MERIT Long-term Overseas Dispatch: Report

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[Summary]

I visited Cavendish Laboratory in Cambridge University in UK, and stayed in Prof. Henning Sirringhaus's group in Optelectronics group for two month to engage in research activities. That research group mainly focuses on charge transport, thermoelectric and magnetic properties of various materials including organic materials, and has been at a leading position in academic society in those research fields. The students and post-doctoral researchers in the group are specialized in various fields such as Physics, Chemistry or Device Engineering respectively, which enables them to study a wide variety of topics. In this report, the research I conducted in the group is briefly described.

[Research Background]

Rechargeable secondary batteries play a significantly important role in a current society in which enormous numbers of portable devices such as smartphones or computers are prevailed. Additionally, considering increasing numbers of electric vehicles, secondary batteries with larger capacities and longer life cycles are desired.

In general, secondary batteries are composed of a positive electrode, negative electrode, electrolyte and separator. Because positive electrodes especially affect performance of the batteries, many kinds of electrode materials have been studied and developed. Nishihara Lab. has been studying metal-organic frameworks (MOFs) that is composed of organic compounds and metals, aiming at battery applications. MOFs generally have a lot of advantages as electrode materials (e.g. highly tunable design of structures and plenty of redox active sites). On the other hand, most kinds of MOFs have quite low electronic conductivity, and MOFs have been considered to be not suitable for electrode materials which necessarily transport electrons for energy storage functions. As a breakthrough of the issue, our group has been developed a novel type of MOFs with two-dimensional layered structure that possess relatively high electronic conductivity and redox activity, allowing them to be promising as electrode materials.

Until now, we reported that the two-dimensional layered MOF, being named NiDI, functioned as an electrode material. This material has a unique property that it is able to undergo multistep electrochemical reactions with both anion and cation intercalations, because NiDI can take several oxidation states. In these reaction steps, we found that each reaction shows different charge transfer resistance, the value of which is lower during the anion intercalation than the cation intercalation. However, the reason why they show different resistance was not revealed.

[Research in Cambridge]

In Prof. Henning Sirringhaus's group, I investigated the electronic properties of NiDI to reveal the mechanism of the phenomenon about the charge transfer resistance described above. As a result, the electronic conductivity of NiDI was found to largely change depending on the redox states of NiDI, which enables us to explain the different charge transfer resistances at respective electrochemical reactions. The results obtained in this research not only lead to deeper understanding of the properties of NiDI as an electrode material, but also suggest that tuning of the redox states further broaden its potential for other applications such as electronic devices.

The research carried out in this two month will be continued in the future as a collaboration research with Prof. Sirringhaus and his group members.

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