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Review

Co-generation of synthesis gas and C_{2+} hydrocarbons from methane and carbon dioxide in a hybrid catalytic-plasma reactor: A review

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Abstract

The topics on conversion and utilization of methane and carbon dioxide are important issues in tackling the global warming effects from the two greenhouse gases. Several technologies including catalytic and plasma have been proposed to improve the process involving conversion and utilization of methane and carbon dioxide. In this paper, an overview of the basic principles, and the effects of CH_4/CO_2 feed ratio, total feed flow rate, discharge power, catalyst, applied voltage, wall temperature, and system pressure in dielectric-barrier discharge (DBD) plasma reactor are addressed. The discharge power, discharge gap, applied voltage and CH_4/CO_2 ratio in the feed showed the most significant effects on the reactor performance. Co-feeding carbon dioxide with the methane feed stream reduced coking and increased methane conversion. The H_2/CO ratio in the products was significantly affected by CH_4/CO_2 ratio. The synergism of the catalyst placed in the discharge gap and the plasma affected the products distribution significantly. Methane and carbon dioxide conversions were influenced significantly by discharge power and applied voltage. The drawbacks of DBD plasma application in the CH_4–CO_2 conversion should be taken into consideration before a new plausible reactor system can be implemented.

Keywords: Dielectric-barrier discharge; Plasma discharge; Microdischarge; Plasma reactor; CH_4–CO_2 conversions

1. Introduction

Mitigation of CO_2, one of the most important greenhouse gases, is the crucial agenda in global warming issues. Meanwhile, the direct conversion of methane to C_{2+} hydrocarbons and synthesis gas has a large implication towards the utilization of natural gas in the gas-based petrochemical and liquid fuel industries. The CH_4/CO_2 ratio in Natuna's and Arun's natural gas compositions (28/71 and 75/15, respectively) should be strategically utilized for the production of synthesis gas, higher hydrocarbons, liquid fuels and other important chemicals. As a consequence, the conversion and utilization of methane and carbon dioxide are widely researched in the field of C_1 chemistry. Several technologies have been proposed to improve the efficiency of methane and carbon dioxide utilization. In the past decades, from the perspective of catalytic chemistry, most efforts have focused on the utilization of CO_2 as a source of carbon. Only recently it has been proposed that CO_2 might also be utilized as an oxygen source or oxidant as it can be considered to be a non-traditional oxidant and oxygen transfer agent. The potentials of non-conventional DBD plasma reactor for converting the two greenhouse gases, methane and CO_2, to synthesis gas and higher hydrocarbons at low temperature and ambient pressure have also been recently reported [1–4]. A comprehensive review on recent development of plasma reactor technology for the co-generation of synthesis gas and C_{2+} hydrocarbons from methane and carbon dioxide is essential to address the features, drawbacks, challenges, and feasibility of this technology.

Non-thermal plasma can be defined as gas consisting of electrons, highly excited atoms and molecules, ions, radicals, photons and neutral particles in which the electrons have a much higher energy than the neutral gas particles. Non-thermal plasma is also called non-equilibrium plasma due to the significant difference of temperature or kinetic energy between the electrons and the neutral particles [1–4]. The gas temperature can be within the range of room temperature,

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