Field-induced electron spin resonance spectroscopy of organic semiconductors

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Purpose of Research

In recent years, much attention is paid to organic electronic devices based on organic semiconductors due to their flexibility and large area coverage. Typical devices are organic light-emitting diodes, organic transistors and organic solar cells using π-conjugated polymers and small molecules. Among them, organic transistors are drawing interests due to their high mobilities exceeding those of amorphous silicon. The charge carriers of organic transistors accumulate at the interface between the semiconductor and the insulator. Observation of those carriers is an important problem in understanding electronic processes occurring in the device, while their detection in the actual devices is considerably limited because the interface is not easily accessible from the outside of the device.

In this research project, we focus on the observation of charge carriers in organic transistors, by using **field-induced electron spin resonance** (ESR), we have developed, which can detect spins of the charges at the device interface with a high sensitivity (~10^{11} spins). ESR signals provide information concerning electronic states and conduction mechanism of the organic interface, from which we may develop design principles of highly efficient organic devices. In addition, we will search metal transition and spin transition phenomena by high-concentration charge injection using ionic liquids and aim at the development and control of new physical phenomena in organic semiconductors.

Methods

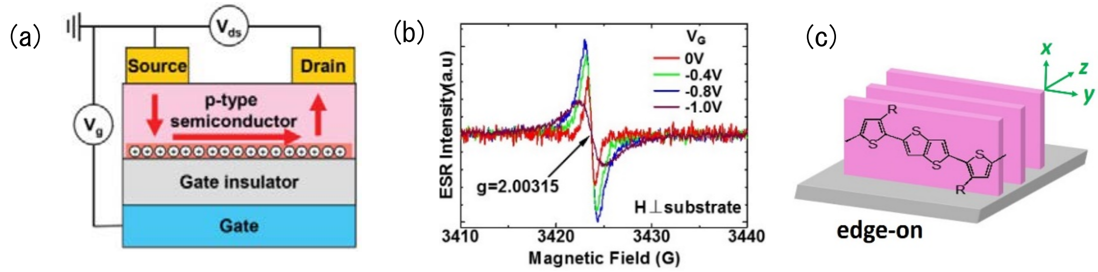

Figure 1 (a) Schematic structure of an organic field-effect transistor with solid gate insulator. (b) Field-induced ESR signals of an ionic-liquid gated polymeric transistor. (c) Molecular orientation of π-conjugated polymers at the device interface.

We first construct organic transistor device structures that fit into ESR cavity. As an insulating material used for the transistor, we mostly employ SiO_2 solid insulating layer on low-doped Si substrates developed by us for ESR measurements that do not deteriorate Q-factor of ESR cavity. We also use ionic liquid insulating films capable of injecting high-concentration charge carriers. As for the organic semiconductors, thiophene-based polymers having high crystallinity or small molecules are used. The electrical characteristics of those devices are measured to obtain the device parameters such as mobility. Then the ESR measurements are carried out on those devices as collaborative research. The g value and the line width obtained from ESR signals are determined and analyzed with the aid of ESR simulation, in collaboration with the theoretical group to determine the electronic or spin states, dynamics of carriers as well as interfacial molecular orientations, which are crucial in determining the performance of devices.

Perspectives

Field-induced ESR is capable of clarifying microscopic information of device interface which is difficult to observe by other methods and contributes to the development of high performance devices. In addition, the transistor structure that can reversibly controls the number of carriers gives a new method of elucidating the structure-function relationship of organic molecular aggregates by carrier injection and contributes to the development of future electronic materials and devices.