【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Mathematics/Physics)

Title of Project： Emergent Iontronics

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Research Area： Solid State Physics

Keyword： Surface/Interface Properties, Strongly-Correlated Electronics, Functional Devices

【Purpose and Background of the Research】

Transistors and batteries are well developed devices, based on physical and chemical concepts, and play crucial roles in modern information technology. This research project is an attempt to establish an interdisciplinary science, "iontronics", which is electronics based on ionic functions, by fusing concepts of transistors and electrochemistry.

【Research Methods】

The key concept is the electric double layer (EDL, Fig. 1), which is formed at the interface between an electric conductor and an ionic conductor (electrolyte) when voltage is applied between them. We have proposed a novel device, an electrical double layer transistor (EDLT), which is a metal-oxide-semiconductor transistors (MOSFETs), using EDL as a gate dielectric. Taking advantage of the huge capacitance and high density charge accumulation by EDL, they anticipated the ability to control electronic phases of solid surfaces, including superconductivity, ferromagnetism, and Mott transitions, by the field effect, providing a versatile concept: Field effect phase control. Other important achievements are materials/chemical developments in the electrolytes and related functional devices.

All these trends strongly indicate that, to strengthen and further develop the related science and technology, this is the right time to launch a project by fusing the two streams in physics, materials, and chemistry, and establish a new interdisciplinary area, which may be called "iontronics".

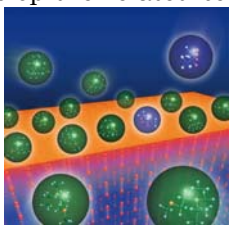

Figure 1 Electric double layer (EDL) formed at the interface between an electric conductor and an ionic conductor

【Expected Research Achievements and Scientific Significance】

The objective of this project is to advance the science and technologies of EDLTs and establish an interdisciplinary area of "iontronics", by strategic collaboration between physicists, materials scientists, and chemists. The project is formed by three subjects. (1) Quantum phase control: Discovery of new states of matter and establishing the methodology for this purpose. Electric field induced control of spin-orbit interaction. (2) Materials study: Search for novel electronic and ionic conductors and their subsequent combinations. (3) Functional device: Fabrication of functional EDLTs such as phase transition FETs, flexible/stretchable/printed transistors, actuators, light-emitting electrochemical cells and high-speed EDLTs (Fig. 2).

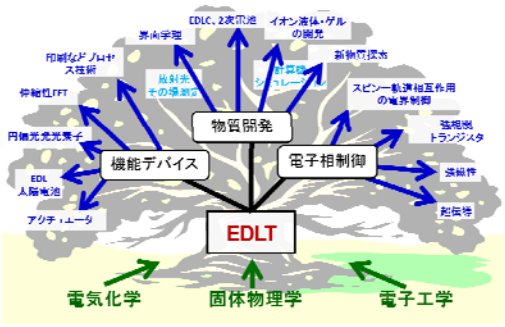

Figure 2 Project scheme

【Publications Relevant to the Project】

"Superconducting Dome in a Gate Tuned Band Insulator", J. T. Ye, Y. J. Zhang, R. Akashi, M. S. Bahramy, R. Arita, Y. Iwasa, Science 388, 1193-1196 (2012).

"Collective bulk carrier delocalization driven by electrostatic charge accumulation", M. Nakano, K. Shibuya, D. Okuyama, T. Hatano, S. Ono, M. Kawasaki, Y. Iwasa, Y. Tokura, Nature 487, 459-462 (2012).

【Term of Project】 FY2013-2017

【Budget Allocation】 472,400 Thousand Yen

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