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Nitrogen and sulfur co-doped mesoporous carbon as cathode catalyst for H₂/O₂ alkaline membrane fuel cell – effect of catalyst/bonding layer loading

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ABSTRACT

In this study, nitrogen and sulfur co-doped mesoporous carbon (N-S-MPC) materials are selected as the platform to demonstrate the potential of N-S-MPC to replace precious metal catalyst for fuel cell cathode oxygen reduction. Using both N-S-MPC and commercial available 40%Pt/C as cathode catalysts, the effects of catalyst and bonding layer in the catalyst layer (CL) on the power generation performances are thoroughly investigated for alkaline membrane fuel cells (AMFCs). Through single cell tests, several observations are reached as follows: (1) For N-S-MPC cathode, with increasing N-S-MPC loading from 1.00 to 5.00 mg cm⁻², the power density reached the maximum (21.7 mW cm⁻²) when the catalyst loading is 3 mg cm⁻². However, for Pt/C cathode the power density reached the maximum (21.3 mW cm⁻²) for a catalyst loading of 0.5 mg cm⁻², with increasing loading from 0.3 to 0.5 mg cm⁻²; (2) Increasing the thickness of catalyst layer resulted in an increase in power density. Thus, raising the local hydroxyl ion concentration was in favor of the process of oxygen reduction reaction. (3) The bonding layer also has a significant influence on the MEA fabrications, where the MEA using 30 μL bonding layer produced a maximum power density of 20.8 mW cm⁻².

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Introduction

The energy crisis and environmental pollution have stimulated significant research into new, efficient and sustainable energy sources to compensate and even replace traditional

ones [1,2]. The polymer electrolyte membrane fuel cell (PEMFC) has been considered as promising green energy device due to its high energy conservation efficiency, the possibility of using regenerative fuels, low or zero levels of noxious emissions of environmental pollutants, a low operating temperature and a relatively quick start-up [3–5]. However, the

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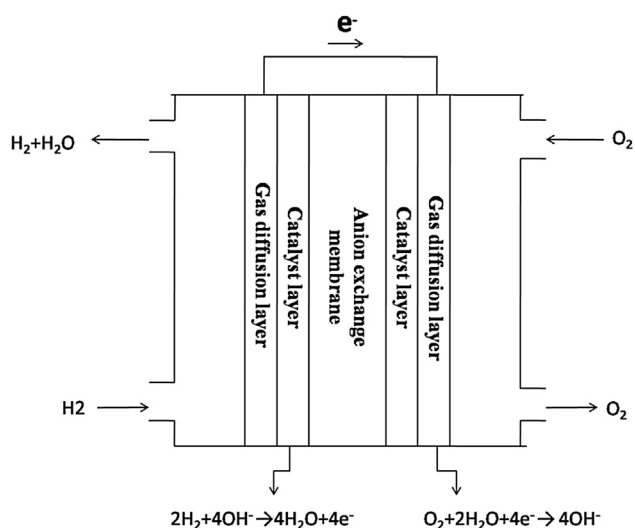


Fig. 1 – A schematic of a typical AMFC (H_2 as the fuel and O_2 as the oxidant).

PEMFC need precious metals such as Pt as electrocatalyst, therefore, the major effort in fuel cell associated technologies have been devoted to reducing Pt loading in catalyst layer (CL) of electrode by exploring more active catalysts, and/or replacing Pt metal using other non-precious metals such as Fe, Co and Cu [6–8].

PEMFC can be divided into two kinds of systems, according to the media (proton or hydroxyl ion transport) the PEMFC

operated. Recently, the growing interest in the application of alkaline membrane fuel cells (AMFCs) is principally motivated by the prospective use of cheap, easy to start, and relatively abundant non-precious metal catalysts [9,10]. Regarding non-precious metal catalysts, extensive work have been done to develop transition metal N-containing complexes, conductive polymer-based catalysts, transition metal chalcogenides, metaloxides/carbides/nitrides/oxynitrides/carbonitrides and enzymatic compounds [6,11,12]. However, compared with Pt-based catalysts, these alternatives usually suffer from high activation polarization and poor durability, partly caused by the instability of transition metals [13–15]. At the same time in the study of Pt-based noble metal catalysts, many efforts have been made to either enhance the performance of Pt-based catalysts through the shape and size control of the Pt or the fabrication of the carbonaceous support especially in cathode owing to its sluggish kinetics of oxygen reduction reaction (ORR) [16–18]. In the study of the above, nitrogen-doped carbon nanotubes have been seen to be much effective for performance enhancement, particularly in alkaline electrolytes. However, carbon is usually used as the carrier of Pt instead of the catalyst to catalyze the ORR [19,20]. More recently, certain types of heteroatom-doped nanocarbon materials, in particular nitrogen- and sulfur-doped ones, have shown high activity for the ORR [21,22], and the extensive research efforts have been made to explore N-doped non-noble metal or “metal-free” ORR catalysts [23]. S-doped ones as well as N and S co-doped carbon materials, on the other hand, have not been studied extensively [23–25]. For this reason, the study of power performances by applying N and S

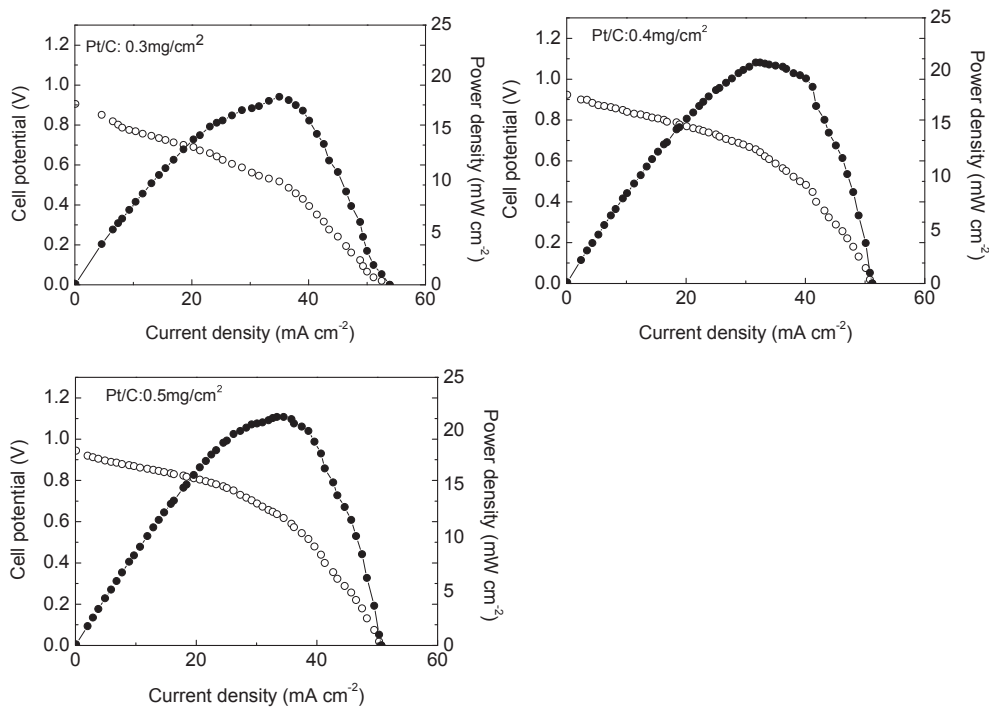


Fig. 2 – Polarization and power density curves of H_2 – O_2 AMFC based on N-S-MPC and Pt/C catalysts. MEA active area: 4.0 cm^2 ; N-S-MPC catalyst loading in cathode: 3 mg cm^{-2} ; Anode catalyst loading of 40%Pt/C: 0.3, 0.4, 0.5 mg cm^{-2} ; Membrane: Tokuyama A201.

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