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Platinum nanoparticle-decorated TiO_2 nanotube arrays as new highly active and non-poisoning catalyst for photo-electrochemical oxidation of galactose

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ABSTRACT

Platinum nanoparticles were doped on the TiO_2 nanotube using a microemulsion method. The TiO_2 nanotube arrays were successfully fabricated by the anodizing of titanium sheets. The morphology and surface analysis of the Pt-TiO_2 nanotubes were investigated using SEM, EDX and XRD respectively. The electro-oxidation of galactose on this catalyst in alkaline medium was studied using cyclic voltammetry and chronoamperometry methods. The results showed that the oxidation peak currents on the Pt-TiO_2 nanotubes for galactose oxidation are larger than those on a smooth platinum electrode and confirmed the better electro-catalytic activity and stability of these new catalysts. The photo-catalytic properties of the TiO_2 make the Pt-TiO_2 nanotubes electrode reusable after a short UV treatment, and the electro-oxidation current density of the Pt-TiO_2 nanotubes after UV-cleaning can be re-established.

1. Introduction

Direct electrochemical oxidation of carbohydrates is of a very high interest from several points of from biomedical applications involving blood sugar analysis, fuel cells applications to ecological approaches like waste water treatment in food industrials. Carbohydrates that comprise more than 80% of available biomass are the most abundant compounds. The ideal fuel for fuel cells in power generation systems is the direct use of a fuel like carbohydrates in the form of a liquid phase [1–4]. This allows easier use with negligible energy input for the enrichment of the fuel. Fuels such as glucose, galactose or other carbohydrates can easily be utilized by mixing them directly in the electrolyte without the use of any auxiliary reforming equipment, membrane barriers, or additional microbial cultures. Great efforts have been made to develop catalytically active electrode materials for this reaction in the past two decades. Various authors have shown that various carbohydrates can be oxidized directly at a variety of electrode materials, including metals such as platinum [5], gold [5,6], copper [5,7–9], indium [5], rhodium [5], nickel oxide [10], tungsten oxide [11] and ruthenium oxide [12]. However, systematical study showed that these electrodes were subject to serious poisoning due to adsorbed intermediates from the oxidation of carbohydrates [13]. To mitigate the poisoning effect, significant attention has been focused on preparing new electrodes with high electro-catalytic activity. Immobilization of the noble metal nanoparticles in an active matrix may enhance the overall reactivity of the catalytic metal centers. For a good electro-catalyst, both the high catalytic activity and the low cost must be considered to meet the final purpose of wide commercialization of fuel cells. High surface area electro-catalytic electrodes are of interest for fuel cell technology. The high surface area electro-catalysts can be made by sintering, electro-deposition or dispersion of active electro-catalytic materials on a proper support with a relatively high surface area. During search for novel and stable support for the noble metal catalysts, TiO_2 nanotubes come into sight because of their good physical and chemical properties and high stability in acidic and alkaline solutions. Titanium dioxide nanotubes are very biocompatible, inexpensive and environmentally benign [14,15]. Titanium dioxide nanotube arrays have demonstrated a number of important applications including gas sensors, solar cells, photo-catalysts, tissue engineering, biosensors and electro-catalyst [16–19]. TiO_2 nanotubes can be synthesized by different methods including sol–gel, hydrothermal, template and anodic oxidation [20–25]. Obviously, if TiO_2 nanotubes can be directly produced on a metallic titanium substrate by the anodic oxidation method, it would be advantageous and convenient for fuel cell applications where an electric current collector is required. Moreover, the morphology and the structure of the TiO_2 nanotubes layer can also be easily modulated by changing the anodic oxidation conditions [26]. Our recent studies have shown that the immobilization of the metal nanoparticles in a porous matrix improves the electro-catalytic activity to a

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