Plasma-Assisted Methane Conversion: A Comparative Study of Swirl Induced Arc Reactor and Corona Discharge Reactor Performance

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Abstract: This work focuses on pyrolysis of methane using non-thermal plasma processes. A comparative study on the conversion of methane using a swirl-induced rotating arc discharge reactor and a corona discharge reactor was performed. The key findings demonstrate that corona discharge reactor produces better quality graphitic carbon and the rotating arc reactor shows higher conversion of methane along with amorphous carbon.

1. Introduction

The global net-zero race has kept countries at their feet to mitigate major greenhouse gas (GHG) emissions[1]. Reduction in methane emissions, along with lowering the existing concentration in the atmosphere, seems to be the most effective way to minimize the impact of methane on global warming. Hydrogen, the fuel of the future with zero carbon emissions unlike fossil fuels, is being explored globally. In the current scenario, the commercialized technologies for hydrogen production are water electrolysis and steam methane reforming. Although these technologies are contributing to large scale production of hydrogen, they are falling short in becoming energy efficient and carbon-free. A potential alternative to these methods is methane pyrolysis where methane is decomposed into hydrogen and solid carbon. This is one such technology which help us achieve both the objectives by producing hydrogen with zero carbon emission and reducing the methane concentration.

2. Methods

A point-plane electrode plasma reactor was used for the rotating arc discharge[2]. The plane ground electrode, through which pure methane was fed to the reactor, had angled vanes with 45^{0} inclination providing it the swirl motion and eventually leading to recirculation of the input methane gas. The point/needle electrode was connected to high voltage terminal. Whereas, a concentric wire-cylinder electrode configuration was used for the corona discharge. The steel body of the reactor was grounded and the inner wire electrode served as high voltage electrode. An AC power source with 40kV peak to peak voltage and frequency range 19kHz to 100kHz was used for generating plasma. Voltage-current profiles were obtained using high-voltage probe, current probe and oscilloscope. The plasma parameters were obtained by OES analysis. The gaseous products were analyzed by gas chromatography and solid carbon was characterized using SEM, TEM, Raman spectroscopy, and TGA.

3. Results and Discussion

Fig. 1(a and c) compare the conversion of methane using rotating arc discharge reactor and corona discharge reactor. It is clearly shown that the methane conversion of 19% is very high in arc discharge reactor than in corona discharge reactor. This can be explained by the high intensity of plasma in arc discharge. Higher current is produced in arc discharge and it is leading to higher conversion of methane. The other factor is the higher residence time of methane in plasma due to recirculation in swirl reactor. The highest yield of hydrogen obtained from arc discharge reactor is shown to be 16% and it reduces with increase in flowrate (Fig. 1(b)). However, the carbon produced by the corona discharge reactor is microporous and comes under the class of vertically oriented graphene. This morphology of carbon is proven to have higher surface area and is multilayered. Whereas, the carbon from arc discharge reactor shows amorphous, spherical carbon morphology(Fig. 1(d)).

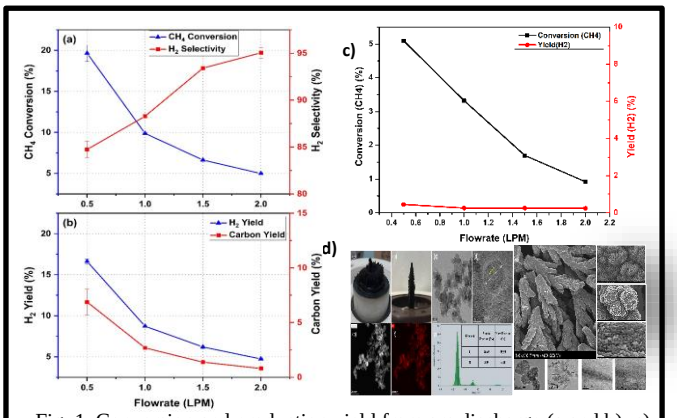

Fig. 1. Conversion and production yield from arc discharge (a and b), c) corona discharge. d) carbon morphology in arc and corona discharge.

4. Conclusion

The comparative study of methane conversion using two different discharge processes has shown that the arc discharge reactor is a very promising method for higher conversion and higher yield of hydrogen. The corona discharge reactor results in lower conversion but produces high quality graphene carbon. Further studies on scaling up the arc discharge reactor is on-going.

References

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