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

Broad Section D

Title of Project： Spintronics based on the Information thermodynamics

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Research Project Number: 20H05666 Researcher Number：50344437
Keyword：Magnetic skyrmion, Information thermodynamics, Spintronics

【Purpose and Background of the Research】

In this research, the concept of "information flow (to be exact, called transfer entropy)" will be introduced into the field of spintronics, which has been focusing on the generation, control, and conversion of "spin currents". By that way, a new field of the spintronics that is based on the information thermodynamics will be established. The new science will be a base to design highly intelligent and energy saving spintronic information devices and systems. (see Fig. 1).

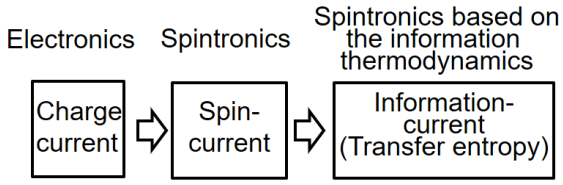

Fig. 1 Paradigm shift from spin current to spintronics that handles information flow (transfer entropy).

【Research Methods】

Specifically, we will realize an information heat engine that uses the thermal motion of the magnetic skyrmion (see Fig. 2), clarify the performance of spintronics elements from an information thermodynamic point of view, and reduce the energy consumption required for the information heat engine. We will pursue ultra-low energy sensing technology. Furthermore, as applications, we will demonstrate the operation of an ultra-low energy consumption spintronics computer. (See Figure 3)

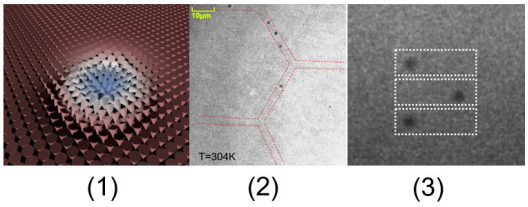

Figure 2 (1) Schematic image of the magnetic structure of the magnetic skyrmion. The vertices of the small cones indicate the direction of magnetization in the thin film (direction of N-pole). (2) Skyrmion channel created using local potential control. Skyrmions smoothly pass through the three-way junctions by Brownian motion without being trapped. (3) Interaction between skyrmions confined in rectangular wells. Skyrmions oscillate between equivalent energy states.

【Expected Research Achievements and Scientific Significance】

Our goal is to elucidate a possibility to realize IT equipment that has the same energy efficiency as biological systems and can process information as much as the human brain by expanding and developing the theory and technology of the spintronics.

In this research, there is engineering significance in creating elements and systems that approach the thermodynamic limits, using information thermodynamics as a guiding principle, rather than simply applying information thermodynamics to the spintronics.

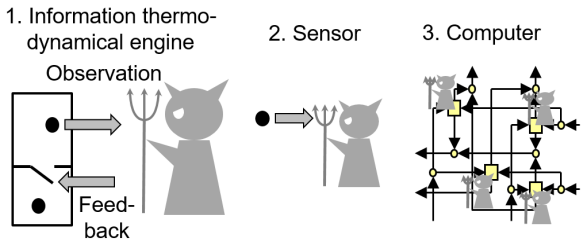

Figure 3 Three R & D subjects of the spintronics based on the information thermodynamics.

【Publications Relevant to the Project】

[1] “Skyrmion Brownian circuit implemented in continuous ferromagnetic thin film”, Yuma Jibiki, Minori Goto, Eiiti Tamura, Jaehun Cho, Soma Miki, Ryo Ishikawa, Hikaru Nomura, Titiksha Srivastava, Willy Lim, Stephane Auffret, Claire Baraduc, Helene Bea, and Yoshishige Suzuki, Applied Physics Letters, 117, 082402 (2020).

[2] “Theory of Skyrmionic Diffusion: Hidden Diffusion Coefficients and Breathing Diffusion”, E. Tamura, Y. Suzuki, arXiv：1907.06926.

【Term of Project】

FY2020-2024

【Budget Allocation】

147,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://suzukilab.jpn.org/