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

Science advances by spin-polarized positron beam

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Project Information	Project Number : 23H05462 Project Period (FY) : 2023-2027 Keywords : Positron spin, matter, lives, cosmos, asymmetry

Purpose and Background of the Research

●Outline of the Research

"Spin-polarized positron beam" has been developed as a unique probe for electron spins in materials. This method is also thought to hold potential in revealing the mysteries of life homochirality and the matter-antimatter asymmetry of universe. In this research project, we pursue the possibility of spin-polarized positron beam in the research from matter, life and to the universe.

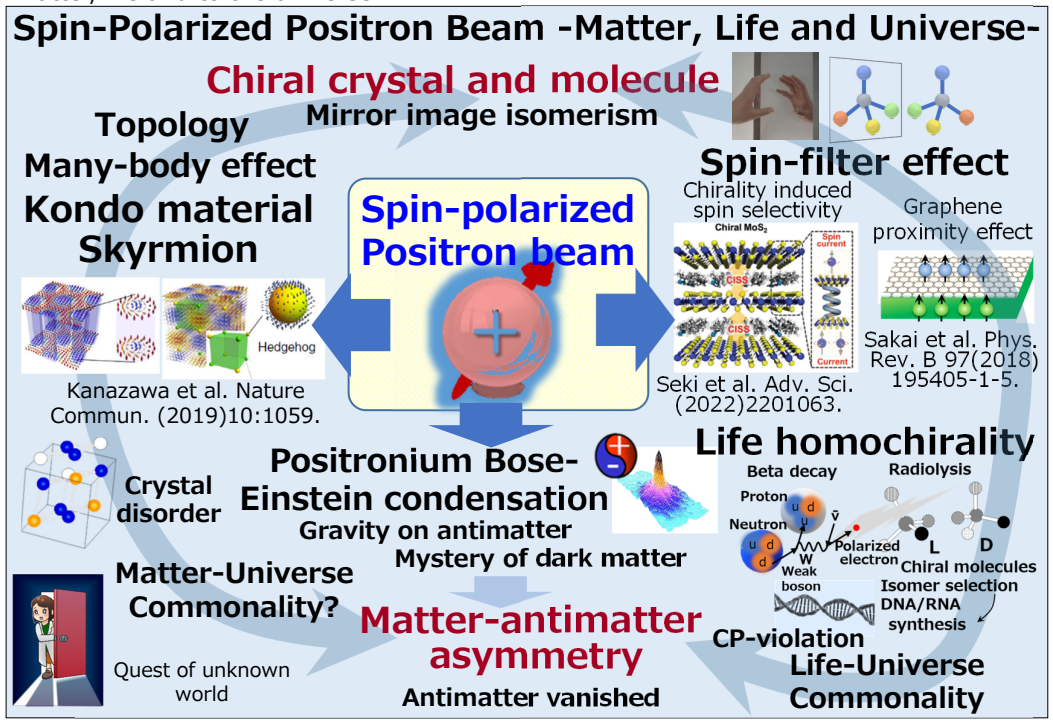


Figure 1. Concept of this project.

●Spin, Chirality and Symmetry breaking

Spin is the particle magnetic moment. Chirality is a topological term of mirror image isomerism. Symmetry breaking is the change of physics rules by mirroring operation and/or reversing charge and time. These things are related to various amazing phenomena like super-conduction, the life's homo-chirality and the matter-antimatter asymmetry of universe. In other words, these might form a universal principle through the hierarchy composed of elementary particles, atoms and molecules, matter and life to the universe.

●Spin, chirality and symmetry breaking revealed by spin-polarized positron beam

A positron and an electron pair-annihilate with emitting gamma rays. The number of gamma rays and their energies depend on the mutual direction of positron and electron spins (Fig.2). Using this characteristics, one can study electron spin, chirality and symmetry breaking.

Figure 3 exhibits an example about Gd-doping effect on GaN, changing non-magnetic GaN to a ferromagnet. In spite of extensive studies, the detailed mechanisms has not been clarified. Spin-polarized positron beam revealed that multiple spins at large vacancy clusters are the source of ferromagnetism.

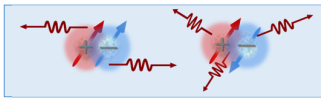


Figure 2 Spin-dependent positron-electron annihilation.

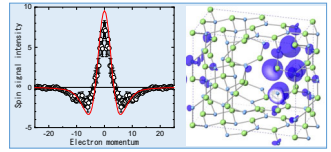
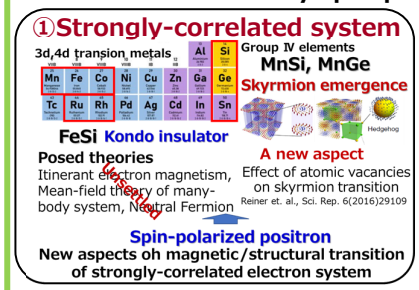
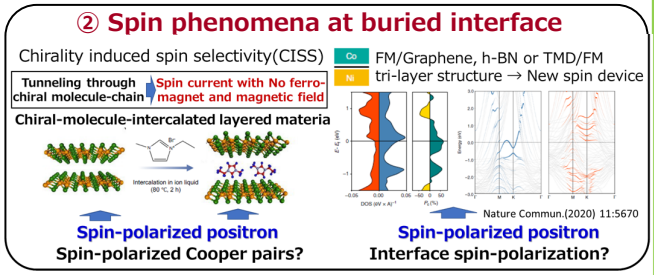


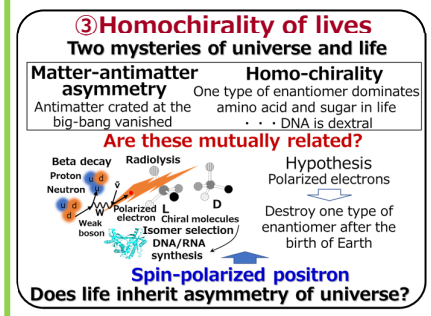
Figure 3 (Left) Spin signal from Gd-doped GaN and (Right) it's origin, spins at vacancy cluster.

Expected Research Achievements

●Materials research by spin-polarized positron

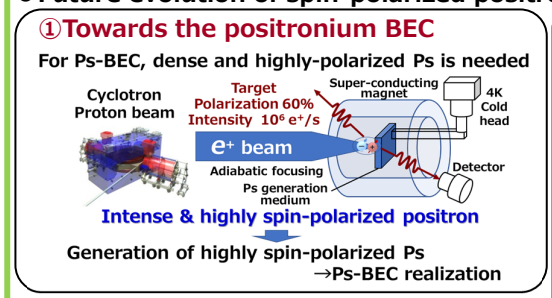


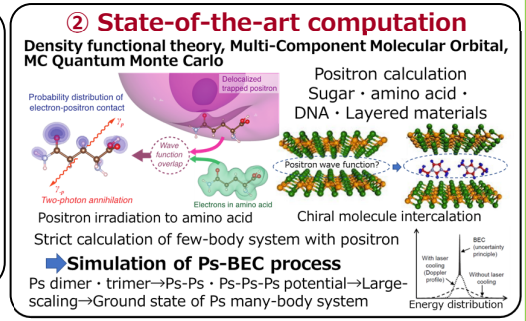




In this research plan, we promote three subjects of materials physics, chemistry and life that spin-polarized positron beam may be effectively applied. First, we reveal various novel spin phenomena in strongly-correlated electron systems and at buried interfaces. Second, we attempt to settle the 40 year's hypothesis that the life homochirality may be originating from the beta-decay. Furthermore, for realizing Ps-BEC, we develop a technology to generate dense and highly spin-polarized positronium and a precise simulation method based on the state-of-the-art computation.

●Future evolution of spin-polarized positron





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