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# Modelling and optimization of catalytic–dielectric barrier discharge plasma reactor for methane and carbon dioxide conversion using hybrid artificial neural network—genetic algorithm technique

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**Abstract**

A hybrid artificial neural network-genetic algorithm (ANN-GA) was developed to model, simulate and optimize the catalytic–dielectric barrier discharge plasma reactor. Effects of $CH_4/CO_2$ feed ratio, total feed flow rate, discharge voltage and reactor wall temperature on the performance of the reactor was investigated by the ANN-based model simulation. Pareto optimal solutions and the corresponding optimal operating parameter range based on multi-objectives can be suggested for two cases, i.e., simultaneous maximization of $CH_4$ conversion and $C_{2+}$ selectivity (Case 1), and $H_2$ selectivity and $H_2/CO$ ratio (Case 2). It can be concluded that the hybrid catalytic–dielectric barrier discharge plasma reactor is potential for co-generation of synthesis gas and higher hydrocarbons from methane and carbon dioxide and performed better than the conventional fixed-bed reactor with respect to $CH_4$ conversion, $C_{2+}$ yield and $H_2$ selectivity.


*Keywords:* Chemical reactors; Optimization; Reaction engineering; Numerical analysis; ANN-GA; Pareto optimal solution; Plasma reactor

## 1. Introduction

High energetic electrons in the plasma reactor are potential for development of efficient chemical reactors with low energy requirement. Non-conventional dielectric barrier discharge (DBD) plasma reactor is an efficient tool for converting $CH_4$ and $CO_2$ to synthesis gas and higher hydrocarbons at low temperature and ambient pressure (Caldwell et al., 2001; Larkin et al., 2001; Liu et al., 1999; Zou et al., 2003). The energetic electrons collided with molecules in the gas, resulting in excitation, ionization, electrons multiplication, and formation of atoms and metastable compounds (Caldwell et al., 2001; Larkin et al., 2001; Kogelschatz, 2003). When the electric field in the discharge gap was high enough to cause breakdown in most gases a large number of microdischarges were observed. The active atoms and metastable compounds subsequently collided with molecules and reactions may occur.

Up to recently, only few researchers focussed on modelling studies of DBD plasma reactor. Eliasson and Kogelschatz (1991) showed information on single microdischarge combined with reaction chemistry in a single barrier reactor. Another study, Kang et al. (2003) presented a numerical study for understanding the influences of barrier arrangements on the evolution and characteristics of discharges in DBD. The motions of electrons, positive ions, and negative ions in DBD were described by a set of continuity equations. The model included the direct interactions of electrons and photons with neutral gas particles, such as electron impact ionization, electron attachment, and photon impact ionization. However, literatures on comprehensive plasma modelling in DBD reactor pertaining to optimization of process parameters are limited. The comprehensive plasma reactor model should take into account the various subjects, such as chemistry, chemical reaction and

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