Improved sensitivity of thin film sensor for humidity measurement inside a operating PEMFC

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Abstract. Water management inside a proton exchange membrane fuel cell (PEMFC) is an important issue for improving the performance of a PEMFC. It is necessary to understand water transport phenomena inside a PEMFC for water management. Especially humidity measurement near the membrane electrode assembly is indispensable. In order to measure the humidity, we fabricated the capacity type humidity sensor with thickness of 7 μm using micro-electromechanical system techniques. In addition, in order to measure the humidity locally, we reduced the parasitic capacitance by changing the shape of the sensor, and improved the sensitivity of the sensor by carrying out O₂ plasma etching on the humidity sensitive layer. Finally, the improved sensor was inserted between the catalyst layer and micro porous layer inside a PEMFC, and the humidity inside it during power generation was measured to confirm that the sensor was functioning.

1. Introduction
A PEMFC has attracted attention as a clean energy device and has been put into practical use as automobiles and household power. In order to promote the PEMFC further, higher efficiency and lower cost are required. As Performance of PEMFC improves with water management, water management within the PEMFC is necessary [1].

As a method of understanding this water management, there is a humidity measurement inside a PEMFC. However, most of the previous studies have many humidity measurements outside the membrane electrode assembly (MEA) such as flow channels, and there are few humidity measurement near MEA [2,3]. The reason of this is generally humidity sensor has the order of millimetre and it is too thick for measurement inside PEMFC because the film thickness of MEA is about 30 μm. In other words, it disturbs the reaction inside a PEMFC and cannot measure original humidity.

In our previous study [4], we have developed MEMS technology for 7 μm thick electrostatic capacity type thin film humidity sensor (TFHS) as shown in Figure 1. The TFHS consisted of Parylene, Cr and Au. We measured the humidity in the vicinity of MEA in PEMFC during power generation.

As a problem of TFHS so far, it had parasitic capacitances and capacitance change with humidity is small. Therefore, it was not possible to measure the humidity locally.

In this research, we improved the sensitivity of a capacitive humidity sensor which is suitable for humidity measurement in a PEMFC. Specifically, we designed the sensor to reduce the parasitic
capacitance and carry out the O$_2$ plasma etching on the humidity sensitive layer. Finally, a sensor was inserted into the PEMFC during operation and the humidity was measured.

2. Improved sensitivity of the TFHS for humidity measurement

First of all, we cut down the area of the conductive wire which is not related to the measurement to reduce the parasitic capacitance. Specifically, the line width of the conductive wire was thinned from 500 μm to 50 μm. The capacitance change was measured with an LCR meter (3522 LCR HiTESTER, HIOKI) when 80 %RH air was flowed in order to evaluate the parasitic capacitance. As a result, the parasitic capacity that occupied 40 % of the measured value was reduced to 10 %.

Next, we performed O$_2$ plasma etching on the humidity sensitive layer in order to improve the sensitivity of TFHS. Fabrication process of the TFHS was shown in Figure 2. As a result, the electrostatic capacity change increased from 5.6 pF to 10.7 pF in the range of 20 %RH to 90 %RH at 60℃ as shown in Figure 3. This is probably because the surface of the humidity sensitive layer was roughened and a rough surface which could catch water easily might appear by etching.

Finally, we inserted the TFHS between the catalyst layer and micro porous layer inside the PEMFC during power generation and we measured humidity inside PEMFC. There are no degradation of cell performance inserting the TFHS into PEMFC as shown in Figure 4. As a result, the capacitance increased as the current density increased as shown in Figure 5. Because the current density increased, the amount of generated moisture also increased, then we considered that the electrostatic capacity also increased.

![Figure 1. A schematic drawing of the TFHS.](image1)

![Figure 2. Fabrication process of the TFHS.](image2)
3. Conclusion

In this research, we improved the sensitivity of a capacity type humidity sensor which is suitable for humidity measurement in an operating PEMFC. Specifically, the width of the wire portion of the sensor was thinned to reduce the parasitic capacitance. Also, by performing O₂ plasma etching on the humidity sensitive layer, the amount of electrostatic change with respect to humidity increased. Finally, TFHS was inserted inside an operating PEMFC and humidity was measured. It was confirmed that the sensitivity of the sensor increased as the capacitance change with the humidity of the sensor became large.

Reference

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