# Ionic-Liquid Gel based Carbon Dioxide Gas Sensor

**Masahito Honda**[1, 2], Y.Takei[3], K.Ishizu[3], H.Imamoto[2], K.Matsumoto[3], I.Shimoyama[3], T.Itoh[1, 4] and R.Maeda[1, 4]
[1]NMEMS Technology Research Organization, [2]OMRON corp., [3]The University of Tokyo and [4]Naional Institute of Advanced Industrial Science and Technology (AIST)
E-mail : mhonda@nmems.or.jp

We propose a low-power-consumption $CO_2$ gas sensor using IL gel (ILG). We use an ionic liquid (IL) of imidazolium salt $EMIMBF_4$. The sensor consists of an ILG film patterned on electrodes. The impedance of the ILG changes when the ILG adsorbs $CO_2$ gas. The impedance of the ILG increases along with increase of the $CO_2$ gas concentration. The power consumption of our proposed $CO_2$ gas sensor is several tens of microwatts, and this value is 1/1000 smaller compared with conventional $CO_2$ gas sensors (NDIR).

Recently $CO_2$ gas sensor is investigated. However the conventional $CO_2$ gas sensors have the following problems, 1) large power consumption, 2) large size and 3) long detection time. Our $CO_2$ gas sensor uses $CO_2$ adsorption of the IL, because ILs have several splendid properties such as nonvolatile, chemically stable and selective gas solubility [1], [2]. However, it is still difficult to use IL for application process and reliability because they are liquid. Therefore we propose to use ILG instead of IL. Figure 1 shows a schematic illustration of our proposal $CO_2$ gas sensor with IL film. ILG is the mixture material of ILs and polymer. Its form is like film as shown in Figure 2.

We used 1-Ethyl 3-Methyl imidazolium tetrafuloroborate ($EMIMBF_4$) as IL, and poly-vinyliden fluoride-cohexafluoropropylene (PVdF (HFP)). $EMIMBF_4$ and PVdF (HFP) were dissolved into organic solvent dimethylacetamide (DMAc) and then ILG was processed by evaporating its solvent [3].

In this research, we measured impedance of IL and ionic gel which changes according to the adsorption of the $CO_2$. We confirmed a high-speed response, low power consumption, and a frequency characteristic.

Rosen et al. have investigated the chemical reaction on electrodes when voltage was applied to $EMIMBF_4$ and indicated that $EMIMBF_4$ worked as a catalyst for the reaction to convert $CO_2$ into CO [4].As increasing $CO_2$ concentration, the reaction comes to occur on cathode, and thus the cell's impedance changes as well. Applying DC bias to our sensor is needed in order to measure $CO_2$ gas concentration. The overview and schematic illustration of the sensor is shown in Figure 3. The fabrication process of the electrode pattern is as follows. First, Cr/Pt (3nm/50nm) electrodes were patterned on the surface of a glass insulator. Second, a pool-like round hole was formed by CYTOP in order to hold IL or ILG, because CYTOP is hydrophobic. The 1μl IL droplet was then put onto yhe hole by micro pipette. And finally the IL droplet was heated by the hot plate with temperature of 60 ºC for 5minutes and the IL change into ILG.

To evaluate our $CO_2$ gas sensor of ILG, we measured response of the sensor when $CO_2$ gas concentration got higher. The cell was set in a chamber. $CO_2$ was able to be introduced by a gas cylinder. Experiment was applied to measure $CO_2$ gas adsorption. Figure 4 show the experimental results. As $CO_2$ gas concentration increase (0ppm to 3000ppm), impedance of the ILG was decreased. At the frequency of 0.1Hz, the ILG impedance was $3.0\times10^6\Omega$ when $CO_2$ gas concentration was 0ppm. When

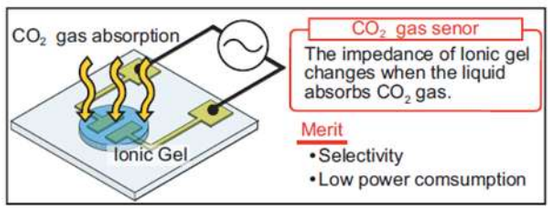


Fig. 1. A schematic illustration of our proposed $CO_2$ gas sensor with ILG.

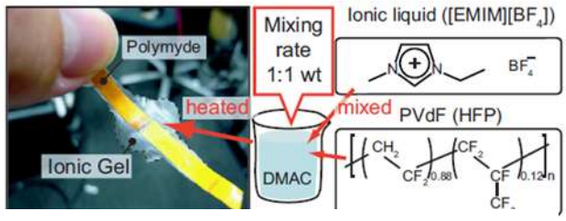


Fig. 2. IL ($EMIMBF_4$) and polymer material (PVdF) can dissoleve into organic solvent (DMAC).

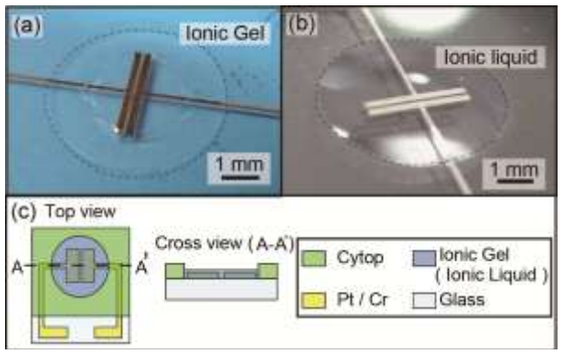


Fig. 3. Photograph of (a) cell with ILG, (b) IL ($EMIMBF_4$) and (c) a schematic illustration of sensor.

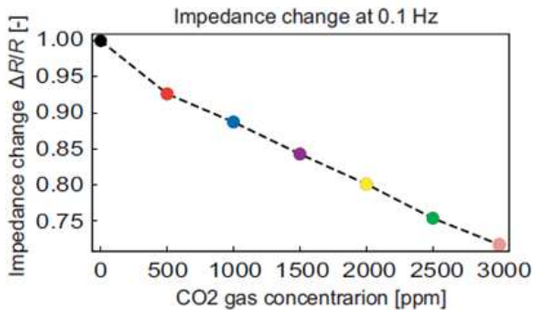


Fig. 4. Impedance measurement of ILG cell (DC bias : 1.5 V, AC bias : 100 mV)

$CO_2$ gas concentration was increased to 3000ppm, the ILG impedance was decreased to $2.1\times10^6\Omega$.

From the result shown in Figure 4, the power consumption of our sensor is estimated to as order of $10^{-8}$W (Impedance: $3\times10^6\Omega$, Current: 100mV), excluding power consumption of the measurement circuit. Thus our sensor system is expected to be low power consumption.

In conclusion, we demonstrated $CO_2$ gas sensor using the ILG. We measured the ILG impedance with changing $CO_2$ concentration, and confirmed that the ILG impedance was decreased according to the increase of the $CO_2$ concentration. The power consumption at the ILG is estimated as low as $10^{-8}$W. And our sensor is lower than the conventional sensor by 1/1000, and has high resolution of a 100 ppm.

**References**

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