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Oxygen reduction and hydrogen oxidation reaction on novel carbon supported Pd_xIr_y electrocatalysts

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ABSTRACT

In the present work Vulcan XC-72 carbon supported Pd, Ir and Pd_xIr_y (with x:y atomic ratios of 3:1, 1:1, 1:3) electrocatalysts are thoroughly investigated for the reactions of hydrogen oxidation (HOR) and oxygen reduction (ORR). The catalysts are prepared via a pulse-microwave assisted polyol synhtesis method. The techniques of X-ray diffraction (XRD) and Transmission Electron Microscopy (TEM) are adopted to investigate the elemental composition, the structure, and the morphology of the as prepared electrocatalysts.

Their electrocatalytic properties toward HOR and ORR are evaluated by the aid of cyclic voltammetry (CV) and rotating disk electrode (RDE) techniques. It is found that after the addition of even a small amount of iridium, the electrocatalytic activity of pure palladium is enhanced toward both reactions.

According to the obtained results the highest HOR and ORR electrocatalytic activity enhancement is exhibited by PdIr (1:1) sample. The order of the electrocatalytic activity is found to be PdIr > $PdIr_3$ > Pd_3Ir > Pd > Ir for HOR and PdIr > Pd_3Ir > $PdIr_3$ > Pd > Ir for the ORR, respectively.

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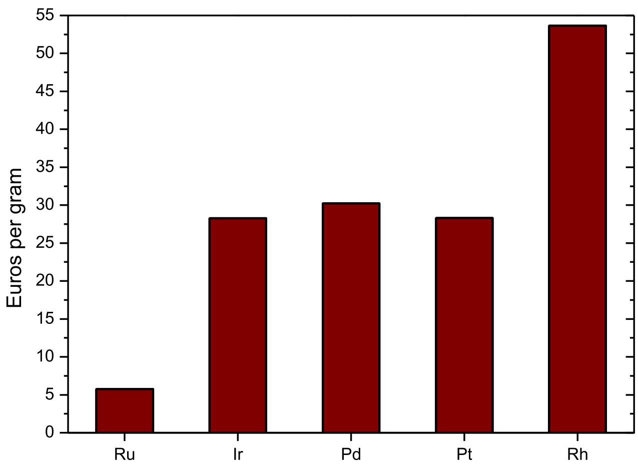

Fig. 1 – Average price in Euros per gram of metal for the period of February 2018 [2].

Introduction

It is well known that platinum-based materials are considered among the most efficient ones to catalyze the electrocatalytic reactions occurring in the hydrogen fed proton exchange membrane fuel cells (H_2-PEMFCs) [1], especially for the sluggish oxygen reduction reaction (ORR). However, due to platinum's rareness and costliness (Fig. 1), it is necessary to develop low-Pt or non-Pt catalysts, with enough activity for the aforementioned reactions.

The last decade, strong improvements were made toward the design and development of such kind of catalysts, aiming at simultaneously maintaining activity and enabling progressively reduced platinum loading [3]. In this context, the utilization of metal palladium has been proposed as an alternative to avoid platinum at all. Pd-based electrocatalysts may play a key role in totally or partially replacing costly Pt in both the anode and cathode of low temperature fuel cells [4].

After years of research, novel strategies and preparation methods for Pd-based catalysts have been appeared, exhibiting better activity than those based on Pt in acidic environment, mostly due to their high solubility, permeability and selectivity [5–7].

Many attempts have also been made to incorporate Pd with other elements in order to enhance HOR activity of pure Pd. Various Pd-based catalysts with novel nanostructures, such as hollow, porous, core/shell, near-surface alloys etc. have been synthesized [8,9], including bimetallic Pt–Pd [10–12], Pd–Ru [13], Pd–Ni [14] and tri-metallic Pd–Pt–Rh [15], Pd–Ru–WO_x [16], Pd–Ir–WO_x [16] catalysts.

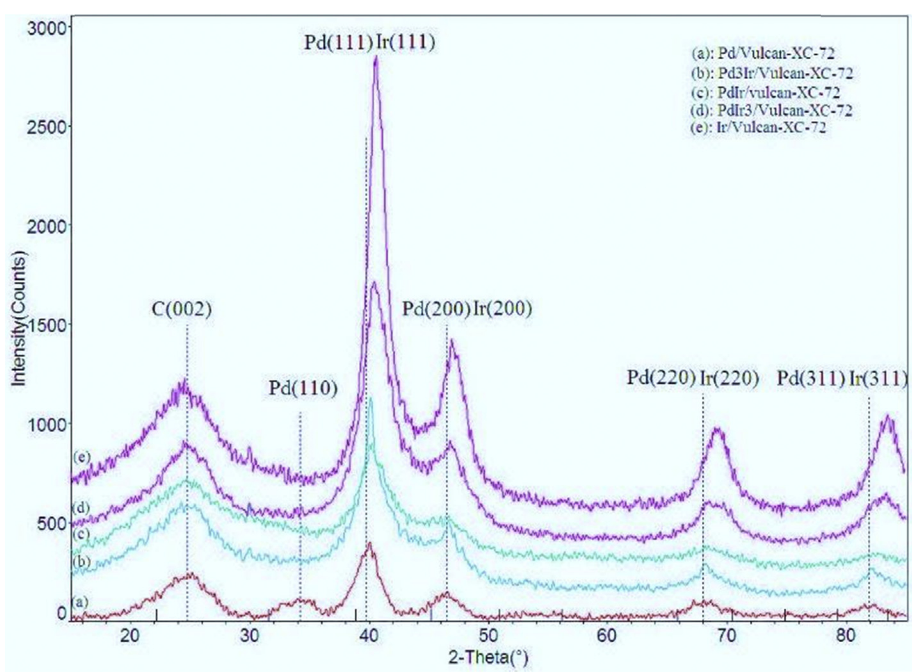

Fig. 2 – XRD patterns of Vulcan XC-72 supported: (a) Pd, (b) Pd_3Ir, (c) PdIr, (d) $PdIr_3$ and (e) Ir [37].

Table 1 – Results obtained from the physicochemical characterization.

Electrocatalyst	Lattice parameter (nm)	Crystallite size (nm)	Internal distance (nm)	Particles size (±0.3 nm)
Pd/C	0.38615	3.00	0.18701	4.30
Ir/C	0.38448	3.50	0.16655	5.70
Pd_3Ir/C	0.38843	3.50	0.16835	4.50
PdIr/C	0.38810	3.00	0.16812	4.40
$PdIr_3$/C	0.38503	4.00	0.16688	5.30

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