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

Science and Engineering (Interdisciplinary science and engineering)

Title of Project : Controlling and Inducing Magnetism with Electric Field Effects

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Research Area : Applied Physics
Keyword : Spintronics

【Purpose and Background of the Research】

The final goal of this study is to determine a method for furthering the advancement of a new energy-saving intermaterial fusional function that features a highly efficient utility implementation using electric field effects to develop functions that cross material boundaries. In this study, we focus on magnetism for establishing a method to freely manipulate magnetism in typical metals by using electric field effects. We recently discovered that applying an electric field to a 3d transition metal magnet makes it possible to enhance or lose its ferromagnetic order [1,2]. By using this means, it may be possible to electrically convert metals that are not magnets in nature into magnets. This is expected to pave the way for groundbreaking technologies of freely manipulating magnetic properties. In addition, this study is expected to verify and further the understanding of the underlying physics. We lead the field of spintronics through this Scientific Research.

【Research Methods】

Capacitor consists of an insulating layer sandwiched by metallic electrodes. In recent years, forming electrical double layer by using ionic liquid has been utilized to achieve huge capacitance. The basic element structure used in this study is made by using a magnetic metal as one of the electrodes of the capacitor. Applying a voltage to such a structure results in the accumulation of an electric charge in the magnetic metal. This is equivalent to increasing or decreasing the electron concentration on the metal surface by increasing or decreasing the number of electrons initially held by the chemical element. When one of the electrodes is made of cobalt, a 0.1 per atom change in the number of electrons can result in a change in Curie temperature in the range of ±100 K across the room temperature [2]. Understanding such unexpected significant effects is one of the topics of this study.

The second subject in this study is to make non-magnetic metal ferromagnetic. For sake of simplicity, we consider nickel and copper, which are placed adjacent to each other in the periodic table. Nickel is ferromagnetic, although copper is not. If a single electron can be removed from copper, would it be possible to make copper ferromagnetic? The objective is to control the magnetism of the metal freely using an electric field.

We also discuss the application of the above techniques to nano-structures and the energy conservation of magnetic recording elements through magnetization switching by electric fields.

【Expected Research Achievements and Scientific Significance】

It is possible to tune the characteristics of magnets during fabrication. However, controlling the characteristics of a magnet electrically after fabrication has not been possible thus far. Thus, the proposed technique can potentially be a new material searching method. This technique should help to produce a more detailed understanding of the underlying physics of magnetism. Such an understanding can lead to a common technology foundation that would extend “electric field effects” to new technologies based on diverse materials. Furthermore, we also believe that this will lead to future studies on related subjects.

【Publications Relevant to the Project】

[1] D. Chiba *et al.*, Electrical control of the ferromagnetic phase transition in cobalt at room temperature Nature Materials **10**, 853-856 (2011).
[2] K. Shimamura, D. Chiba, S. Ono, S. Fukami, N. Ishiwata, M. Kawaguchi, K. Kobayashi, and T. Ono, Electrical control of Curie temperature in cobalt using an ionic liquid film Applied Physics Letters **100**, 122402 (2012).

【Term of Project】 FY2013-2017

【Budget Allocation】 172,300 Thousand Yen

【Homepage Address and Other Contact Information】

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