Catalytic degradation of polyethylene terephthalate

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Highlights

- Various solid acid catalysts were synthesized.
- Degradation of polyethylene terephthalate was performed in high pressure micro reactor.
- Conversion to terephthalic acid was calculated.

1. Introduction

Polymers are materials that we use daily practically everywhere in our lives. Their use in the food, cosmetics, construction, and electrical industries has increased significantly in recent decades. [1]

Life without synthetic materials is no longer conceivable. Population growth, higher living standards and the revolution in technology are the reasons for the high production of polymers. Most of the plastics and polymer products produced are non-biodegradable, which has a significant impact on environmental pollution. Researchers are looking for an economic, technological, and environmental solution to replace polymer materials and recycle or convert them into other useful products.

The increasing use of plastics and polymers, such as polyethylene terephthalate, raises the question of how to deal with end-of-life products. The recycling of plastic waste has been studied extensively, but due to the low production costs of virgin plastics, the recycling rate remains relatively low. In the treatment of polyethylene terephthalate waste, chemocatalytic and thermal decomposition processes to terephthalic acid and ethylene glycol have been used with great success to date. [2]

The most suitable catalysts for the decomposition of polyethylene terephthalate are synthesized based on zeolites or silicates, such as ZSM-5 or SBA-15. SBA-15 is a silica material that has a large specific surface area and is very well suited as a support for active components - catalysts. Among the various mesoporous silica structures, SBA-15 is currently receiving the most attention. It is characterized by its pore size, large specific surface area, ease of synthesis and functionalization, and high thermal and mechanical stability. [3] ZSM-5 is a synthetic zeolite containing silica and alumina. Silica dominates this ratio. ZSM-5 can consist of more than five different mass ratios of silica and alumina. [4]

2. Methods

Different solid acid catalysts were synthesized using two different methods. The ZSM-5 catalyst was synthesized using the direct synthesis method. For the other catalysts, the post-grafting method was used. Namely, SBA-15 was synthesized as a support and then various active components were attached to the support by wet impregnation. The synthesized catalysts were characterized by N_2 adsorption, scanning electron microscopy, temperature programmed NH_3 desorption, thermogravimetric analysis, dynamic light scattering and infrared spectroscopy with Fourier transformation. The degradation products of polyethylene terephthalate were analyzed by HPLC in combination with a UV-VIS detector.

3. Results and discussion

Catalysts based on SBA-15 were synthesized using the wet impregnation method. The following active salts were used: $NiNO_3$, $Al(NO_3)_3$, $Mg(NO_3)_2$, ZnO, MgO and $ZnCl_2$. ZSM-5 was synthesized by the direct method. All the synthesized catalysts have acidic properties as shown by the results of temperature programmed NH_3 desorption. The pore size of the catalysts based on SBA-15 was between 5.6 and 7.8

nm and the BET surface area was between 610 and 440 m^2/g, while ZSM-5 has a much smaller pore size of 2 nm and a surface area of 360 m^2/g. The reactions of the degradation of polyethylene terephthalate were carried out in a high-pressure microreactor using the Differential Scanning Calorimeter DSC 3 at 300 °C for 10 min. The conversions of polyethylene terephthalate to terephthalic acid with various catalysts are presented in Table 1.

Table 1. Conversions of polyethylene terephthalate to terephthalic acid.

Catalyst	Conversion / %
SBA-15-ZnO	100
SBA-15-$ZnCl_2$	99.3
ZSM-5	94.9
SBA-15-MgO	88.2
SBA-15-$Mg(NO_3)_2$	81.3
SBA-15-$Al(NO_3)_3$	77.9
SBA-15-$NiNO_3$	76.1
SBA-15	75.1
No catalyst	64.4

4. Conclusions

The reactions took place in a differential scanning calorimeter. In addition, the characterization of the catalyst was carried out using different methods. It was confirmed that the synthesized catalysts have acidic properties. With the synthesized catalysts, we were able to increase the conversion of polyethylene terephthalate to terephthalic acid. The most active catalyst was SBA-15-ZnO and the least active was SBA-15-$NiNO_3$. Some improvements still need to be made as we did not have the possibility to stir the reaction medium in this type of reactor. Stirring would increase the contact between catalyst and reaction medium and thus increase the conversion.

References

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Keywords

polyethylene terephthalate, degradation, catalyst