Reverse Engineering, Characterization and Testing of Unknown Polymer Sample

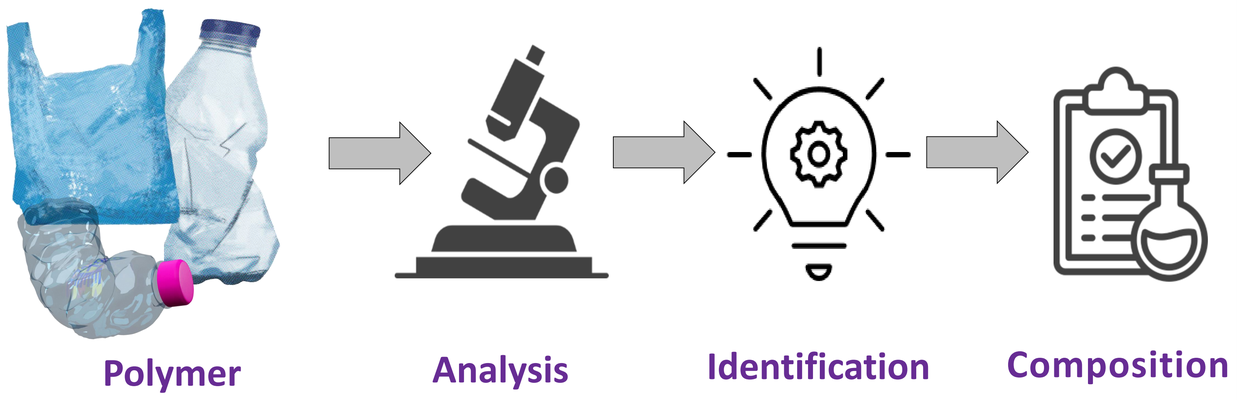
Arinya Ketburom[1,2], Patchareeya Suriyachai[2], Kraivich Mosom[2],
Pitchaya Mungkornasawakul[1], Runglawan Somsunan[1]
[1]Department of Chemistry, Faculty of Science, Chiang Mai University 50200, Thailand
[2]EPG Innovation Center Co., Ltd, 111/1 Moo 2, T. Makhamku, A. Nikompattana, Rayong 21180, Thailand

Abstract

The objective of this research is to study the reverse engineering process for analyzing an unknown polymer sample, focusing on the identification and separation of its main polymer components and various additives. The visual inspection was performed to examine and record the external characteristics of the sample, and a burning test was conducted to study its combustion behavior. Several analytical instruments were used in this study, including a thermogravimetric analyzer for examining thermal degradation behavior and residue content, a differential scanning calorimeter for determining melting points and crystallinity, and a Fourier transform infrared spectrometer for identifying chemical functional groups in polymers. In addition, an ash content test using a chamber furnace was performed to determine the amount of inorganic residue. The analysis results revealed that the sample consisted of a blend of several polymers, primarily ethylene-vinyl acetate, high-density polyethylene, polypropylene, and acrylonitrile-butadiene-styrene, which together accounted for 84.12 wt%. In addition, the sample contained additives, including 13.87 wt% of calcium carbonate and 1.45 wt% of carbon black. From the preliminary calculations, the overall composition of the sample could be effectively determined. These findings demonstrate that the reverse engineering approach is a reliable method for separating and identifying the components of unknown polymer samples. Moreover, this analytical approach can be applied in quality control, product development, and material formulation research.

Introduction

Polymer materials play an essential role in modern life and industrial applications, including automotive parts, electronics, packaging, and medical devices. Their popularity is due to their lightweight nature, good mechanical properties, and the ability to tailor their performance by blending different polymers and adding additives such as stabilizers and fillers. However, the composition of polymer products is often undisclosed because it is considered proprietary information. This makes it difficult to identify the exact materials and additives used, which can limit material selection, product improvement, and recycling processes. Therefore, reverse engineering is an important approach for identifying polymer types and their components. In this study, unknown polymer samples were analyzed using techniques such as FT-IR, DSC, and TGA to determine their composition. The results can support material selection, product development, and recycling management.



Objectives

To analyze and identify the composition of the unknown polymer samples using the reverse engineering process.

Methodology

1. Preliminary identification tests
- Visual inspection
- Burning test

2. Composition and chemical analysis
- Chamber
- Fourier transform infrared spectroscopy (FT-IR)
- Test the ash with chemical reagents : 3 M HCl and 3 M NaOH

3. Thermal analysis
- Differential scanning calorimeter (DSC)
- Thermogravimetric analysis (TGA)

References

[1] Kumar, A., Jain, P. K., & Pathak, P. M. (2013). *Reverse engineering in product manufacturing: An overview*. In B. Katalinic (Ed.), *DAAAM International Scientific Book 2013* (pp. 471–488). Vienna, Austria: DAAAM International.
[2] Rathore, N., & Jain, P. K. (2014). Reverse engineering applications in manufacturing industries: An overview. In B. Katalinic (Ed.), DAAAM International Scientific Book 2014 (pp. 633–652). Vienna, Austria: DAAAM International.
[3] Callister, W. D., & Rethwisch, D. G. (2018). Materials science and engineering: An introduction (10th ed.). Wiley.

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Results and Discussion

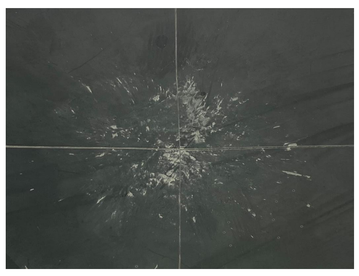


Figure 1 : Unknown polymer samples

Visual inspection

The unknown polymer sample appeared as a solid, opaque material with a black-gray color. The material showed moderate flexibility, and when bent, a fold mark appeared and gradually recovered after the applied pressure was released. These characteristics suggested that the material was likely a thermoplastic polymer containing fillers or additives.

Burning Test

The sample melted and burned during combustion, indicating typical thermoplastic behavior. The burning characteristics suggested that the material was composed of hydrocarbon-based polymers, which supported the possibility of polymers such as PE, PP, EVA, or ABS.



Figure 2 : Burning test of unknown polymer samples

Ash content analysis instrument by chamber

- Ash content analyzed by burning in chamber. After combustion of the organic components, a residual ash of approximately 5.06 wt% remained. This indicated the presence of inorganic fillers in the sample. The ash was later identified mainly as calcium carbonate ($CaCO_3$).

FT-IR spectrum

Table 1 : IR Spectrum for unknown polymer samples

Peak	Frequency (cm^{-1})	Assignments
1	2916-2848	C-H stretching
2	1737	C=O stretching
3	1462-1374	C-H bending
4	1239-1019	C-O stretching
5	874-719	C-H rocking

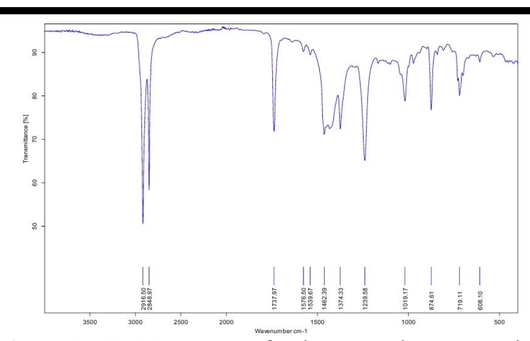


Figure 3 : FT-IR Spectrum of unknown polymer samples

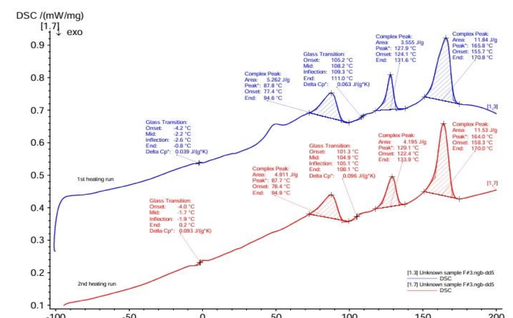


Figure 4: DSC thermograms of unknown polymer samples

Analysis of thermal properties using DSC

Table 2 : DSC thermograms of unknown polymer samples

Peak	Tm (°C)	Tg (°C)	Polymer
1	-1.7	87.7	EVA
2	-	129.1	HDPE
3	104.9	-	ABS
4	-	164.0	PP

Analysis of thermal properties using TGA

Table 3 : TGA thermograms of unknown polymer samples

Step	Temperature (°C)	%Weight loss	Component
1	350-475	84.12	Polymer
2	625-725	8.81	Filler
3	750-800	1.45	Carbon black
4	948.4	5.05	Residual ash

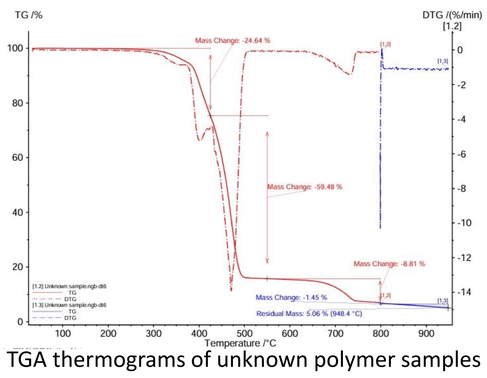


Figure 5 : TGA thermograms of unknown polymer samples

Chemical analysis of additives by 3M HCl and 3M NaOH

- Calcium carbonate ($CaCO_3$): Identified by reaction with 3 M HCl, producing CO_2 gas effervescence.
  $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$
  - Content: 14.20 wt%
- Carbon Black: No reaction observed with 3 M NaOH, indicating an inert carbonaceous residue.
  - Content: 1.63 wt%

Conclusions

The unknown polymer sample consisted of approximately 84.12 % of polymer and 15.32 % of fillers. The polymer might be composed of EVA, HDPE, PP, and ABS, while the filler contains 13.87 % $CaCO_3$ and 1.45 % carbon black. These results indicate that the sample is a polymer blend filled with inorganic additives, providing both strength and color to the material.