The 22nd SCEJ Symposium on Fluidization and Particle Processing
Institute of Industrial Science, The University of Tokyo December 8th, 2016

Effect of Dispersion of Catalyst Particles and Ionomer on PEFC Performance

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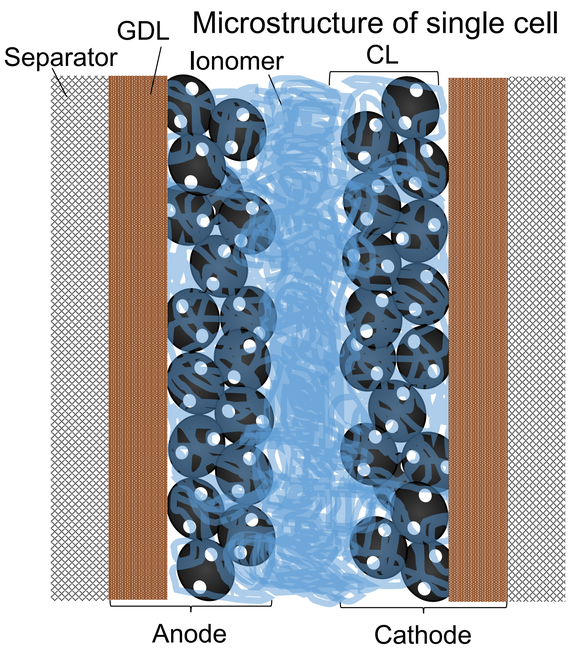
Introduction



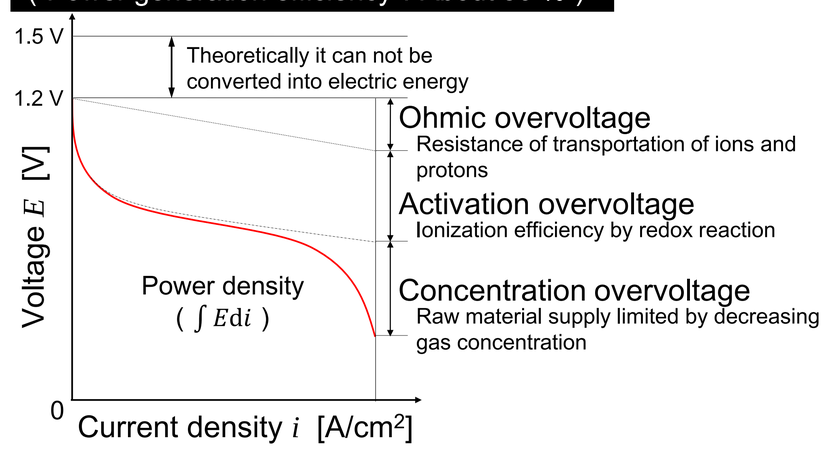
Platinum : Redox reaction catalyst
Carbon : Electron transport
Ionomer : Proton transport
Pore : Gas permeation and water removal

Current Status of PEFC

Theoretical voltage of fuel cell : 1.2 V (80℃ , 1 bar)

Resistance and loss inside the stack
→ Decreasing voltage

Actual voltage : 0.6 ~ 0.7 V
(Power generation efficiency : About 50 %)



- Material cost reducing Pt usage to realize cost reduction
- Reducing voltage drop, improve battery performance, aim for effective use of Pt

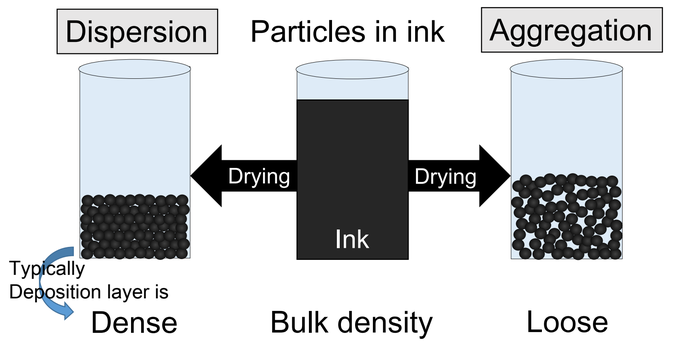
Focus of the Research

Focus on the catalyst layer structure (particle aggregation state)

- Pore (Gas permeation)
- Arrangement of carbon and ionomer (Electron and Proton transport)

Optimize the microstructure of PEFC

Control of particles and ionomers packing structure is important



Change dispersion state with ethanol concentration in solvent

Solvent	Carbon state
Water system	Aggregate
Alcohol type	Dispersion

High	Gas permeation resistance	Low	➡ Concentration overvoltage
Low	Substance transmission resistance	High	➡ Ohmic overvoltage

Aim of the Research) Establishment of optimal catalyst ink design guideline for fabricating stack with small voltage drop

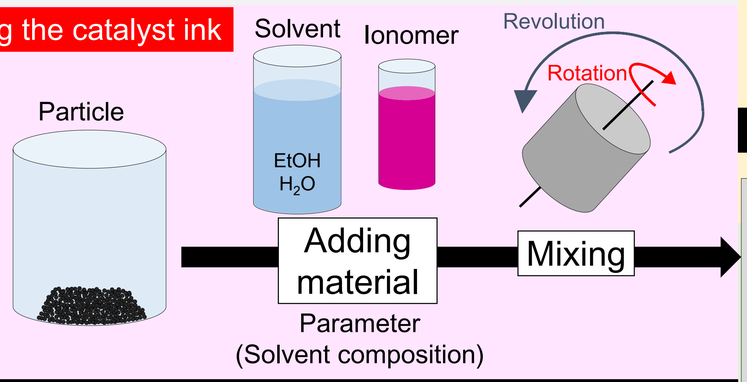
EXPERIMENTS

< 1. Evaluation of catalyst ink and battery performance >

Particle : Pt-C (29wt%Pt, Nominal diameter 12 nm, TKK)
Ionomer : Nafion (10wt%Nafiondispersion sol. DE1021, DuPont)
Solvent : Water and Ethanol

Particle volume fraction : 4.0 vol%
I/C balance : 1.0 [-]
Parameter : Ethanol concentration of solvent

Preparing the catalyst ink

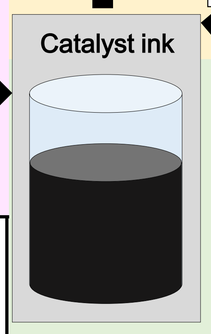


Viscometer

Flow curve

Sorting

Catalyst ink

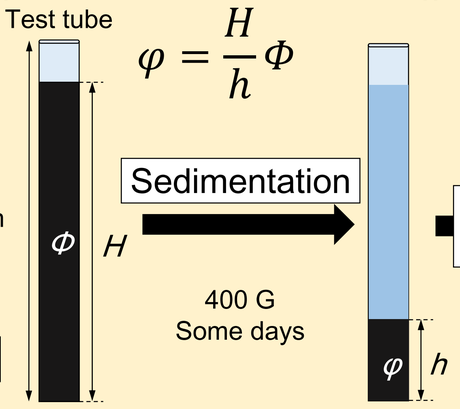


Measuring packing fraction

Test tube

$$\varphi = \frac{H}{h}\Phi$$

12 cm



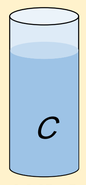
Sedimentation

400 G
Some days

Measuring adsorption amount

$$x_M = \frac{C_0 - C}{W}$$

Nafion solution



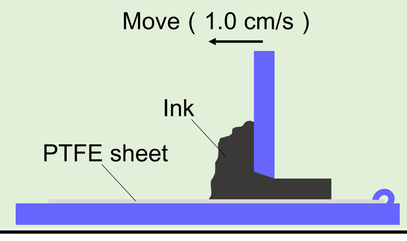
Supernatant collection

Measuring concentration
TG Measuring
➡ Adsorption amount

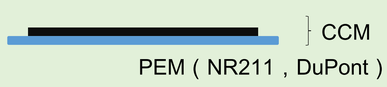
Coating — Room temperature 1 hour — **Drying** — Hot press — **Crimping** → **Power generation evaluating**

< Coating condition >
Doctor blade method
thickness : 120 μm

Move (1.0 cm/s)



< Crimping >
press



Platinum basis weight
0.15 mg/cm²

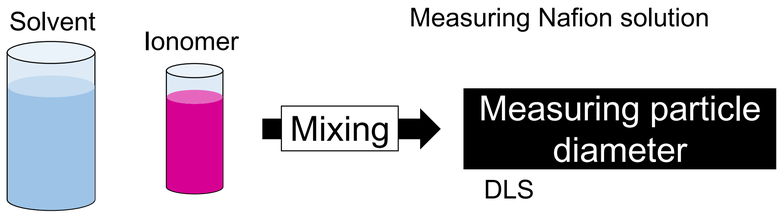
GDL (SGL25BCH)

< Protocol >
Active area : 10 cm² (2 cm×5 cm)
Cell temperature : 80 ℃
Gas supply flux :
H_2 200 cm³/min (RH40, 90)
Air 200 cm³/min (RH40, 90 $O_2$10%)

Coating and power generation evaluating

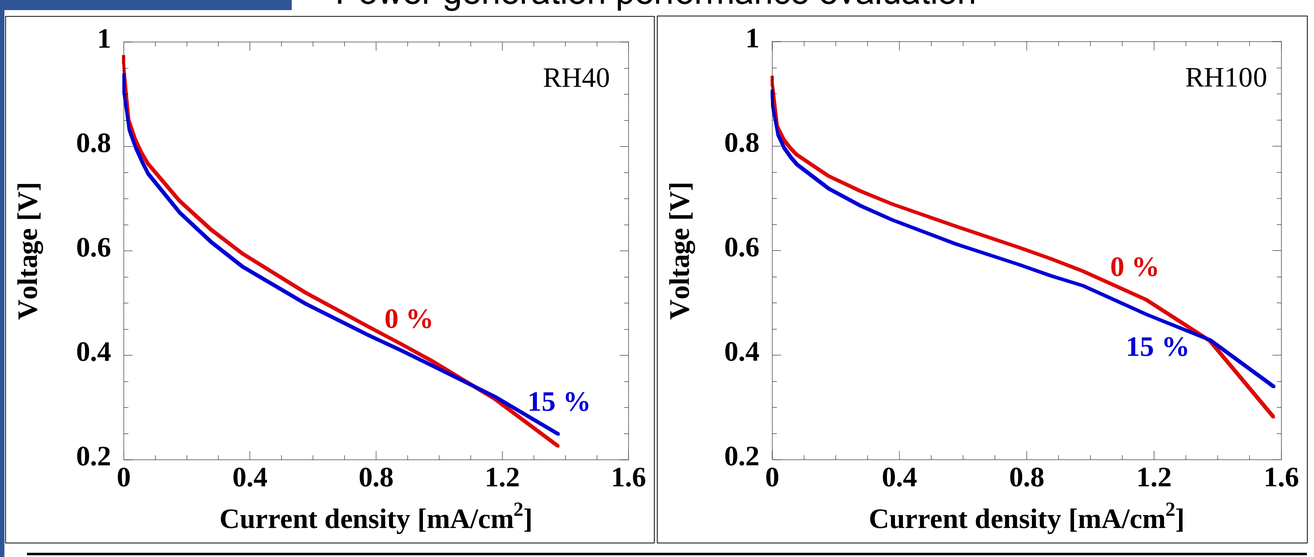
< 2. Evaluation of morphology of Nafion >

Ionomer : Nafion (DE1021 and DE2020, DuPont)
Solvent : Water and Ethanol (Ionomer conc. 0.5 mass%)



RESULTS

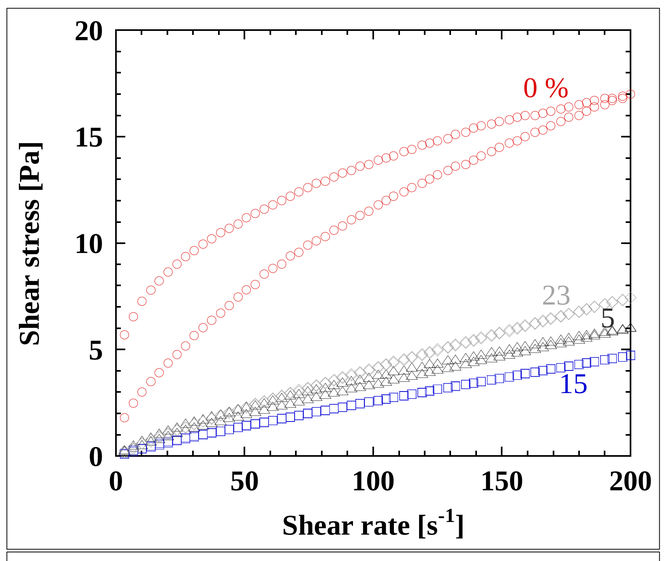
< Power generation performance evaluation >

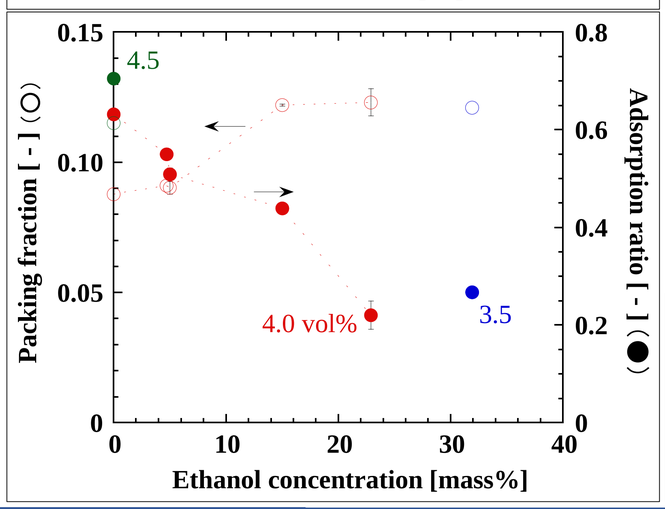


Ethanol Conc.	Voltage drop		Shipping resistance		Possible catalyst structures	
	Low *i*	High *i*	R_{ion} [mΩ/cm²]	R_{other} [m²/s]	Pore	Ionomer
0	Small	Large	95	31	Few	Dense
15	Large	Small	138	24	Many	Loose

The voltage drop is small at medium current density (around 0.5 mA/cm²) in the case of water system (0%), compared with ethanol concentration of 15%. Whereas, it became remarkably large at high current density (over 1 mA/cm²). In water system, the resistance of ion conduction decreases because of the well continuity of the ionomer. On the other hand, the gas diffusion resistance is getting bigger because Nafion would fill the pores of carbon structure. When the power generation condition is highly humidified, it is considered that the pores are filled by the produced water, so the increase of the concentration overvoltage becomes remarkable. It is considered that the gas diffusion would be hindered by accumulating water in the catalyst layer.

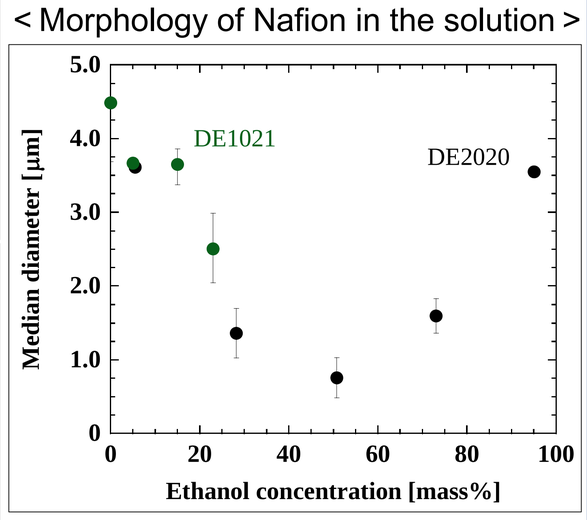
< Evaluation of ink characteristics >





In water system, carbon particles forms a strong aggregate from the results of flow curves and packing fraction. Ethanol was added as a dispersion of carbon generally, but flow curves and packing fraction didn't change in the presence of ionomer. In addition, adsorbed amount of Nafion decreased with an increase in ethanol ratio. Nafion make aggregates in water rich solution, while Nafion disperse well in ethanol/water solution. So, it can be control the Nafion size by changing ethanol concentration.

< Morphology of Nafion in the solution >



Guidelines for improving power generation performance

- Increasing adsorption amount (formation of network)
- Be Nafion finely (increase the gap)

CONCLUSION

< Ink characteristics > It is possible to control the aggregate state of particles and ionomer by changing solvent composition.
< Power generation characteristics > When the adsorbed amount and the size of ionomer were large in the ink, network of ionomer was well formed and proton was transported smoothly.

In water system, carbon particles agglomerate and packing fraction decrease, but the size of ionomer was large and well forms a network

FUTURE WORKS

< Power generation characteristics >
- Evaluating other ethanol concentration (5, 23 mass%)

< Structure analysis of catalyst layer >
- Measuring pore size and volume
- Observing microstructure

Check the relationship between pore structure and gas resistance

法政大学 HOSEI University