. Tachibana and Y. Nagashima, New J. Phys. 14 (2012) 015003.
・K. Michishio, T. Tachibana, H. Terabe, A. Igarashi, K. Wada, T. Kuga, A. Yagishita, T. Hyodo and Y. Nagashima, Phys. Rev. Lett. 106 (2011) 153401.
・K. Michishio, T. Tachibana, R. H. Suzuki, K. Wada, A. Yagishita, T. Hyodo and Y. Nagashima, Appl. Phys. Lett. 100 (2012) 254102.

【Term of Project】 FY2012-2016

【Budget Allocation】 167,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.rs.kagu.tus.ac.jp/ynagahp/