Chapter 9
Dry Reforming of Methane on LaSrNiAl Perovskite-Type Structures Synthesized by Solution Combustion

Pedro J. Rodríguez-Sulbarán
Universidad de Los Andes, Venezuela

Claudio A. Lugo
Universidad de Los Andes, Venezuela

Manuel A. Perez
Universidad de Los Andes, Venezuela

Sergio L. Gonzalez-Cortes
University of Oxford, UK

Renato D’Angelo
Universidad de Los Andes, Venezuela

Jairo Rondon
PDVSA Gas, Venezuela

Hildemaro Melendez
PDVSA Gas, Venezuela

Mahiceth Quintero
Universidad de Los Andes, Venezuela

Patricia Perez
Universidad de Los Andes, Venezuela

Marlin D. Villarroel
Universidad de Los Andes, Venezuela

Freddy E. Imbert
Universidad de Los Andes, Venezuela

Hector L. Del Castillo
Universidad de Los Andes, Venezuela

ABSTRACT

A comprehensive study of the effect of the combustion fuel (i.e., glycine and sucrose), ignition source (i.e., furnace and microwave radiation), and nickel content is carried out for the dry reforming of methane (DRM) using La$_{0.8}$Sr$_{0.2}$Ni$_y$Al$_{1-y}$O$_3$ (LaSrNiAl) ($y = 0.1; 0.2$ and $0.3$) perovskite-type catalyst precursors synthesized by solution combustion synthesis (SCS). The composition of the catalyst precursor and the combustion fuel rather than the ignition source affected markedly the crystalline phase composition, crystallite size, morphology, specific surface, and reducibility. Those changes are also reflected in the catalytic performance of the SCS-prepared catalyst in the reaction of DRM. The results clearly show that the SCS approach can effectively tune the dry reforming of methane and the reverse water-gas shift reactions by varying the combustion fuels.

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INTRODUCTION

A Brief Overview of Hydrogen Production

Hydrogen can be an ideal sustainable energy carrier, due to the very low level of emissions related to its use and its vast sources and if it is produced from renewable vast resources and at low costs, then the hydrogen economy will be fully advantageous.

The global demand for environmental concerns and energy production, due to rising standards of living and increasing population are very sensitive and significant issues in the 21st century (Dudley, 2016; Nikolaidis & Poullikkas, 2017; Sunita & Ghoshal, 2015).

For instance, in 2015, the world total primary energy supply (TPES) reached 13,423 Mtoe (1 Mtoe = 11.63 TWh), of which 81% came from fossil fuels and 27% were consumed by transportation sector. 23,816 TWh of electricity were generated in 2014, of which 66% came from fossil fuels (Dupont, 2007; Conti, et al., 2016). The increase in world oil consumption was predicted to rise from 82 to 121 million barrels per day between 2006 and 2030 (Dupont, 2007). While for the year 2040, the energy consumption is estimated to be 20,533 Mtoe (Conti, et al., 2016). The CO₂ emissions as a result of fossil fuel utilization, in 2014 were 32,381 Mt (Birol, 2016) (Meyer & Pachauri, 2014). The instability in the crude oil price, the limited reserve of fossil fuels, the increased environmental worries related to greenhouse gas (GHG) emissions and global warming, the overall human health and safety considerations will gradually decrease the fossil fuel production over time, and motivate the research for alternative non-fossil fuel energy sources, that could greatly reduce the CO₂-related emissions and their adverse effect on global warming (Muradov & Veziroğlu, 2008; Balat & Balat, 2009; Birol, 2016). An estimated 30–40% of the carbon dioxide from human activity released into the atmosphere dissolves into oceans, rivers and lakes. The uptake of carbon dioxide (CO₂) from the atmosphere causes the ocean acidification (decrease in natural ocean alkalinity). Part of the CO₂ absorbed by the ocean reacts with the water to form carbonic acid, some of these extra carbonic acid molecules react with a water molecule to give a bi-carbonate ion and a hydronium ion, thus decreasing ocean natural alkalinity by increasing H⁺ ion concentration.

Renewable energy is the world’s fastest-growing source of energy, at an average rate of 2.6%/year compared to 2.3%/year of nuclear energy, 1.9%/year for natural gas, coal growing at an average rate of 0.6%/year and with an average increase of 1.4%/year in total world energy demand (Conti, et al., 2016). According to the latest Eurostat statistics, the share of renewable energy in gross final energy consumption in the European Union (EU) reached 16.7% in 2015, which nearly doubles the 2004 level of 8.5%. The EU aims to reach a 20% share by 2020 and at least 27% by 2030. Eleven countries have already reached the level required to meet their national 2020 targets: Sweden (53.9% vs. 49%), Finland (39.3% vs. 38%), Denmark (30.8% vs 30%), Croatia (29% vs. 20%), Estonia (28.6% vs 25%), Lithuania (25.8% vs. 23%), Romania (24.8% vs. 24%), Bulgaria (18.2% versus a 16% target), Italy (17.5% vs. 17%), the Czech Republic (15.1% vs. 13%) and Hungary (14.5% vs. 13%) (Dupont, 2007).

Hydrogen is considered an important future alternative source for sustainable energy systems in the stationary power, transportation, industrial and residential sectors (GII, 2014; Serfass, 2011; Edwards, et al., 2008; Riis, et al., 2006) as it can be safely transported through conventional means (GII, 2014; Serfass, 2011; Pasman & Rogers, 2010; Zhou, 2005). Hydrogen can be stored as compressed gas, cryogenic liquid or solid hydride (Zheng, et al., 2012; Lipman, 2011; Sakintuna, et al., 2007; Riis, et al., 2006; Züttel, 2004; Züttel, 2003). Hydrogen can be used as the fuel either for direct combustion in an internal