Table 1. The volumes of 5% wt of Nafion solutions were added to catalyst inks, and the amount of 20 wt% Pt/C catalysts was kept constant at 34.5 mg (Pt loading of 0.3 mg/cm$^2$, and reactive area of 23 cm$^2$). The density of 5%wt Nafion solution is 0.85 g/cm$^3$; thus, the percentage of Nafion : Pt/C catalyst was calculated.

| Nafion solution 5% wt added in catalyst inks (μL) | Dry Nafion weight (mg) | Pt/C catalyst weight (mg) | Percent weight of Nafion per Pt/C (%) |
|---|---|---|---|
| 300 | 12.7 | 34.5 | 37.0% |
| 400 | 17.0 | 34.5 | 49.3% |
| 500 | 21.2 | 34.5 | 61.6% |
| 600 | 25.5 | 34.5 | 73.9% |

Table 2. Mass fraction analysis of C, F, and Pt from the EDX analysis shown in Figure 6.

| Element | Weight % | C, Pt Weight % |
|---|---|---|
| C | 60.9 | 83.07 |
| F | 26.6 | - |
| Pt | 12.5 | 17.0 |

Table 3. Summary of chemisorption data. No chemisorption activity observed for Nafion-coated Nafion membrane. For the 20 wt% Pt/C powdered catalyst, average Pt particle size is calculated to be 4.4 nm diameter to give a Pt dispersion of 25.8%. Dispersion is defined as the fraction of total Pt atoms in a particle that are present on the surface. Coated membrane was analyzed by chemisorption before (fresh) and after electrochemical surface area determined (used).

| Samples | Pt weight in samples (mg) | $H_2$ uptake (millimoles/$g_{Pt}$) | | No. of Pt surface sites/$g_{Pt}$ | |
|---|---|---|---|---|---|
| | | Average | Standard Dev. | Average | Standard Dev. |
| Blank membrane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Catalyst particles (20 wt% Pt/C) | 9.9 | 1.98 | ± 0.01 | $8.0 \times 10^{20}$ | $\pm 2.8 \times 10^{18}$ |
| Coated membrane, fresh (49.3 wt% Nafion : Pt/C) | 13.8 | 0.96 | ± 0.05 | $3.8 \times 10^{20}$ | $\pm 1.8 \times 10^{19}$ |
| Coated membrane, used (49.3 wt% Nafion : Pt/C) | 13.8 | 0.99 | ± 0.05 | $3.9 \times 10^{20}$ | $\pm 1.8 \times 10^{19}$ |

Table 4. Summary of Electrochemical Surface Area (ESA) for an MEA of 49.3 wt% of Nafion : Pt/C by cyclic voltammetry using a scanning rate of 25 mV/sec. The mass of Pt was approximately 6.9 mg (0.3 $mg_{Pt}/cm^2$ for 23 $cm^2$ surface area for both anode and cathode); the Pt charge per surface area Pt = 2.1 $C/m^2$.

| Description | Electric charge (Coulomb) | | Pt surface area ($m^2/g_{Pt}$) | | No. of Pt surface sites/$g_{Pt}$ | |
|---|---|---|---|---|---|---|
| | Average | Standard Dev. | Average | Standard Dev. | Average | Standard Dev. |
| Electrochemical Surface Area (ESA) | 0.183 | $\pm 1.10 \times 10^{-3}$ | 12.63 | $\pm 0.08$ | $1.6 \times 10^{20}$ | $\pm 9.5 \times 10^{17}$ |

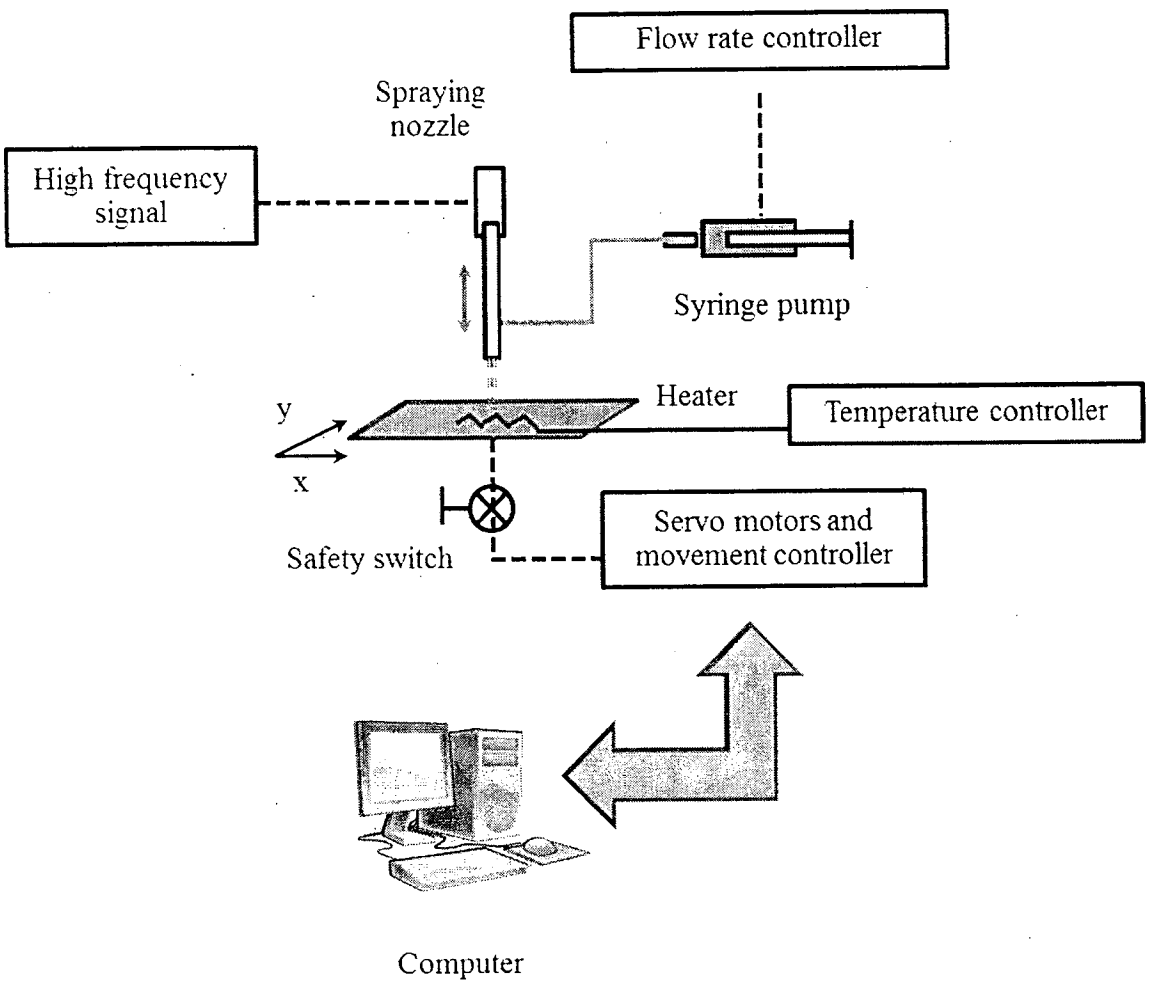


Figure 1. Schematic of ultrasonic spraying system used to fabricate MEAs in this study.

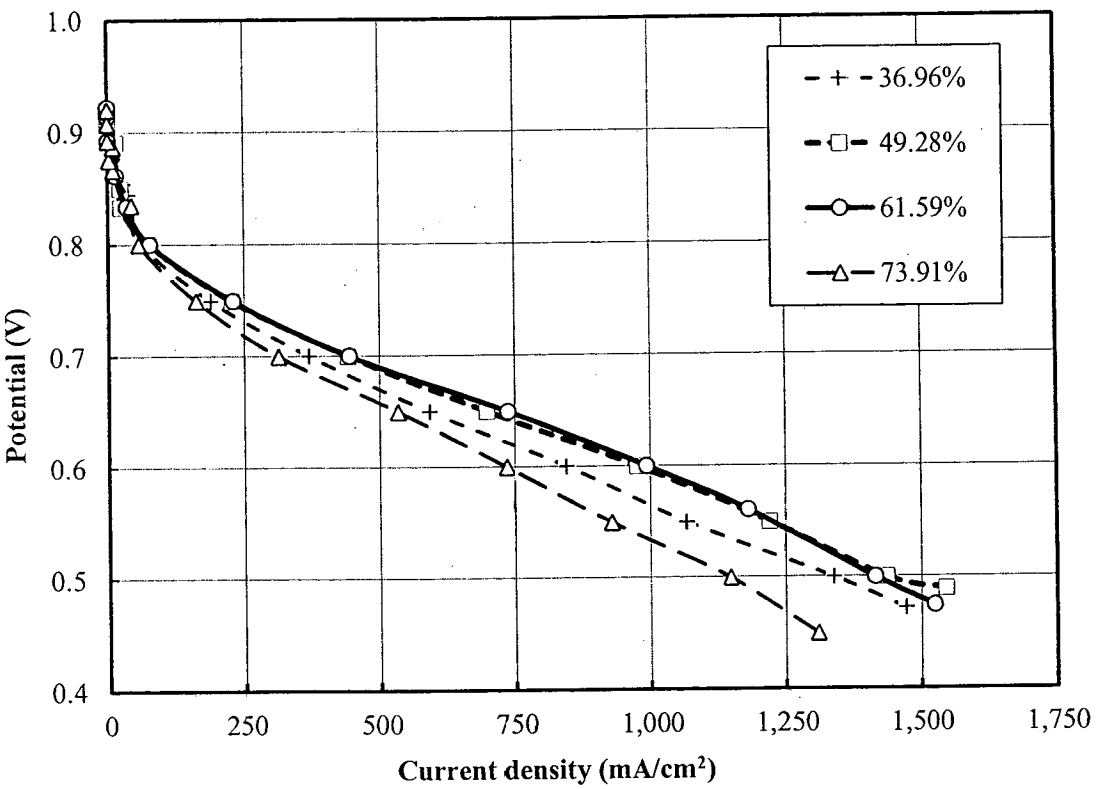


Figure 2. Polarization curves of four MEAs with percentages of Nafion : Pt/C catalyst at 37.0% (+) , 49.3% (□), 61.6% (○) , and 73.9% (Δ). The cell temperature was 75 °C, the humidity was 95%RH at both anode and cathode, the stoichiometric ratio of $H_2$/air was set at 1.2/3.0, and back pressure was ambient pressure at both anode and cathode.

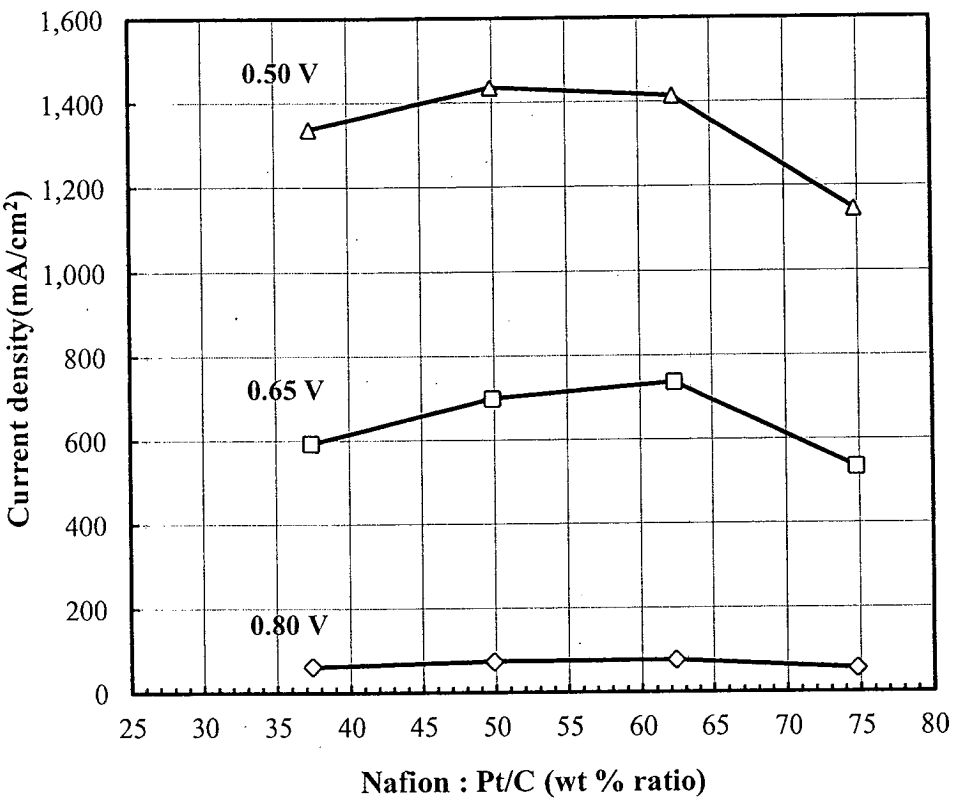


Figure 3. Current density versus Nafion : Pt/C catalyst ratio at cell potential of 0.50, 0.65, and 0.80 V (from Figure 2).

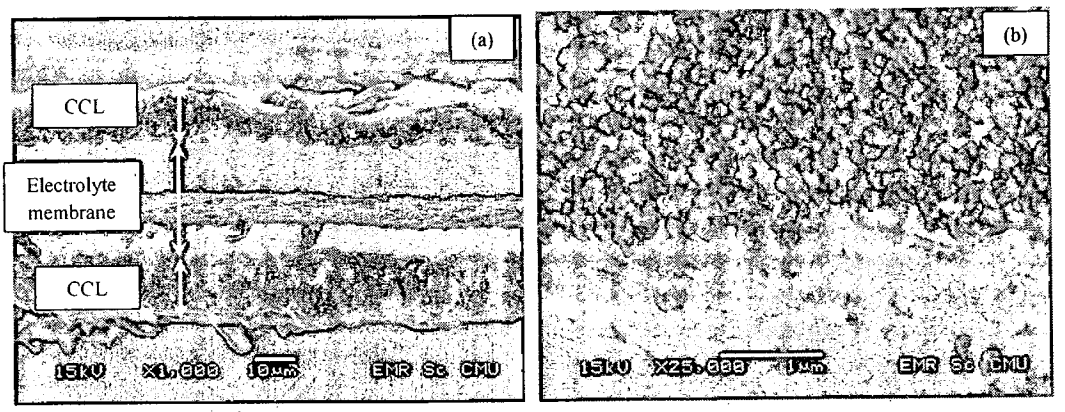


Figure 4. Cross sectional SEM images of MEA with 49.3% of Nafion : Pt/C; (a) CCL/electrolyte membrane/CCL at a magnification of 1,000 times, and (b) CCL/Electrolyte membrane interface at a magnification of 25,000 times.

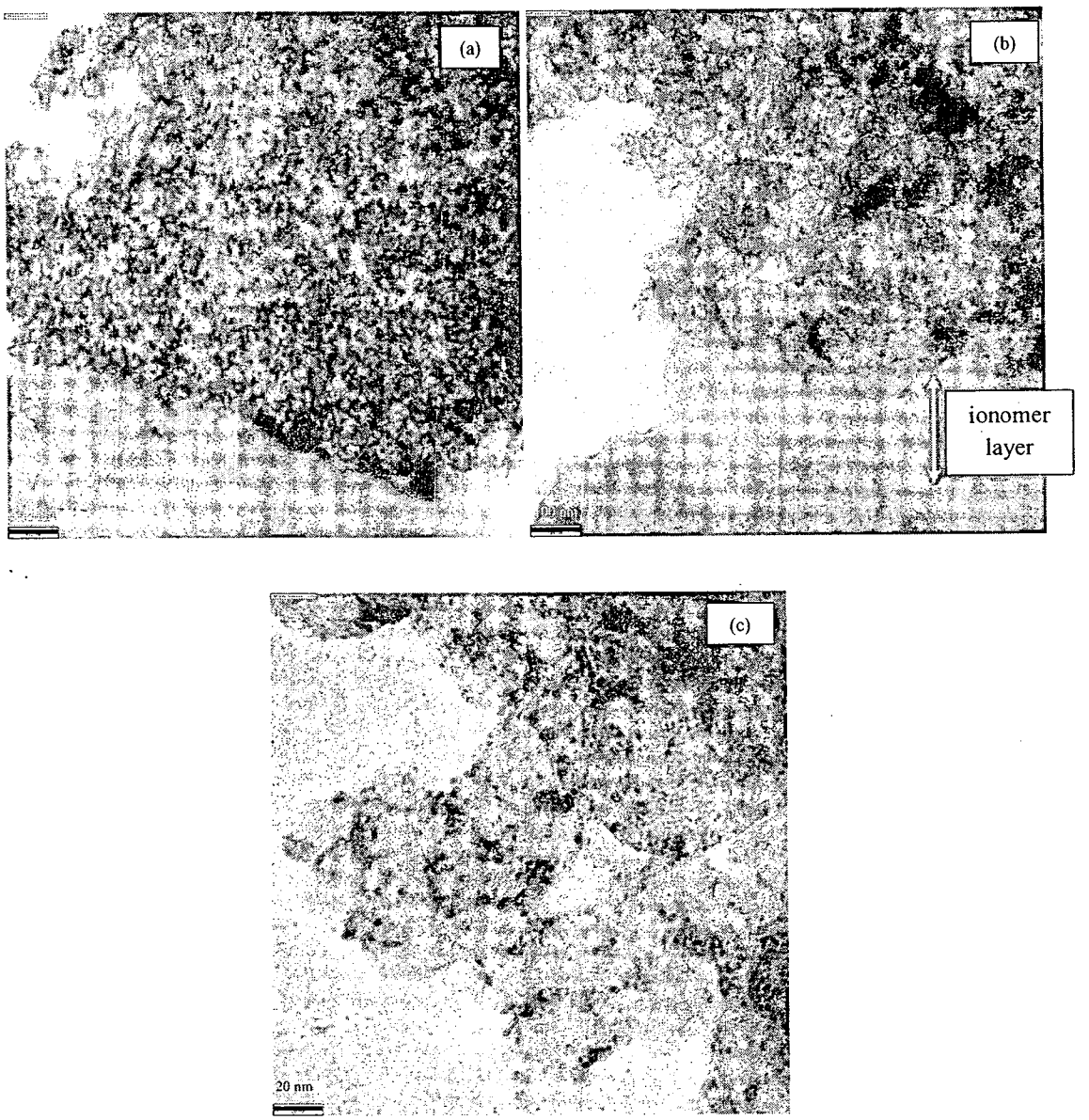


Figure 5. The TEM image of MEA (49.3% of Nafion : Pt/C) at the interface between CCL and electrolyte membrane (a) at a magnification of 4,000 and (b) magnification of 20,000. Figure 5(c) shows the catalyst-coated layer of the MEA at a magnification of 100,000. The black Pt particles are clearly visible in (c).

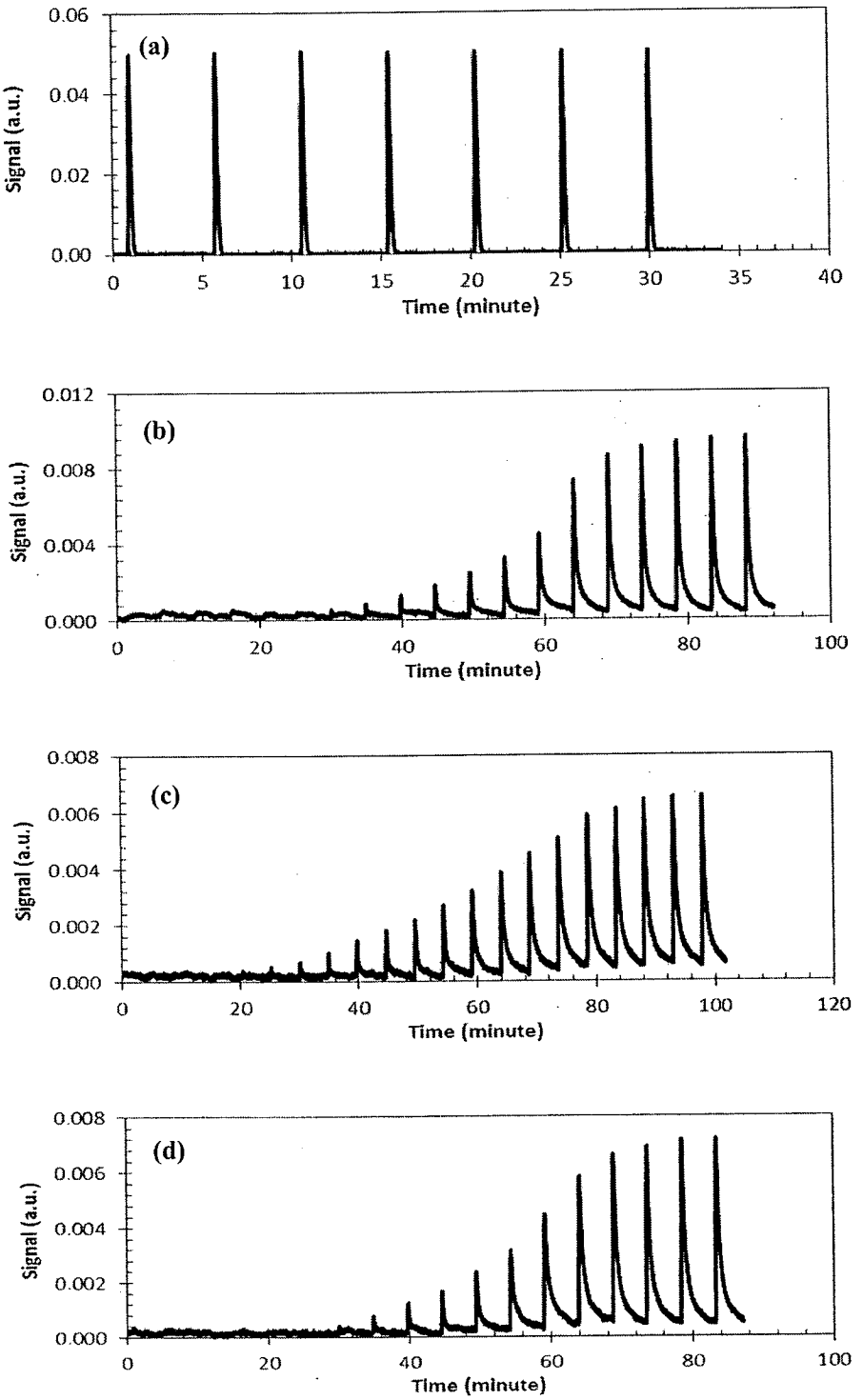


Figure 7. Chemisorption spectra of (a) electrolyte membrane coated with 400 μL of 5% Nafion, (b) powdered 20%wt Pt/C catalyst, (c) 49.3 wt% Nafion : Pt/C, fresh MEA , and (d) 49.3 wt% Nafion : Pt/C, used MEA.

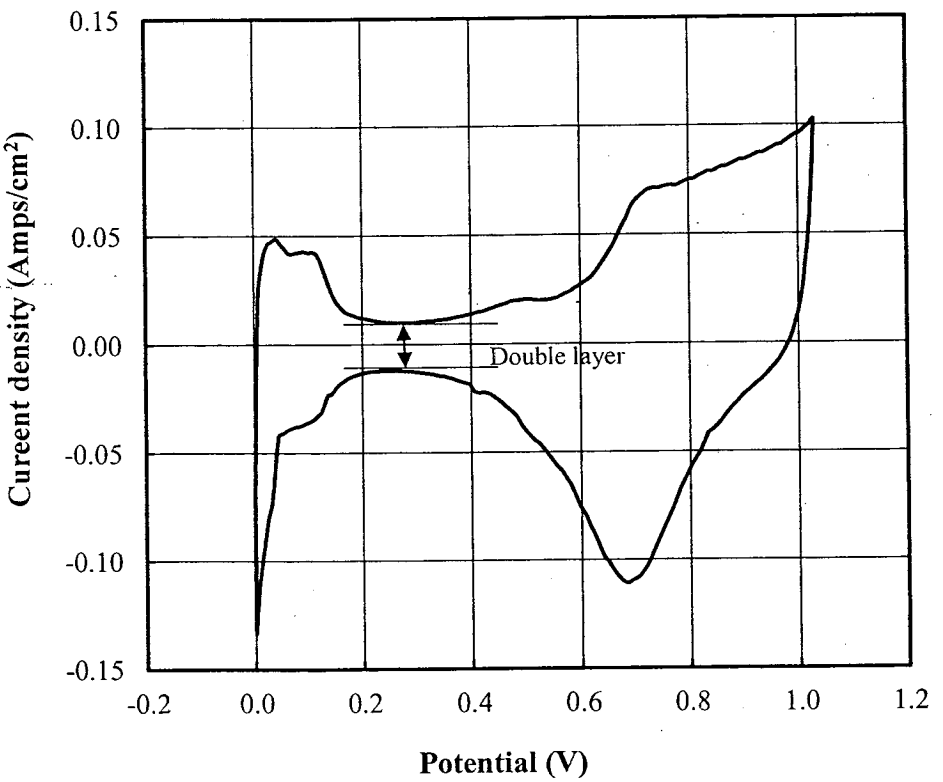


Figure 8. Cyclic voltammetry of MEA (49.3% Nafion : Pt/C) with surface area of 23 $cm^2$ scanned from open circuit voltage (OCV) to 1.14 V with scanning rate of 25 mV/sec, cell temperature of 75 °C, $H_2/N_2$ (A/C) at 300/300 sccm, ambient pressure, and 95% RH both anode and cathode.

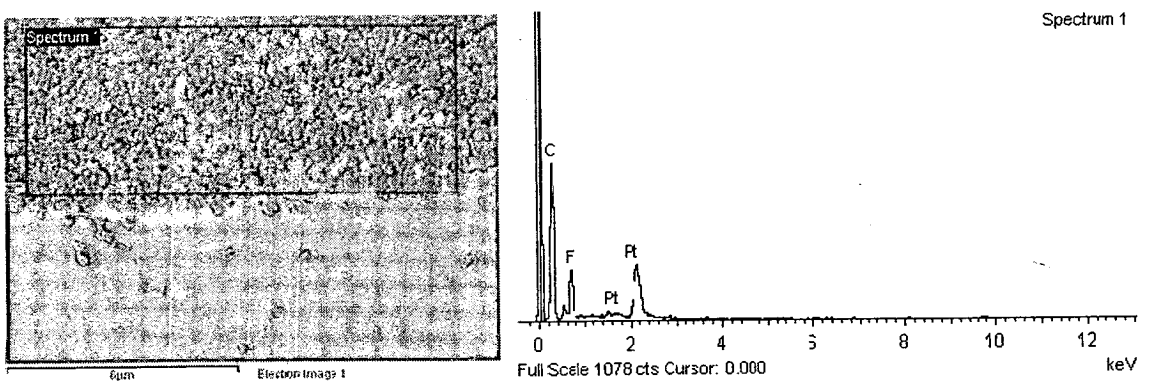


Figure 6. Electron Diffraction X-Ray analysis (EDX) of a cross section of the MEA (49.3% of Nafion : Pt/C). Platinum, carbon, and fluorine (from Nafion) peaks from the highlighted portion of the SEM image are shown in the EDX spectrum.