Investigation for catalyst ink structure during drying process by CV-SANS

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Polymer electrode fuel cells (PEFCs) are one of the most promising energy sources. Since PEFCs are zero emission devices that convert chemical energy into electricity through a chemical reaction of hydrogen and oxygen, PEFCs are an ultimate clean energy. However, there are several problems to be solved, such as reduction of the cost of Pt catalyst and the durability of the cell. In order to solve these problems, optimization for fabrication process of PEFC electrodes are required. Electrodes of PEFCs are often manufactured from " catalyst ink ", consisting of carbon, platinum, water, and ionomers. Catalyst ink is prepared by mixing ionomer solutions, carbon powder with Pt catalyst, and dispersing solvent, such as water and alcohol. In our previous study, we elucidated the structure of catalyst ink by using contrast-variation small-angle neutron scattering (CV-SANS)[1]. However, PEFC electrodes are manufactured by drying catalyst ink, and it is of particular importance to elucidate the structure evolution in catalyst ink during its drying process. In this measurement, the structural evolution of catalyst ink was investigated by CV-SANS. The scattering functions of the catalyst ink at various concentrations were successfully decomposed to corresponding partial structure factors, SCC(q), SPP(q), and SCP(q) for all ink concentrations (Figure 1), where the subscripts C and P denote carbon and polymer, respectively, and q is the magnitude of the scattering vector. The cross term, i.e., SCP(q), indicates that the microscopic structure of the catalyst ink maintains the clusters of carbon agglomerates surrounded by Nafion during drying process. This result is consistent with other results previously reported.[2] The carbon partial structure factor, SCC(q) indicates that the size of carbon agglomerates decreases with solvent evaporation. The Nafion partial structure factor, SPP(q) indicates that the thickness of Nafion shell becomes smaller with evaporation. Both the shrink of carbon agglomerates and Nafion shell is attributed to the interaction between carbon and Nafion shell. These findings are important for the precise control of catalyst ink towards fuel cell application although the concentrations are limited only for 3 to 11 wt%. It was confirmed that ionic clusters are present even at 1.5 wt% and the inter-ionic-cluster distance becomes smaller by drying. The ionic clusters may percolate to each other as concentration increases and play a role of ion conduction. The confirmation of this hypothesis is an issue of future study.

References

[1] M. Shibayama et al., J. Appl Polym. Sci. 131, 3 (2014)
[2] S. Holdcroft, Chem. Mater. 26, 381-393 (2014)