Synthesis and Characterization of Photocatalyst for Conversion of CO_2 to Methanol under Visible Light Irradiation

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***Abstract*—**The aim of this study is to understand the mechanism for the production of photocatalyst nano-particles of specific shape and size for CO_2 conversion into liquid fuel and to investigate the photocatalytic activity of the reduction of CO_2 on synthesized photocatalysts. Carbon dioxide is one of the primary green house gases causing Earth's global warming effect. Currently photocatalytic reduction of CO_2 to the formation of liquid fuels (methanol) is corresponded a major scientific challenge to provide sustainable energy solutions and metal oxide-based systems utilize mostly the photo-catalytically activate due to wide band gap energy. Calcium ferrite, $CaFe_2O_4$ was developed by sol-gel method and was characterized by Field Emission Scanning Electron Microscopy (FE-SEM), X-ray powder Diffraction (XRD) and Brunauer-Emmett-Teller (BET), X-ray photoelectron spectroscopy (XPS), Thermo gravimetric analysis (TGA), Fourier Transform Infrared Spectroscopy (FT-IR) and gas pycnometer. The photocatalytic activity for the photocatalytic reduction of carbon dioxide to liquid fuel was investigated and the obtained experimental data demonstrate that the optimum preparation condition was at temperature 1050 °C and the powdered nano structured $CaFe_2O_4$ exhibited good photocatalytic properties to photo reduction of water.

***Keywords*—**Photocatalyst, Carbon dioxide reduction, Visible light

I. Introduction

A rapidly growing population and industrialization has caused the world's natural resources difficulty in keeping up with demands. Today, fossil fuels such as coal, oil or natural gas are burned in power plants to produce energy. Additionally, civilization and industrialization have brought not only technology, modern life, convenience to humanity but also pollution and emissions from factories, vehicles, and chemical plants, especially with an increase in atmospheric CO_2 concentration [1]. Carbon dioxide is one of the primary green house gases causing Earth's global warming effect. Finding solutions for energy and environmental crisis has become a challenge.

Currently, photocatalytic reduction of CO_2 to the formation of liquid fuels (methanol) is corresponded a major scientific challenge to provide sustainable energy solutions. Integrated carbon capture and subsequent sequestration is generally advanced as the most promising option to tackle greenhouse gases in the short to medium term [2]. Many different types of photocatalysts have been investigated for these reactions, including metallic, bimetallic, trimetallic or metal oxide. Metal oxide-based systems utilize mostly the photo-catalytically activate due to wide band gap energy. In addition, size and shape widely affect the photocatalytic reaction.

Some types of semiconductor powders such as TiO_2, ZnS, CdS and SiC have been used as the photocatalyst, where, in principle, the electron produced in the conduction band by light energy reduces CO_2 to organic compounds. However, TiO2, ZnS, and Sic are not suitable as photocatalysts using visible light, because their band gaps are relatively large (>3 eV). CdS also may not be suitable, because it is photo decomposes and then becomes a poison.

Powdered Calcium Ferrite, $CaFe_2O_4$ photocatalyst in nano range is desirable for photo reduction which can be prepared by sol-gel method. This technique is highly beneficial since the process parameters can be readily varied to produce oxide powders and a range of desirable properties. The capability of absorbing visible light irradiation is the advantage of ferrites as photocatalysts along with them have a low band gap of 1.9 eV and large available catalytic site. Moreover ferrites are magnetic in nature giving them an additional advantage of easy recovery after photocatalytic reaction [3]-[6].

In this study, $CaFe_2O_4$ photocatalyst was synthesized and characterized by Field Emission Scanning Electron Microscopy (FE-SEM), X-ray powder Diffraction (XRD) and Brunauer-Emmett-Teller (BET), X-ray photoelectron spectroscopy (XPS), Thermo gravimetric analysis (TGA), Fourier Transform Infrared Spectroscopy (FT-IR) and gas pycnometer. The catalytic activity for the photocatalytic reduction of carbon dioxide to liquid fuel with different calcination temperature was evaluated.

II. Material and Method

A. Synthesis of CaFe2O4

Nano size $CaFe_2O_4$ particles were synthesized by sol-gel technique. Like a typical synthesis method, stoichiometric ratio of calcium nitrate ($Ca(NO_3)_2 \cdot 4H_2O$) and iron (III) nitrate ($Fe(NO_3)_3 \cdot 9H_2O$) were mixed individually in 100 mL of 30% aqueous ammonia solution and stirred for 24 h at room temperature. Thereafter, the solution was heated slowly and raised the temperature up to 80°C and maintained it until the water evaporation. The resulting brown dry gel-like slurry was

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