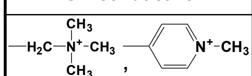
Anion Exchange Membrane and Ionomer for Alkaline Membrane Fuel Cells (AMFCs)

Hiroyuki Yanagi and Kenji Fukuta
Corporate Development Dpt., Tokuyama Corporation
40, Wadai, Tshukuba, Ibaraki 300-4247, Japan

Recently the alkaline system for fuel cells enhance their presence because of possibility of no-precious-metal catalyst and low overpotential at cathodic reaction[1]. The anion exchange membrane(AEM) and ionomer for AMFCs should be a key technology in order to achieve the practical performance as fuel cells. However, only a few membrane and ionomer are roported[2] as the AEMs for AMFCs.

The difference between anion and cation exchange membrane are summarized in Table 1. The cation exchange membrane based on fluorinated polymer and sulfonic acid group is used as major membrane for PEMFC because of the excellent proton conductivity and durability. On the other hand, AEM based on quaternary ammonium group and hydrocarbon polymer backbone has been considered to have low thermal durability and low OH^- conductivity under the condition of fuel cell.

Table 1. Difference between AEM and PEM

Anion exchange Membrane	? Items ?	Cation exchange Membrane
OH^- conductive	Counter ion	H^+ conductive
	Ion-exchange group	$-SO_3^-$, ($-PO_4^-$, $-CO_2^-$)
△Pt free catalyst available △Advantage for cathode O_2 reduction	Features	△High ion conductivity △Excellent Ionomer solution
▼Low ion conductivity ▼Low thermostability ▼Influence of CO_2	Issues	▼High cost materials ▼Fuel crossover

We were originally developing the ion exchange membranes for electrodialysis which are now commercially available. Then, we are focusing on ion exchange membrane and ionomer for fuel cells. The developed AEMs are hydrocarbon polymers which consist of hydrocarbon main chain and quaternary ammonium salts. The basic properties are shown in Table 2.

Table 2. Basic properties of AEMs developed at Tokuyama

Property	A201	A901
Thickness／μm	28	10
Ion-exchange capacity／mmol・g^{-1}	1.7	1.7
Water content／－	0.25	0.15
OH^- conductance[1)]／mS・cm^{-2}	29	11.4
OH^- conductivity[1)]／mS・cm^{-1}	38	42
Burst strength／MPa	0.4	0.2
Dimensional change／wet⇔dry		
MD ／ %	2	1
TD ／ %	6	4

1) Two probe method for in plane conductivity measurement at 23 ℃, 90%RH under N_2 atmosphere

In Table 2, two kinds of membranes, A201 (developing code A-006) and A901 are listed as typical AEMs. The membrane thickness are controllable from 10 μm to 40 μm at dry state. Ion-exchange capacity is ca 1.7 mmol/g. The OH^- conductivities of their membranes are around 40 mS・cm^{-1} , it will be sufficient as electrolyte membrane for AMFCs. The durability test results in water and methanol at 80 ℃ is shown in Fig.1.

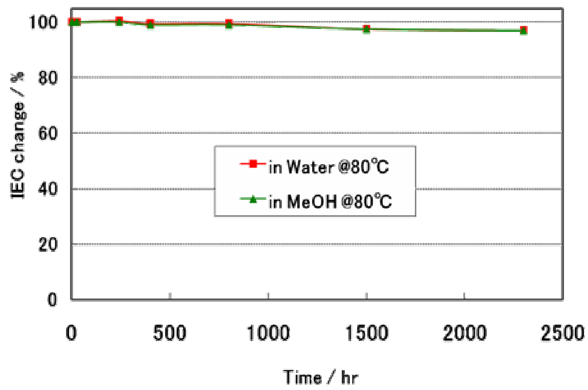


Fig. 1 Thermal durability of AEMs at 80 ℃
Membrane was ion-exchanged to OH^- form before durability test. □ is kept in water, △ is kept in Methanol

The ion-exchange capacity(IEC) is stable for 2300hr at 80 ℃, it will be enough for practical usage.

For construction the AMFCs the OH^- conducting ionomer should be essential. In case of PEMFC the conventional Nafion® is very suitable as ionomer. But, it has only cation conductivity and is not applicable to alkaline system. We are searching for various types of anion-conducting ionic polymer which is soluble to solvent of ink and insoluble to water, methanol and ethanol. Finally we can found the special hydrocarbon-type ionic polymer (developing code A3Ver.2) which contains the quaternary ammonium group shows the acceptable property as the ionomer of AMFCs. The properties of newly developed ionomer are shown in Table 3.

Table 3. Properties of A3Ver.2 Ionomer

State	Features	A3 ver.2
solution	Polymer concentration／wt%	5
	Solvent	Tetrahydrofurane & 1-Propanol
membrane (cast film)	Ion-exchange capacity／mmol・g^{-1}	0.7
	Ion coductivity／mS・cm^{-1}	2.6
	Solubility to solvent	
	Water	not soluble
	MeOH	not soluble
	EtOH	not soluble

The solubility of A3Ver.2 is sufficient for alcohol fuel, but the ion conductivity is not so high comparing with the AEMs. It will be attributed to low ion-exchange capacity of ionomer. We will report the improved ionomer at this session.

The potential of new AEMs and ionomer developed at Tokuyama will be also reported at this meeting as the better performance of AMFCs.

References

1. H. A. Gasteiger *et.al.,* FC EXPO 2008, Technical conference FC-10.
2. J. R. Varcoe *et. al*., Chem Mater, 19, 2686(2007).