Hydrogen Extraction from Plastic Waste via Atmospheric-Pressure Dielectric Barrier Discharge Plasma

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Abstract: We investigate hydrogen production from low-density polyethylene (LDPE) plastic as a plastic waste model using a pin-to-plate streamer dielectric barrier discharge (sDBD) plasma reactor. This design enhances process intensity and efficiency while allowing for scalability and flexibility. Operation with nitrogen and atmospheric pressure conditions achieve hydrogen yield of 3.6 mmol/g-LDPE at an energy cost of 2.7 MWh/kg-H_2.

1. Introduction

Plasma pyrolysis of plastics is a promising technology that can turn the plastic disposal challenge into a prospect of recovering valuable products, such as hydrogen and carbon. For example, Bhatt et al [1] used a continuous plasma pyrolysis process to turn plastic waste into hydrogen-rich syngas. In our previous work [2], we investigated hydrogen production from low-temperature plasma treatment of low-density polyethylene (LDPE) and cellulose separately, as well as LDPE and cellulose mixtures [3]. In this work, we utilize a revised version of the pin-to-plate streamer Dielectric Barrier Discharge (sDBD) plasma reactor for the nonthermal plasma pyrolysis of solid waste, particularly plastics, to produce hydrogen. The compact modular reactor design (Fig. 1a) allows for a more intense, selective and efficient plasma treatment process, enhancing hydrogen production and lowering the energy cost of the produced hydrogen.

2. Methods

An alternating-current (AC) high-voltage power supply is used to power the sDBD plasma reactor (Fig. 1a). The feedstock sample is confined between the sDBD plasma and a dielectric barrier, used to limit the transferred current. The sDBD reactor is characterized operating with nitrogen and no feedstock (Fig. 1b, left) and then used to treat samples of 1 g of LDPE using nitrogen as working gas for 15 min (Fig. 1b, right). The LDPE pyrolysis treatment is characterized by a root-mean-square voltage of ~ 15 kV and depicts the rapid melting, mixing, and carbonization of the LDPE feedstock (yellow-red glow in Fig. 1b, left). Gas products are analyzed for hydrogen content using gas chromatography and solid products are characterized using carbon-hydrogen-nitrogen (CHN) elemental analysis.

3. Results and Discussion

The optical emission from the reactor operating with no feedstock (Fig. 1b, left) was used to estimate heavy-species temperature (T_h) and electron temperature (T_e) (Fig. 1c). T_h is estimated at ~ 2000 K, significantly higher than that typical in thermochemical pyrolysis and conducive to the production of solid carbon. T_e is estimated at 11500K (~ 1 eV) is consistent with previous estimations using a modified Boltzmann plot method [2] and highlights the nonthermal nature of the process.

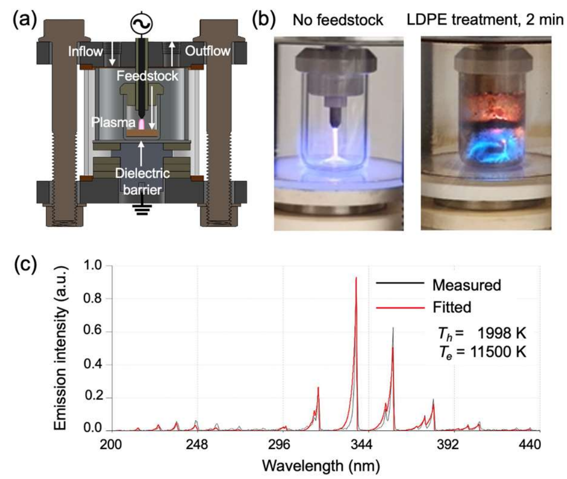

Fig. 1. Nonthermal plasma pyrolysis of plastic. (a) Atmospheric-pressure streamer-DBD (sDBD) plasma reactor, (b) reactor operation with nitrogen and no feedstock and with 1 g of LDPE feedstock within 2 min of treatment, and (c) optical spectrum and its fitting to estimate electron T_e and heavy-species T_h temperatures.

Experimental results show hydrogen production of 3.6 mmol/g-LDPE, significantly greater than the results reported in [3], but at a comparable energy cost of 2.7 MWh/kg-H_2. This result potentially evidences the greater intensity of the process due to the reactor re-design.

Acknowledgment

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References

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