Imaging of Carbon-Paper Gas Diffusion Layer of Fuel Cells Using Phase-Contrast X-Ray Imaging Technique

For observations of polymer electrolyte fuel cells (PEFCs), measurements of carbon-paper as gas diffusion layers (GDLs) of fuel cell were performed by phase-contrast X-ray imaging via X-ray interferometric imaging (XII) and diffraction enhanced imaging (DEI) techniques. In this study, it was revealed that the XII technique is applicable to in-situ observations of water evolution process due to the reaction of hydrogen (H_2) and oxygen (O_2) in operating PEFCs, and the DEI technique provides a way for the tomographic imaging of GDLs in PEFCs

Polymer electrolyte fuel cells (PEFCs), which convert the chemical energy of hydrogen (H_2) directly into electrical energy, are considered to be one of the most promising energy-conversion devices. In PEFCs, water (H_2O) produced by the reaction of H_2 and oxygen (O_2) plays a crucial role, because PEFCs operate in a moderate temperature range between 60 and 110 °C, which means the water can be in either a gas or liquid phase. In this study, phase-contrast X-ray imaging by means of X-ray interferometric imaging (XII) and diffraction enhanced imaging (DEI) techniques using 35 keV X-rays were performed to visualize and investigate the behaviour of water in carbon-paper gas diffusion layers (GDLs) of PEFCs.

Non-destructive imaging techniques such as magnetic resonance imaging (MRI) and neutron imaging, and X-ray absorption-contrast imaging such as conventional X-ray computed tomography (X-ray CT) and synchrotron radiography, have been adapted to observe water accumulation and transport behaviour in PEFCs. In the case of X-ray imaging, recent high special resolution measurements via the X-ray CT technique have successfully visualized each carbon fiber and pore structure within the GDL. An operating PEFC was also investigated through synchrotron X-ray radiography, but X-ray absorption-contrast imaging techniques can be applied for visualization of carbon paper and water in the absence of the other cell components. It is because lower X-ray photon energies (~10 keV) are sensitive to carbon paper and water, but are readily absorbed by the other cell components. While absorption coefficients of carbon-paper are almost zero at higher X-ray photon energies, phase shifts caused by materials comprised of low-atomic-number elements, such as inorganic materials composed of carbon, nitrogen, and oxygen, is detectable. This is due to the fact that the X-ray-phase-shift cross section is more than hundred times larger than that of the X-ray absorption, and the advantage of phase contrast is even more pronounced in the hard X-ray region. In this respect, phase-contrast X-ray imaging techniques were assessed their applications to non-destructive imaging of carbon-paper GDLs.

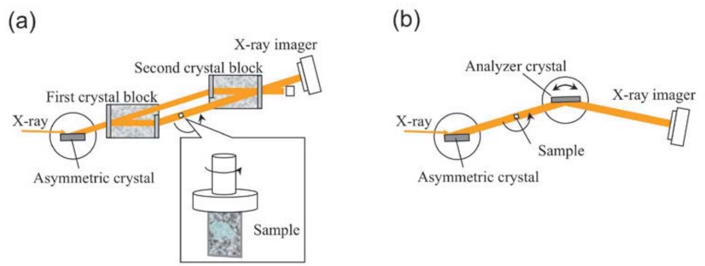

Figure 1
Experimental setup for phase contrast X-ray imaging. Top view of (a) X-ray interferometry and (b) Diffraction enhanced imaging method.

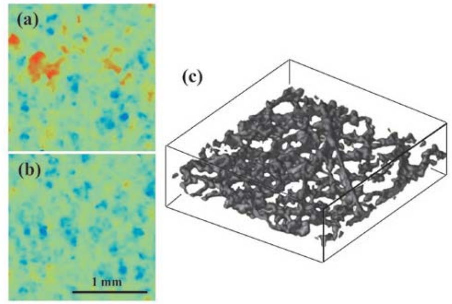

Figure 2
Carbon-paper image obtained by phase-contrast X-ray imaging techniques. (a) Radiographic XII image of water sprayed and (b) radiographic XII image after drying. (c) Three dimensional cut-out image of carbon-paper image with 280 mm in thickness obtained by DEI. Here, an area of dimension 2.5 mm × 2.5 mm is extracted.

In this study, carbon-paper GDLs of 200 and 280 µm in thickness were imaged via phase-contrast X-ray imaging by means of XII and DEI techniques. The XII method is useful for the radiographic imaging of GDLs. As is shown in Fig. 1(a) and 1(b), it was proven that the technique is detectable the difference of water absorbed into the GDL due to its high density resolution (~ 0.001 g/cm^3).[1] Thus, it suggests that the imaging technique is applicable to in-situ observations of the water evolution process in operating PEFCs. On the other hand, the DEI method is not suitable for the radiographic imaging of GDLs because of its horizontal noise. However, the DEI method provides a way for the tomographic imaging of GDLs in PEFCs as is shown in Fig. 1(c) [2].

Since phase-contrast X-ray imaging with 35-keV X-rays is applicable to the imaging of heavy materials together with carbon paper, these phase-contrast X-ray-imaging techniques used herein have proven to be valuable for the investigation of GDLs. In additional, phase-contrast X-ray imaging techniques equipped with a cryo-chamber [3] may allows temperature dependent observation such as the low-temperature imaging of super-cooled water or ice in PEFCs or high-temperature imaging from –80 °C to about +100 °C.

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