Fuel cell characterization - Summary

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C.Sruthi Mishra

Fuel cell needs to characterized for its performance to find optimum operating conditions as it contains several components that are physically coupled.

Characterization techniques include -

Electrochemical / In-situ characterization Techniques which are current-voltage measurement, current interrupt measurement, electrochemical Impedance spectroscopy and cyclic voltammetry.

Ex-situ characterization techniques which are scanning scanning electron microscope, Transmission electron microscope X-Ray diffraction, porosity determination, BET surface area determination etc

Test conditions involve warm-up of operating the cell at a fixed current load of 30-60 min prior to testing, maintaining constant fuel cell temperature, increased pressure, flow rates in fixed flow rate and fixed stochiometric conditions and an optimal cell compression force for best performance.

current - voltage measurement is best summarized by j-V curve measurement at steady state.

current interrupt measurement is extremely fast, can be implemented on high power fuel cell system and can be conducted in parallel with a i-v curve measurement.

R_{ohmic} can be calculated using

$$R_{ohmic} = \eta_{ohmic}/i$$

In cyclic voltammetry (CV), the voltage applied to system is swept linearly with time back and forth and resulting current is measured as a function of time.

cyclic voltametry of Pt/c catalyst

$$Pt\text{-}H_{ad} \underset{\text{reverse}}{\overset{\text{forward}}{\rightleftarrows}} Pt + H^+ + \bar{e}$$ in 0.5M H_2SO_4 at a scan rate at 0.01 V/s,

$$A_{active} = Q / 210\,\mu C/cm^2 \times A_{geometric}$$

-Magnitude at peak current given by Randles-Senick equation. at 25°C,

$$i_p = 0.69\times10^5)\, n^{3/2} A D^{1/2} C v^{1/2}$$

Total charge of desorption/adsorption is

$$Q = \frac{1}{v}\int_{E1}^{E2} I\, dE$$

Electrochemical surface area $ESA/ECSA = Q_{Pt}/Q_m \times L$

ECSA of CO on Pt smooth electrode at a scan rate of 50 mV/s is $ECSA_{CO} = \dfrac{Q_{CO}}{420\,\mu C/cm^2 \times L}$

Electrochemical impedance spectroscopy is measured by applying an AC potential to an electrochemical cell and then measuring current through the cell.

EIS measurement $Z_{total} = Z_{real} + Z_{imaginary}$

Electrochemical impedance is measured using a small exitution signal impedance $Z = \frac{V(t)}{i(t)} = \frac{V_0 \sin \omega t}{i_0 \sin(\omega t + \phi)} = Z_0 \frac{\sin \omega t}{\sin(\omega t + \phi)}$

Ex-situ characterization techniques are structure determinations which includes scanning electron microscope, transmission electron microscope porosity determination of catalyst structures, BET surface area measurement, chemical determinations of fuel cell material.

For microscopes, spatial resolution is the ability to distinguish small details of objects and temporal resolution is precision of a measurement with respect to time.