Catalytic Deconstruction Product Tunability Through Atmospheric Air Plasma Pre-Treatment

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Abstract: In this contribution, we show a novel method for tuning the products of a ZSM-5/SBA-15 catalytic deconstruction using an atmospheric air plasma pre-treatment. This can be used to shift product distribution to improve viability during market fluctuations when the major product may drop in selling price. This may not completely change the product but provides a method to partially shift products as needed.

1. Introduction

The large amount of waste plastic produced is becoming a greater concern as production of single use plastic continues to increase. Catalytic deconstruction is viewed as one potential method for deconstruction of waste plastics into usable material. Plasma assisted catalytic deconstruction has become more prominent due to the potential to increase reactivity of the catalyst with plastic or deconstruction products with the plasma to better homogenize products [1-2].

In this work, we use an atmospheric pressure air plasma to pre-treat the plastics, to better facilitate reaction with the catalyst. It has been found that this pre-treatment can tune the products of the catalytic deconstruction to change the distribution of products as needed.

2. Methods

Plasma treatment is performed in a sealed vial with a rubber septum cap. A steel hypodermic needle is used to both deliver synthetic air and apply a high voltage in a pin-to-cup configuration. The grounding cup is made up of a copper pipe soldered to a copper plate. The vial is placed in this with the whole assembly surrounded with a 3D printed holder to prevent arcing from the high voltage to ground. A second hypodermic needle is then used to allow air to escape. Treatments range from 15-120 minutes at 30-40 kV (6-9 W), a frequency of 450 Hz, and a flow rate of 0-400 SCCM.

The catalyst used was a ZSM-5/SBA-15 composite catalyst, with the ZSM-5 added into the SBA-15 structure during its production [3]. This was reacted with an equal ratio of catalyst to plastic at 400 °C with a constant flow of 1.5 SCCM of N_2. This treatment was continued until products were no longer detected using gas chromatography mass spectrometry (GC/MS).

3. Results and Discussion

Table 1 shows the maximum production of each major product produced by the catalytic deconstruction step and the conditions of the plasma treatment. The best total conversion of 94% was observed with a 30 kV treatment for 30 minutes. While distributions can be shifted to produce less propene, propene is still found to be the major product in all cases tested.

Major Products	% Plastic Converted	Treatment Conditions
Propene	**62**	**30-35 kV for 30 minutes**
Butane	**11**	**Push-Pull Configuration**
Propane	**20**	**30-35 kV for 10 minutes**
Methane	**6**	**40 kV for 120 minutes**
CO	**9**	**35-40 kV for 120 minutes**

Table. 1. The different conditions found to optimize the product distributions for each major product found. Catalytic deconstruction conditions are kept constant.

Molecular dynamics simulations have shown the mechanism of the plastic degradation in plastic to be due to a reaction with ozone. Ozone measurements were then taken to investigate different conditions. At 40 kV ozone productions drop drastically after an initial burst, indicating why the higher powers show worse conversion and why lower powers show better conversion and methods for maximizing most products.

4. Conclusion

Through variations in plasma pre-treatment, catalytic deconstruction can be tuned to produce different product distributions. While this cannot shift the total distribution of products, it could increase the viability of catalytic deconstruction despite market fluctuations.

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References
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