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A High Performance Microbial Fuel Cell with Nickel Nanoparticle as Cathode Catalyst

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ABSTRACT

The electrochemical performance of an H-type microbial fuel cell (MFC) utilizing anaerobically digested sludge inoculum as bio-anode and Ni nanoparticles as cathode material using anaerobic digestion (AD) effluent of macroalgae substrate was studied. Both the anode and cathode electrodes were made of carbon clothes (2 cm x 4 cm) with proton exchange membrane (PEM) held between the chambers. The cathode electrode was prepared by loading Ni nanoparticles blended with carbon black (Ni/C) on the geometric active surface of the carbon cloth. The electrochemical performances of Ni/C were compared with standard Pt/C catalyst using AD effluent and acetate fuels. It was found that the Ni/C enhanced the oxygen reduction reaction (ORR), thereby displayed comparable power outputs to Pt/C based MFC. The maximum power density of the MFC with Ni/C catalyst was 540 mW m^{-2} using AD effluent substrate, and 560 mW m^{-2} when sodium acetate substrate used. The MFC power performance was comparable to previously reported values.

INTRODUCTION

Microbial fuel cells (MFCs) are bio-electrochemical devices that drive current by employing electrogenic bacteria from biodegradable organic materials, which holds great potential for simultaneously addressing the needs for energy regeneration and organic waste treatment. However, the application of these electrochemical devices is marred due to requirements for Pt and the sluggish kinetics of ORR in a near neutral medium, which seriously limits the power density. In this regard, nanostructured electrode material opens up new opportunities for the development of high-performance MFCs.

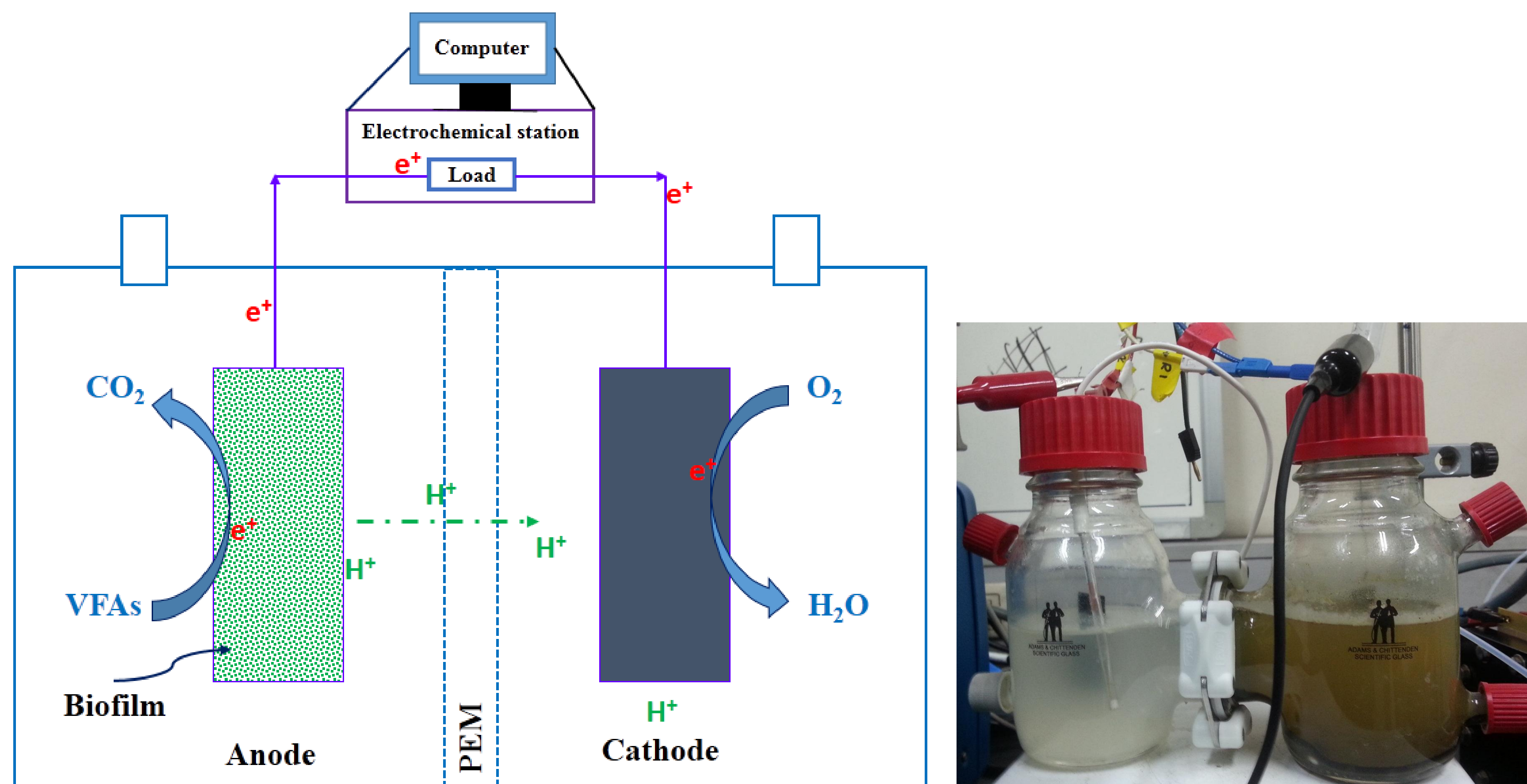


Fig. 1: Schematic representation and picture of MFC

EXPERIMENTAL DETAILS

Catalyst synthesis

Nickel nanoparticle (Ni) was synthesized by chemical reduction of nickel chloride using hydrazine hydrate as a reducing agent.

Electrode preparation

The anode electrode was made by depositing a mixed culture on carbon cloth. For cathode the Ni-based electrode was fabricated as follows, firstly Ni was blended with carbon black in the ratio of 30:70 wt% (Ni/C) using ball milling. Catalyst ink of Ni/C hybrid were dissolved in a 5% Nafion solution and isopropanol, stirred for one day, and sonicated for 10 minutes. Then airbrush technique was used to deposit the ink on the carbon cloth.

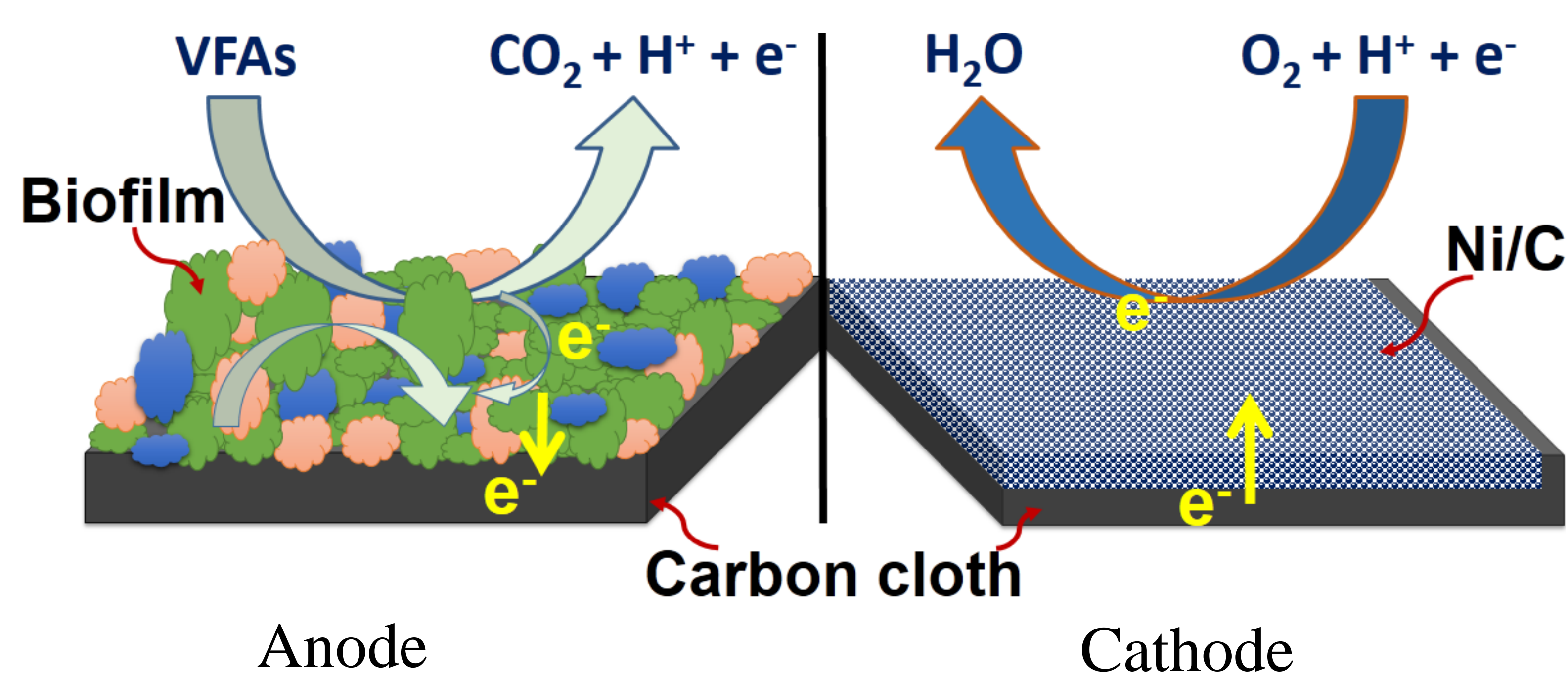


Fig. 2: Electrode preparation

RESULTS AND DISCUSSION

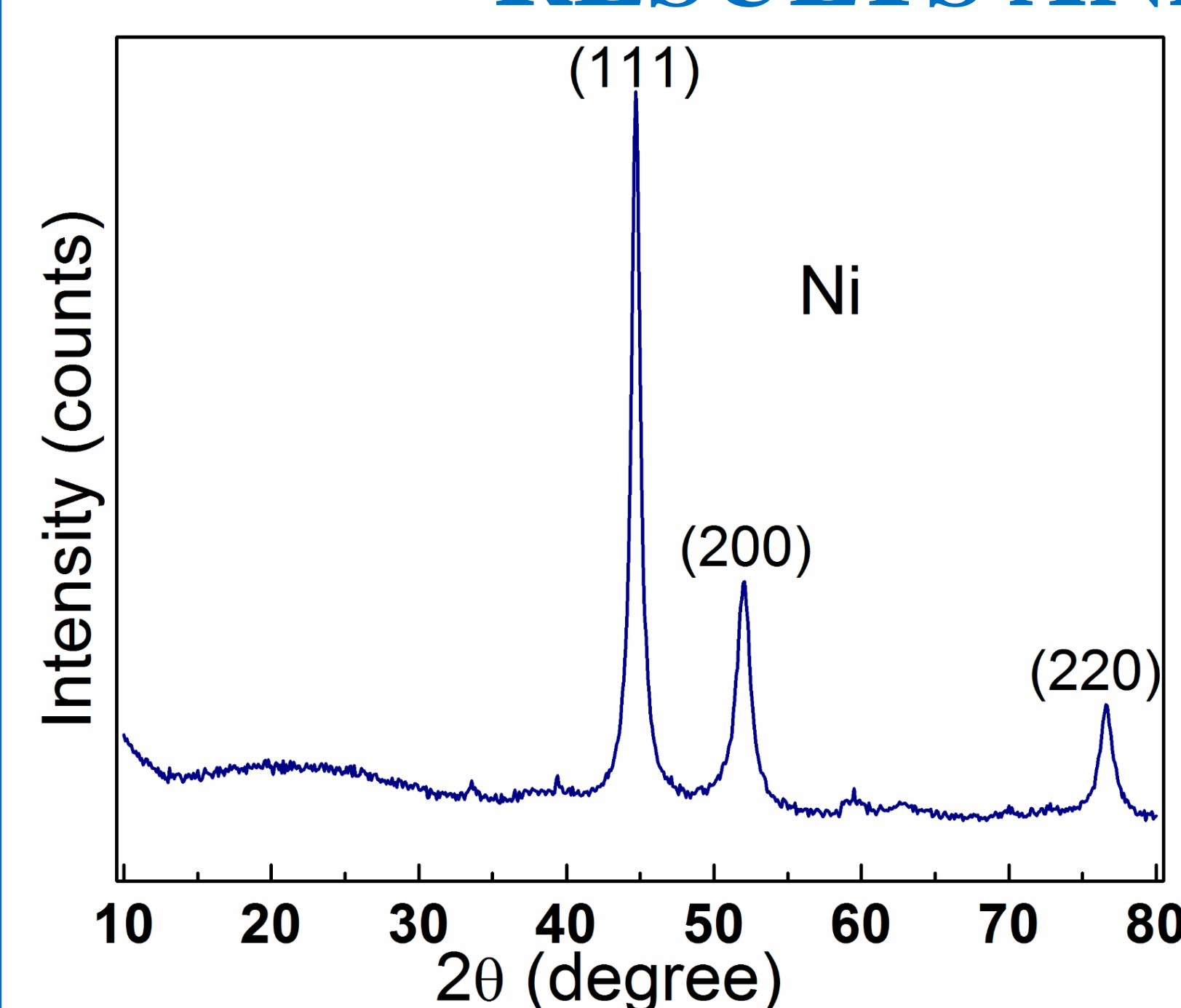


Fig. 3: XRD pattern

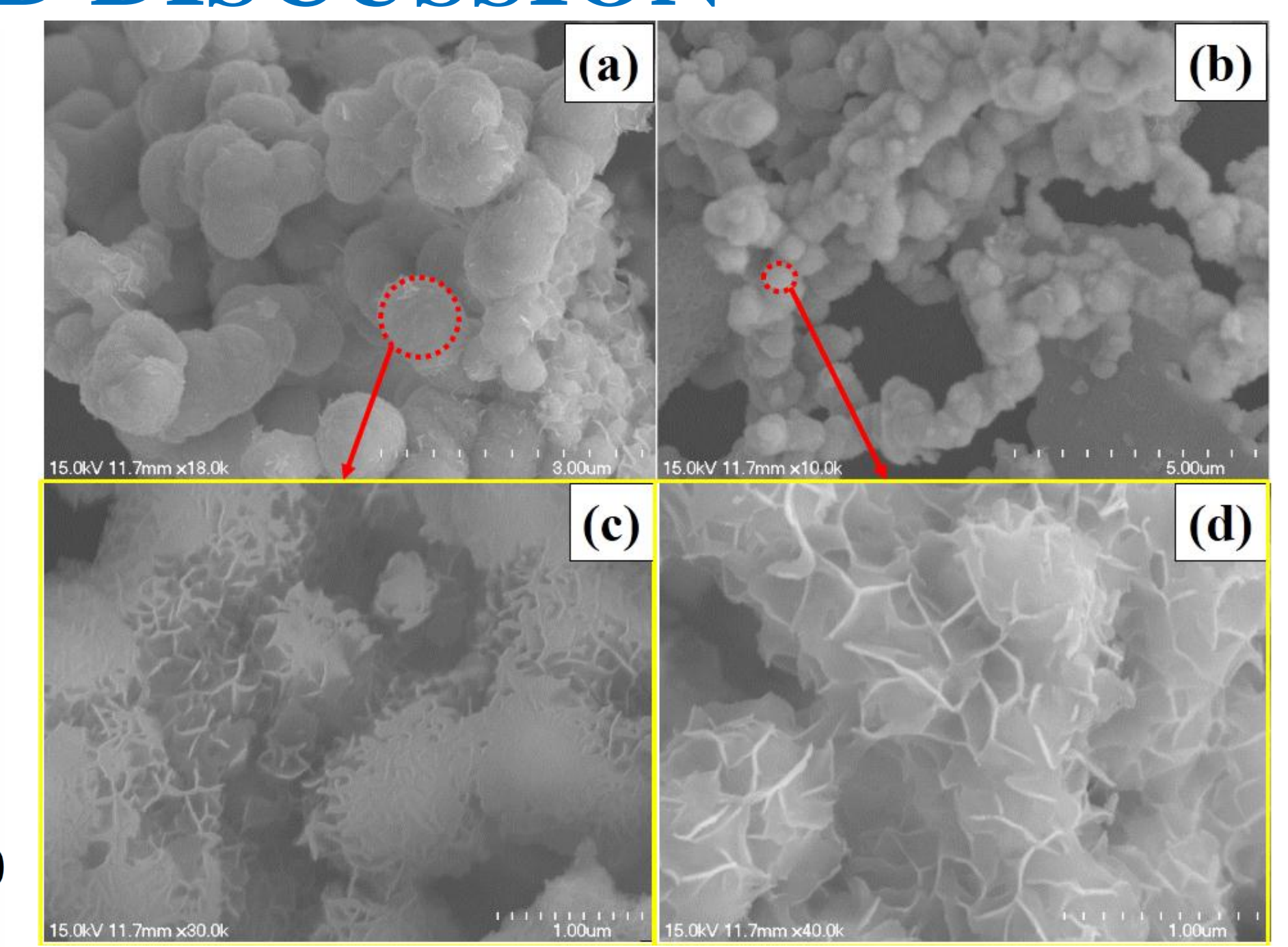
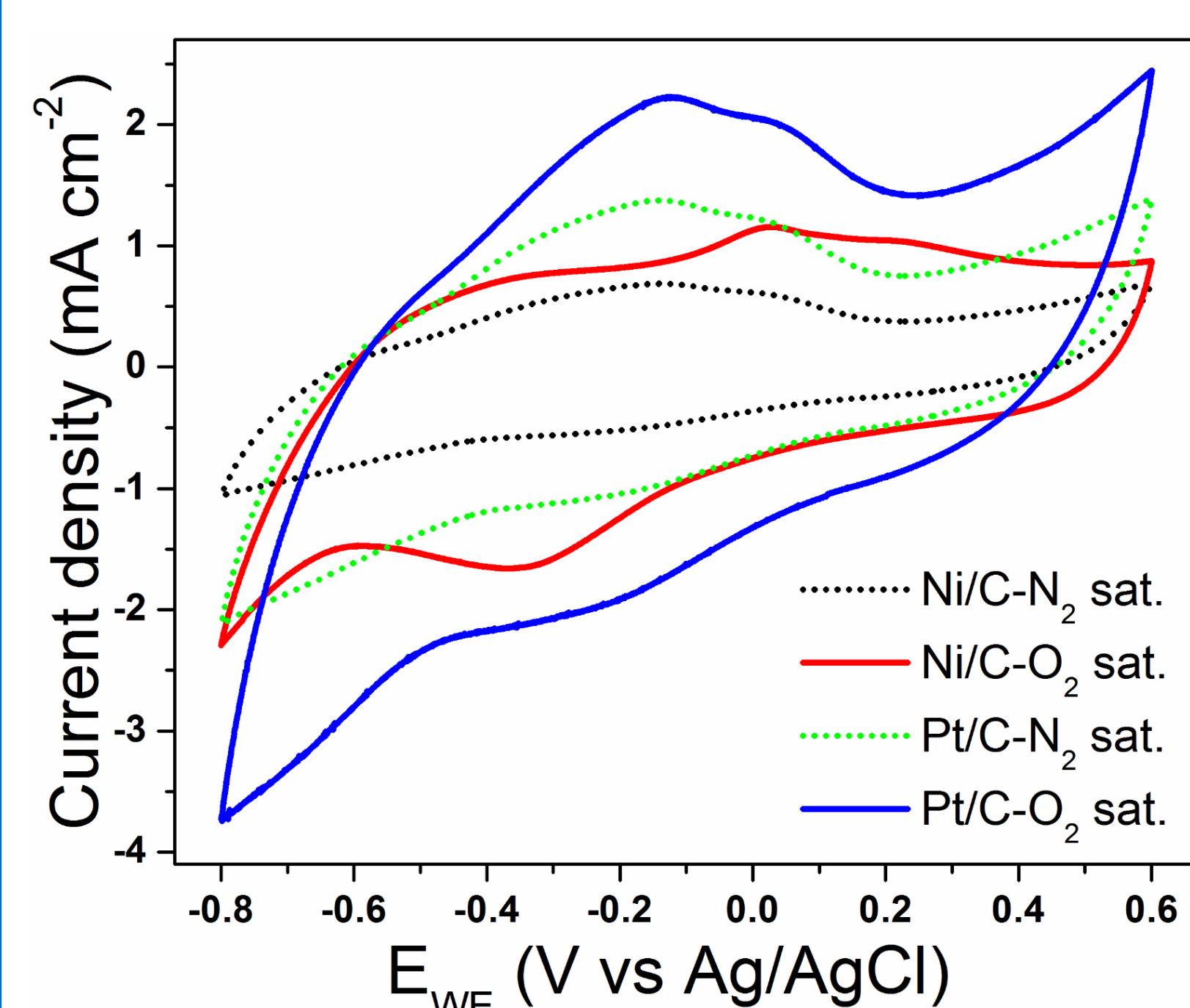


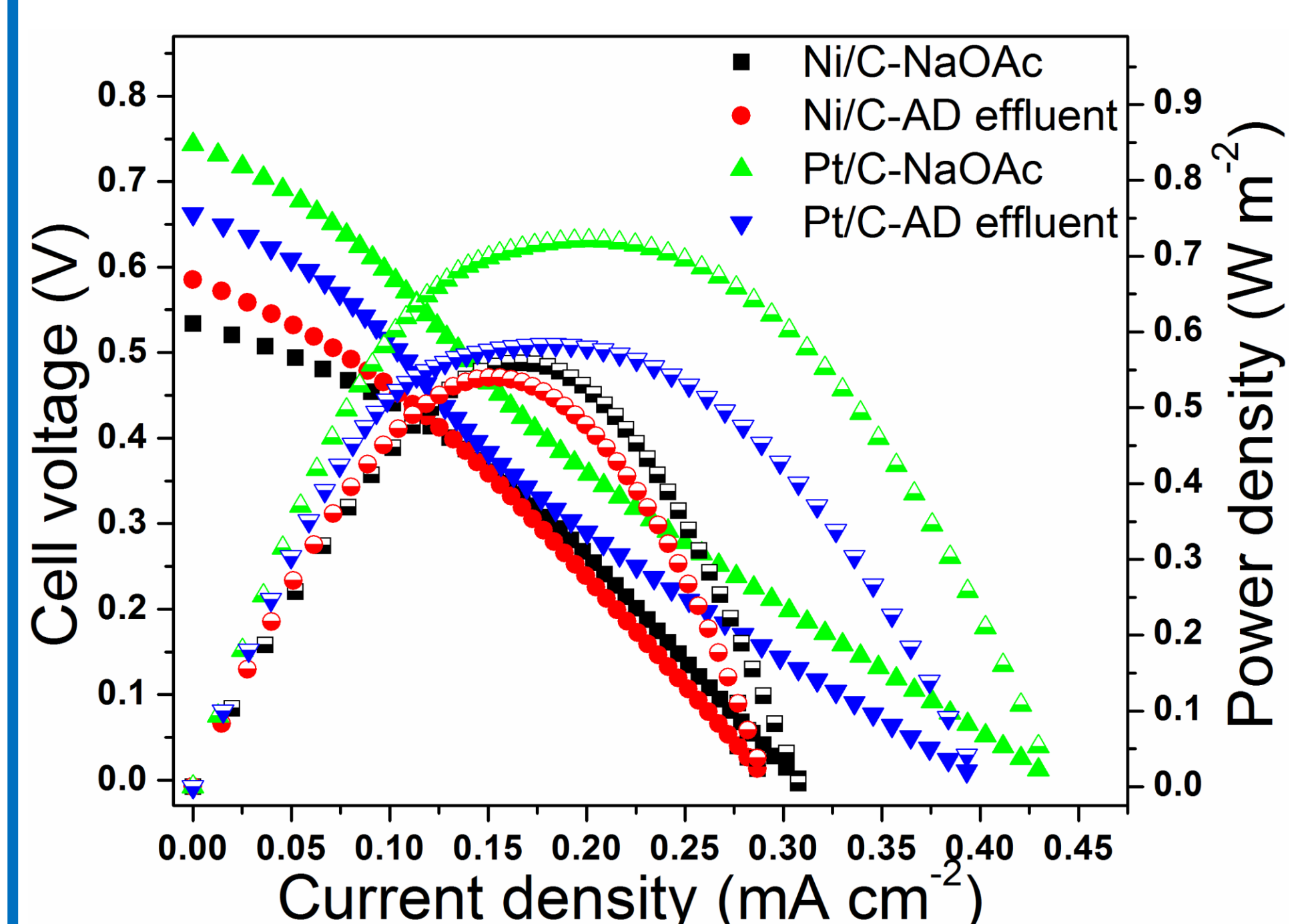
Fig. 4: SEM images

The XRD pattern indicated that the resulting powders were face-centered cubic (fcc) nickel. The SEM images show Ni particles with hydrangea-like morphology.



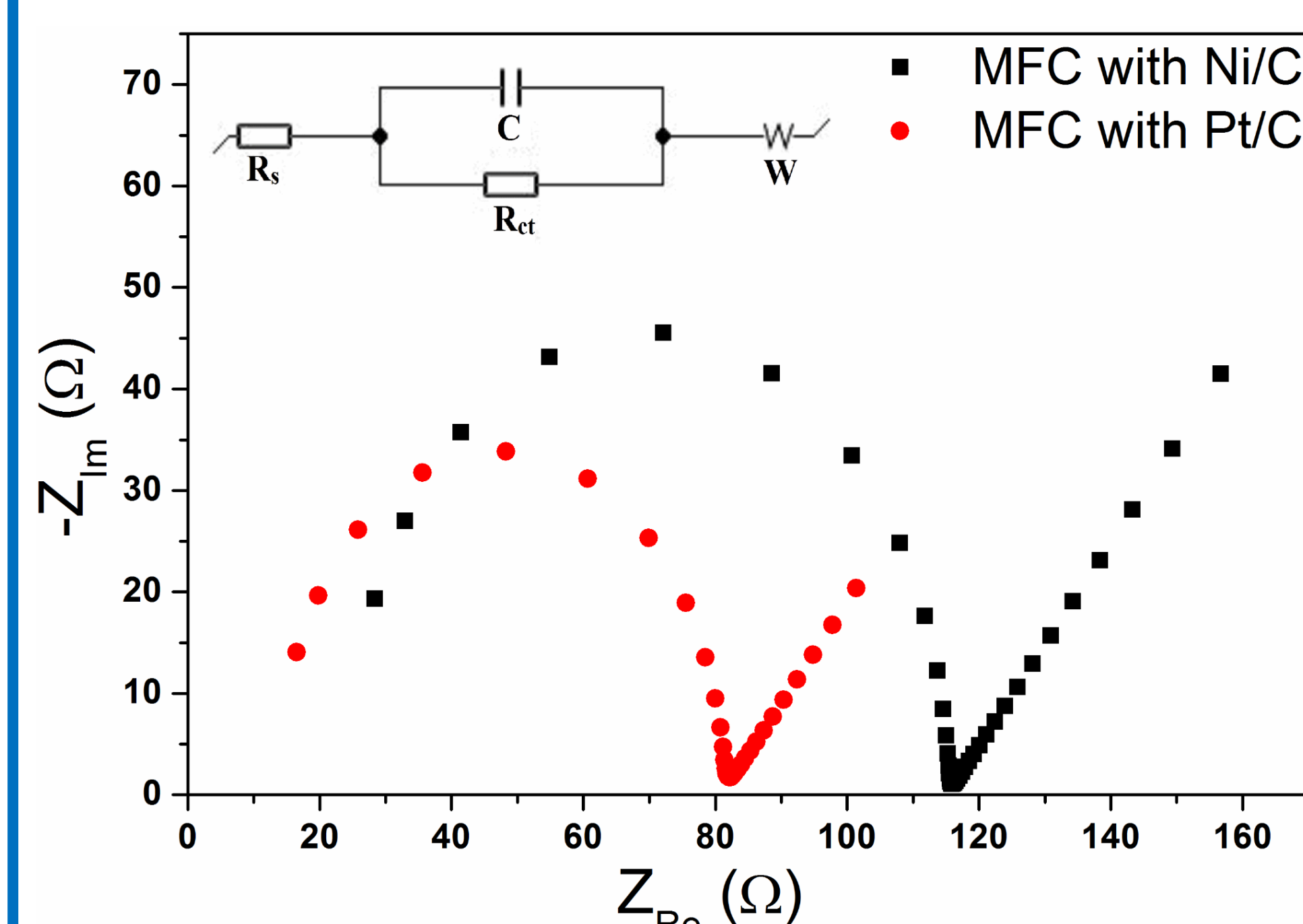
The CV results for Ni/C shows a less positive reduction peak potential, -0.37 V , than Pt/C (-0.22 V), and a peak current density of -1.66 mA cm^{-2} , which is 85% of Pt/C (-1.96 mA cm^{-2}).

Fig. 5: Cyclic voltammetry plots



The maximum power density of the MFC with Ni/C catalyst was 540 mW m^{-2} , 93% of Pt/C (584 mW m^{-2}) using AD effluent; and 560 mW m^{-2} (78% of Pt/C, 721 mW m^{-2}) with acetate.

Fig. 6: Power density curves



The EIS results supported the results obtained from polarization study (inset equivalent circuit).

Fig. 7: Nyquist plots

CONCLUSION

The study demonstrated that Ni/C exhibited good performance for ORR under neutral conditions, thereby displayed comparable power outputs to Pt/C based MFC. In the experimental cell test, higher maximum power density was achieved than some reported values. Moreover, the cost of producing the electrode was greatly reduced.