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Metal-organic frameworks (MOFs): a new leak proof electrolyte for alkaline fuel cell

Everincreasing energy demand of world and pollution associated with fossil fuels,has demanded an urgent need to develop alternate clean energy systems. Fuel cells are the promising energy technology which converts chemical energy into electricity through electrochemical reaction, is clean, quiet, and more efficient than internal combustion engine which uses petroleum based fuels. The fuel cell based electric vehicles are being tested since last decade. However the large scale commercializationis mainly hindered by high cost associated with the technology.

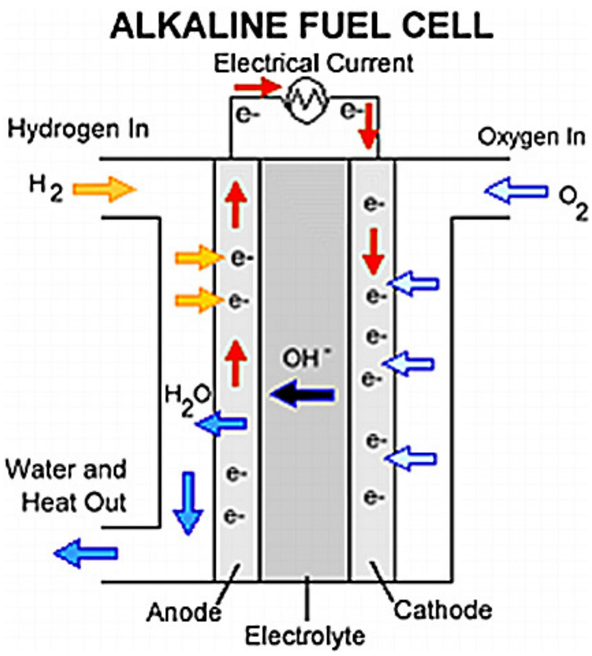

Fig. 1. Alkaline Fuel Cell (Adapted from https://energy.gov/eere/fuelcells/types-fuel-cells)

Alkaline fuel cells use oxygen (O2) and hydrogen (H2) gas as a fuel to generate electricity and water (Fig. 1). NASA used alkaline fuel cells in their famous Apollo Mission to supply electricity and water to astronauts in space. However for the commercial use, electrolyte with high OH– ion conductivity and durability, with improved tolerance to carbon dioxide, water management, higher temperature operation, power density, and anode electrocatalysis technologies needs to be developed. Especially, the OH– ions inherently have lower mobility than H+ which significantly affects the performance of the fuel cell. To address this problem OH– ion conducting liquid electrolytes were tried for commercial development but wettability, increased corrosion, and difficulties handling in varying pressures limit their use. Thus the development of highly OH– conducting solid electrolyte is vital to development of low cost affordable fuel cell technology for wide spread commercial use.

Metal-Organic Frameworks (MOFs) material is made up of metal centres connected by organic ligand at regular interval yielding two/three dimensional (2D/3D) framework structures. It has demonstrated high proton conductivity in solid state and successfully demonstrated fuel cell performance. These proton conducting MOFs commonly contains negatively charged framework with positively charged free H^+ ions and water molecules. We proposed that one can make OH^- ion conducting MOF by creating positively charged framework with negatively charged free OH^- ion with water molecules (Fig. 2a). We synthesized MOF using Nickel (II) and 2-pyrimidinecarboxylic acid (pymcaH) under hydrothermal conditions having formula $[Ni_2(\mu\text{-pymca})_3]OH{\cdot}nH_2O$. MOF consists of honeycomb like cationic framework $[Ni_2(m\text{-pymca})_3]^{1+}$ forming a tube filled with OH^- ions and water (Fig. 2b). The MOF remained stable even in high concentration of OH^- ions (pH = 14) very important property for OH^- ion conducting material. Highest conductivity of 0.8×10^{-4} S cm^{-1} was obtained at room temperature and 99 % relative humidity. This value is comparable to well-known OH^- ion conducting materials reported previously. Being a solid material, there is no issue of leaking of the electrolyte. The conductivity increased on heating from room temperature to 90 ^{o}C (Fig. 2c). The Activation energy value indicates the how easily ions can move in the material. The activation energy value for present Ni based MOF of was found to be 0.19 eV which is comparable to energy required for OH^{-} ions to move in liquids. The high conductivity was maintained for more than 40h (Fig. 2d). During start-up and shut down of fuel cell the humidity values change drastically. The humidity cycling study revealed that the conductivity of the MOF material does not degrade due to humidity cycling demonstrating the durability of the material (Fig. 2e).

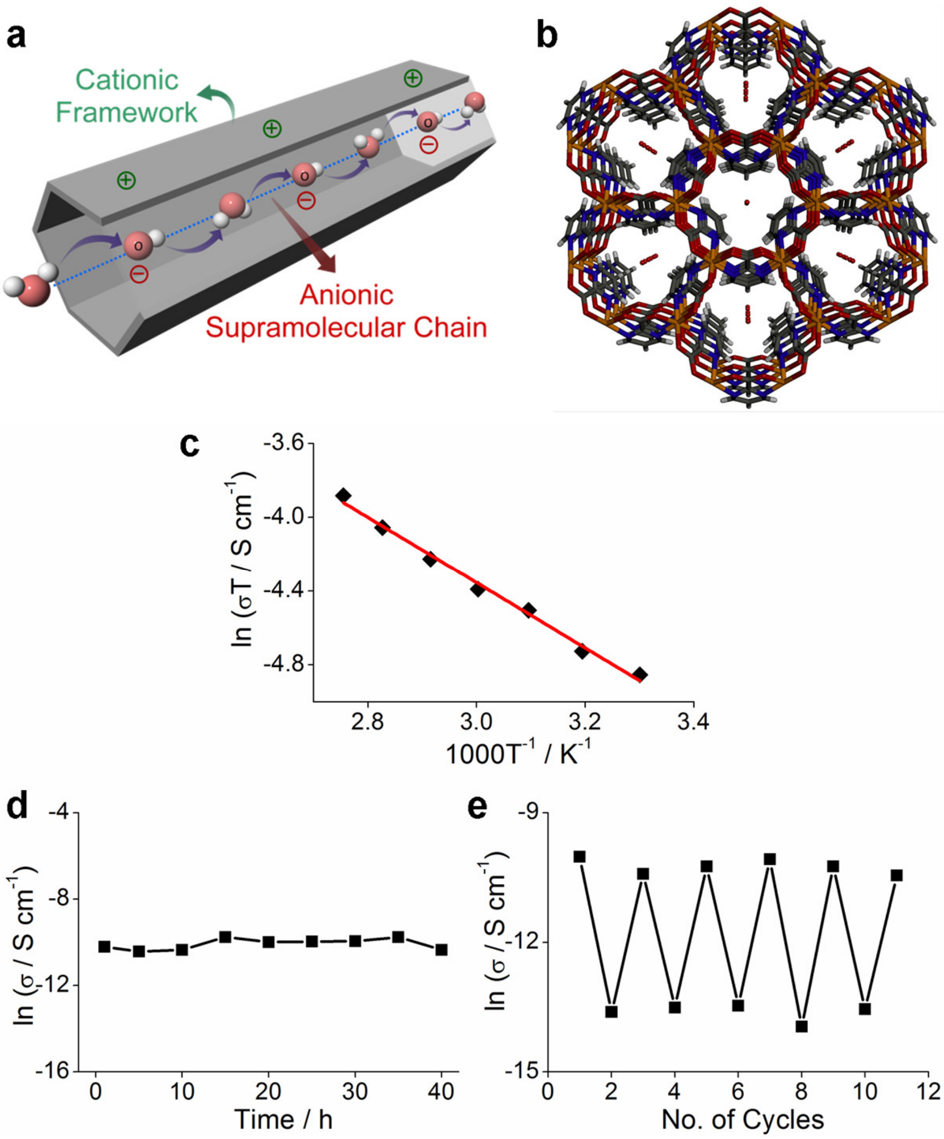

Fig. 2. a) Positively charged framework with anionic OH- and water chain; b) Structure of MOF [Ni2(μ-pymca)3]OH·nH2O; c) Temperature dependent; d) Time dependent; e) Humidity dependent OH- ion conductivity study.

Consequently, we have successfully synthesized a new leak proof OH– ion conducting MOF material for alkaline fuel cell application. The material shows high OH– ion conductivity and durability crucial for the successful performance.

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Publication

High hydroxide conductivity in a chemically stable crystalline metal-organic framework containing a water-hydroxide supramolecular chain.
Nagarkar SS, Anothumakkool B, Desai AV, Shirolkar MM, Kurungot S, Ghosh SK
Chem Commun (Camb). 2016 Jun 28