Progress in The Development of Alkaline Membrane Fuel Cells and Regenerative Fuel Cells.

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The effect of anion functional group on the conductivity and performance of alkaline anion exchange membrane fuel cells (AAEMFCs) is reported. The functional groups used were trimethyl amine, 1,4-diazabicyclo[2.2.2]octane, dimethyl sulphide (DMS), diethyl sulphide, triethyl amine (TMA) and N,N,N0,N0-tetramethyl-1,6-hexanediamine. Membranes and ionomer were characterised in terms of ionic conductivity and separate anode, cathode and cell performances. TMA functionalised (LDPE-co-VBC) or PVBC offered the highest conductivity amongst the various selections of amine/sulphide-based functional groups with conductivities values up to 0.25 (in plane) and 0.043 S cm^{-1} (through plane). Sulphide-based groups showed lower stability with temperature in comparison to amine-based groups. The increase in length of the chain in the aryl group (for example from methyl to ethyl) attached to the nitrogen (amine) or sulphur (sulphide) led to lower conductivity. The high OH^- conductivity in membranes functionalised with TMA is reflected by its low activation energy of 12 kJ mol^{-1}. The ionomer functional group had a great impact on the cathode performance. The ionomer functional groups affected oxygen permeability, the activation energy and the exchange current density for oxygen reduction. TMA functionalised ionomer provided an improved oxygen reduction reaction with exchange current density some 300 times higher than that with DMS. Anode flooding appeared to severely restrict cell performance and was determined, to great extent, by the type of functional group used for the ionomer. TMA functionalized electrodes showed superior cell performance in comparison to the other functional groups with a current density of 0.72 A cm^{-2} at 0.6 V and a peak power density of 478 $mWcm^{-2}$.

A study of a non-precious metal based bifunctional oxygen electrode for use in regenerative fuel cells with alkaline anion exchange membranes was made. Four nanometer size $Cu_xMn_{0.9-x}Co_{2.1}O_4$ (CuMnO) samples were characterized with XRD, SEM, TEM, and cyclic voltammetry. The samples exhibited promising ORR and OER catalytic activities. The gap between ORR half wave potentials of Pt/C and CuMnO in 1 M KOH was only 50 mV. The onset potentials for OER were more than 100 mV more negative than Pt/C in 1 M KOH. MEA with CuMnO bifunctional oxygen electrode was prepared with CCM method and in fuel cell mode the peak power density was over 80 mW cm^{-2} and in electrolyser mode the onset voltage was about 1.55 V.

In order to develop the alkaline anion exchange membrane water electrolysers (AAEMWE), a quaternary OH^- conductive ionomer binder based on polymethacrylate was synthesized by copolymerization of three kinds of methacrylate monomers, which was followed by quaternization. The conductivity of this ionomer was 0.059 S cm^{-1} at 50 ^{0}C. With this ionomer in catalyst layers of an AAEMWE, the voltage of 1.9 V gave a current density of 100 mA cm_2. Satisfactory stability of the membrane electrode assembly was observed from chronocoulometry.