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Bio-ethanol steam reforming: Insights on the mechanism for hydrogen production

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Abstract

New catalysts for hydrogen production by steam reforming of bio-ethanol have been developed. Catalytic tests have been performed at laboratory scale, with the reaction conditions demanded in a real processor: i.e. ethanol and water feed, without a diluent gas. Catalyst ICP0503 has shown high activity and good resistance to carbon deposition. Reaction results show total conversion, high selectivity to hydrogen (70%), CO_2, CO and CH_4 being the only by-products obtained. The reaction yields 4.25 mol of hydrogen by mol of ethanol fed, close to the thermodynamic equilibrium prediction. The temperature influence on the catalytic activity for this catalyst has been studied. Conversion reaches 100% at temperature higher than 600 °C. In the light of reaction results obtained, a reaction mechanism for ethanol steam reforming is proposed. Long-term reaction experiments have been performed in order to study the stability of the catalytic activity. The excellent stability of the catalyst ICP0503 indicates that the reformed stream could be fed directly to a high temperature fuel cell (MCFC, SOFC) without a further purification treatment. These facts suggest that ICP0503 is a good candidate to be implemented in a bio-ethanol processor for hydrogen production to feed a fuel cell.

Keywords: Bio-ethanol; Steam reforming; Fuel processor; Fuel cell; Hydrogen

1. Introduction

Nowadays catalytic steam reforming is a new interest focus as the main pathway to obtain hydrogen from hydrocarbons or alcohols to be supplied to a fuel cell [1,2]. In comparison with other fuels, ethanol presents a series of advantages, since it is easier to store, handle and transport in a safe way due to its lower toxicity and volatility. In addition, this alcohol can be distributed in a logistic net similar to the conventional gas stations. From this standpoint, ethanol steam reforming is one of the best alternatives to obtain hydrogen. Ethanol can be obtained from biomass by fermentation processes, and the ethanol obtained in this way is named bio-ethanol. Vegetables consume the carbon dioxide produced from the use of ethanol as a fuel; therefore the carbon cycle is closed and these carbon dioxide emissions are not considered that contribute to the global warming.

Thermodynamic studies have shown the feasibility of hydrogen production from ethanol steam reforming for fuel cell applications [3–5]. There are several alternatives to carry out the reforming process: auto-thermal reforming, Eq. (1), a self sustained process fed with fuel, steam and oxygen, where a part of the ethanol is consumed to produce the necessary heat to maintain the reaction; and steam reforming, Eq. (2), endothermic reaction where reaction heat has to be supplied by an external device. In order to maximize the hydrogen yield, an excess of water is usually fed to carry out the water gas shift reaction. If it is performed in the same catalytic bed as the reforming, then the net processes proceed according to the following equations.

$$CH_3CH_2OH + \frac{1}{2}O_2 + 2H_2O \rightleftarrows 5H_2 + 2CO_2,$$
$$\Delta H^\circ = -50.3\,\mathrm{kJmol^{-1}} \quad (1)$$

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