

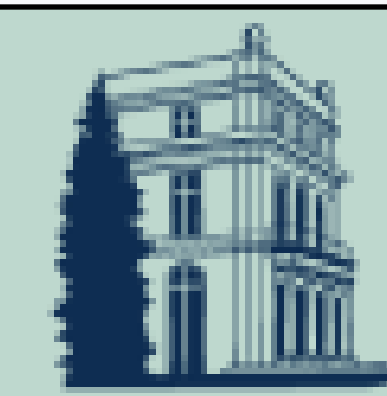
Surface Interactions of Goethite with PET Microplastics: Insights from FT-IR & XPS Characterization

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Abstract

Rationale: This study investigated how goethite (GT) affects the surface of thermoplastic bead microplastics (TPB-MPs) and polyethylene terephthalate MPs (PET-MPs) under simulated natural conditions. Chosen for its prevalence and roles in environmental geochemistry, GT interacts with MPs and influences their behavior and pollutant interactions. The hypothesis was that GT adsorption alters MP surface chemistry, affecting environmental biogeochemistry.

Methodology: MP surfaces were examined before and after GT treatment using XPS. Prior FT-IR analysis identified TPB-MPs as PET-based materials. XPS revealed the chemical compositions and electron binding energies in PET-MPs and TPB-MPs before and following GT adsorption.

Results: GT adsorption decreased surface carbon and increased oxygen content more in PET-MPs than TPB-MPs. PET-MPs showed stronger charge transfer and hydrogen bonding with GT, while TPB-MPs interactions were weaker and dominated by Van der Waals forces. Variations in peak intensity indicated enhanced C-O and O-C=O bonds and masking of C-C/C=C bonds in PET-MP. TPB-MP's interactions with GT were weaker. Shifts in the Fe2p doublet suggested chemical changes from GT adsorption.

Discussion: The results show that GT changes the surface chemistry of PET-MPs, enhancing their environmental transformation and reactivity. Binding energy shifts indicate surface hydrogen bonding and potential oxidation and charge transfer, highlighting GT's role in MP interactions. TPB-MPs exhibit weaker GT adsorption and fewer chemical changes, influencing their persistence and interactions with pollutants. Future research should explore oxidative transformation and microbial responses to MPs with mineral coatings. GT adsorption alters surface composition, electron scattering, and peak intensities mainly through physical interactions, with chemical effects needing further study.

Environmental Context

Plastic pollution is a growing crisis, with tiny microplastic particles spreading through our environment and potentially affecting ecosystems in ways we do not fully understand. This study found that these plastics can chemically interact with naturally occurring minerals, like goethite, changing their surfaces and potentially influencing how pollutants and microbes interact with them. Understanding these transformations is crucial for predicting how microplastics behave in nature and assessing their long-term environmental impact.

Results

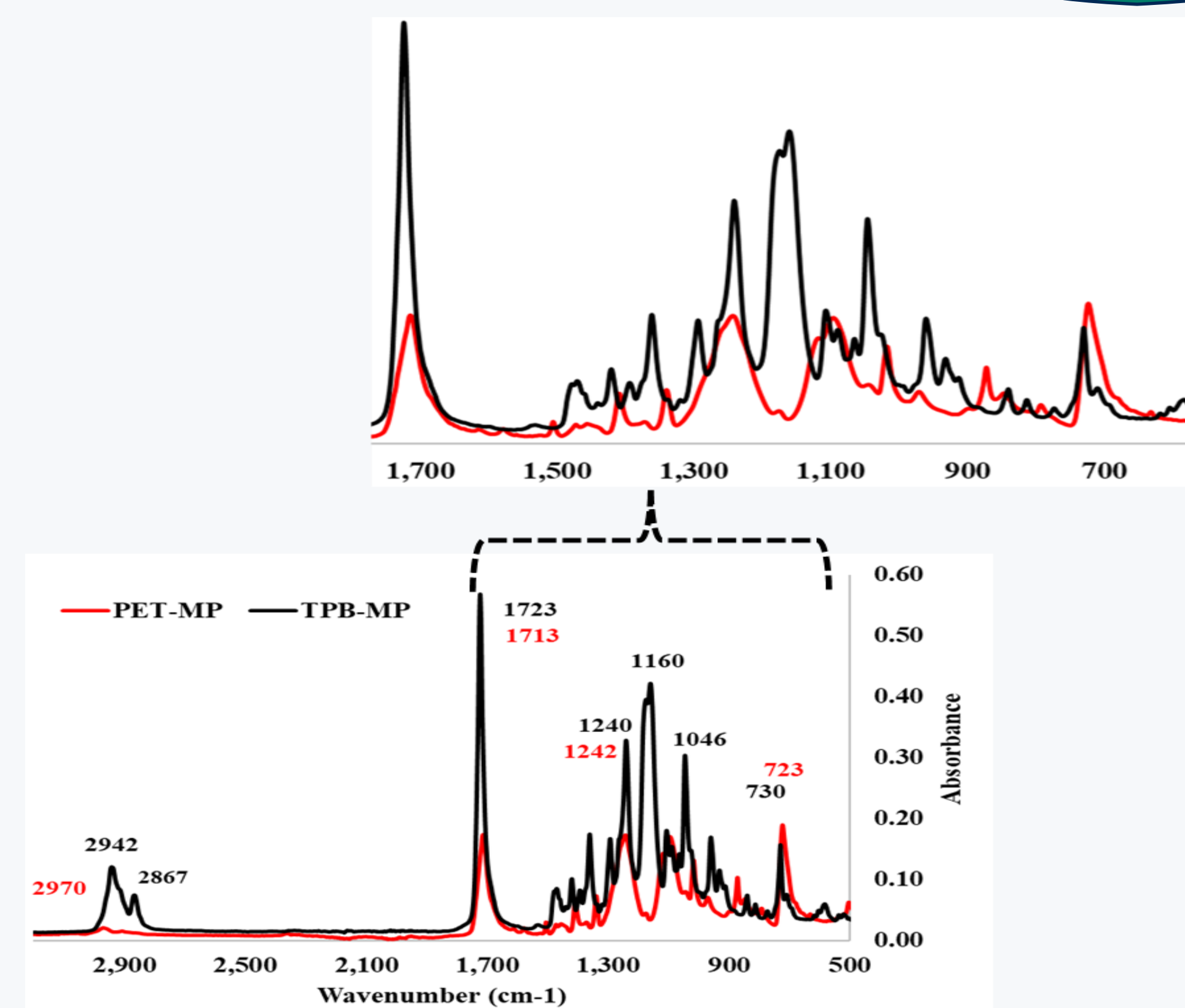


Figure 2. Overlay FT-IR spectra of TPB-MPs and PET-MPs highlighting the characteristic vibrational bands for both materials. Peaks annotated in red belong to PET and those in black are for TPB.

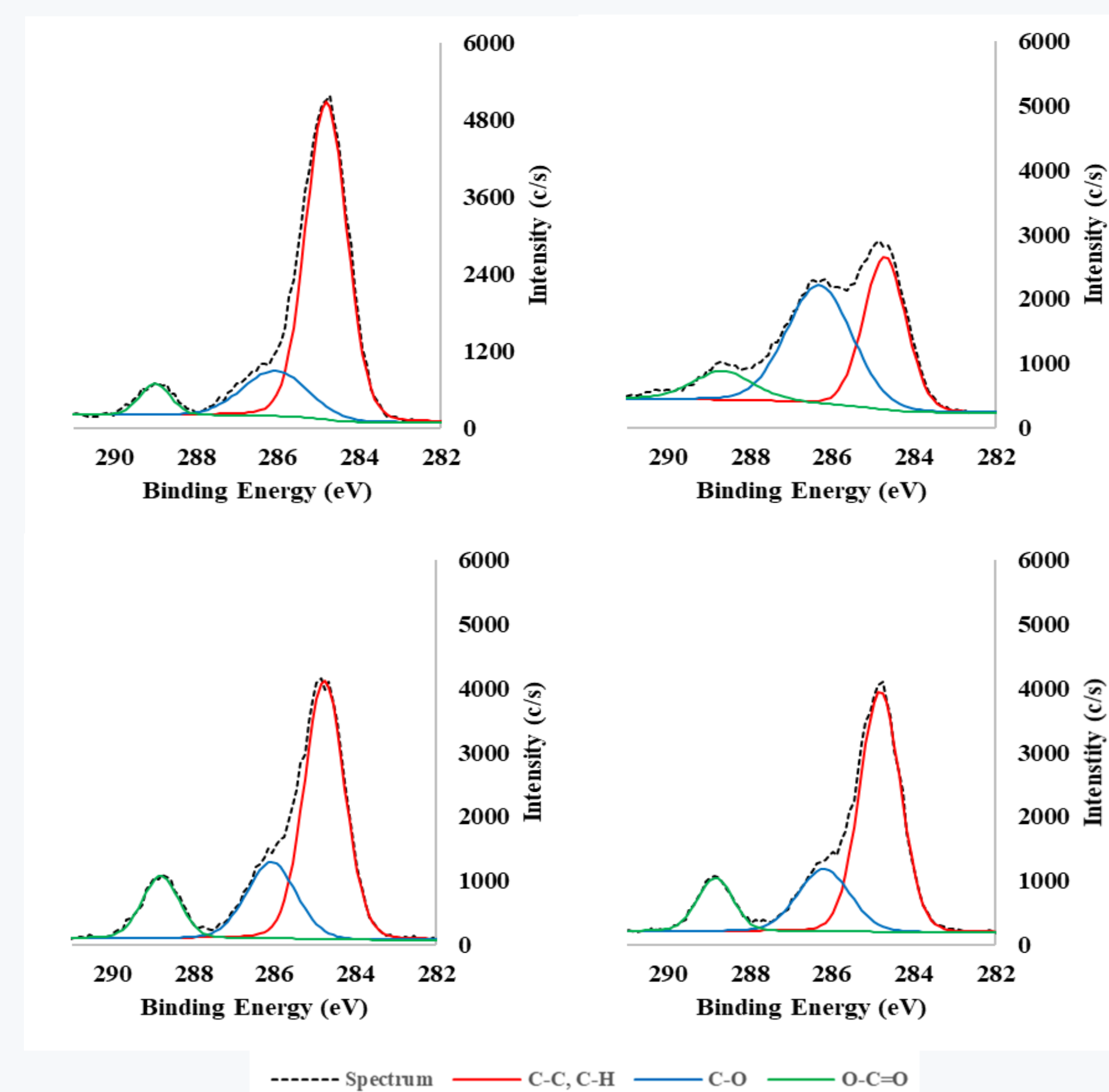


Figure 5. High-resolution C1s spectra and the BEs for the C-C, C-H, C-O, C=O electron emissions for a) PET-MP (289.0 eV; 286.0 eV; 284.8 eV), b) PET-MP-GT (288.8 eV; 286.3 eV; 284.8 eV), c) TPB-MP (288.8 eV; 286 eV; 284.8 eV), d) TPB-MP-GT (288.8 eV; 286.3 eV; 284.8 eV).

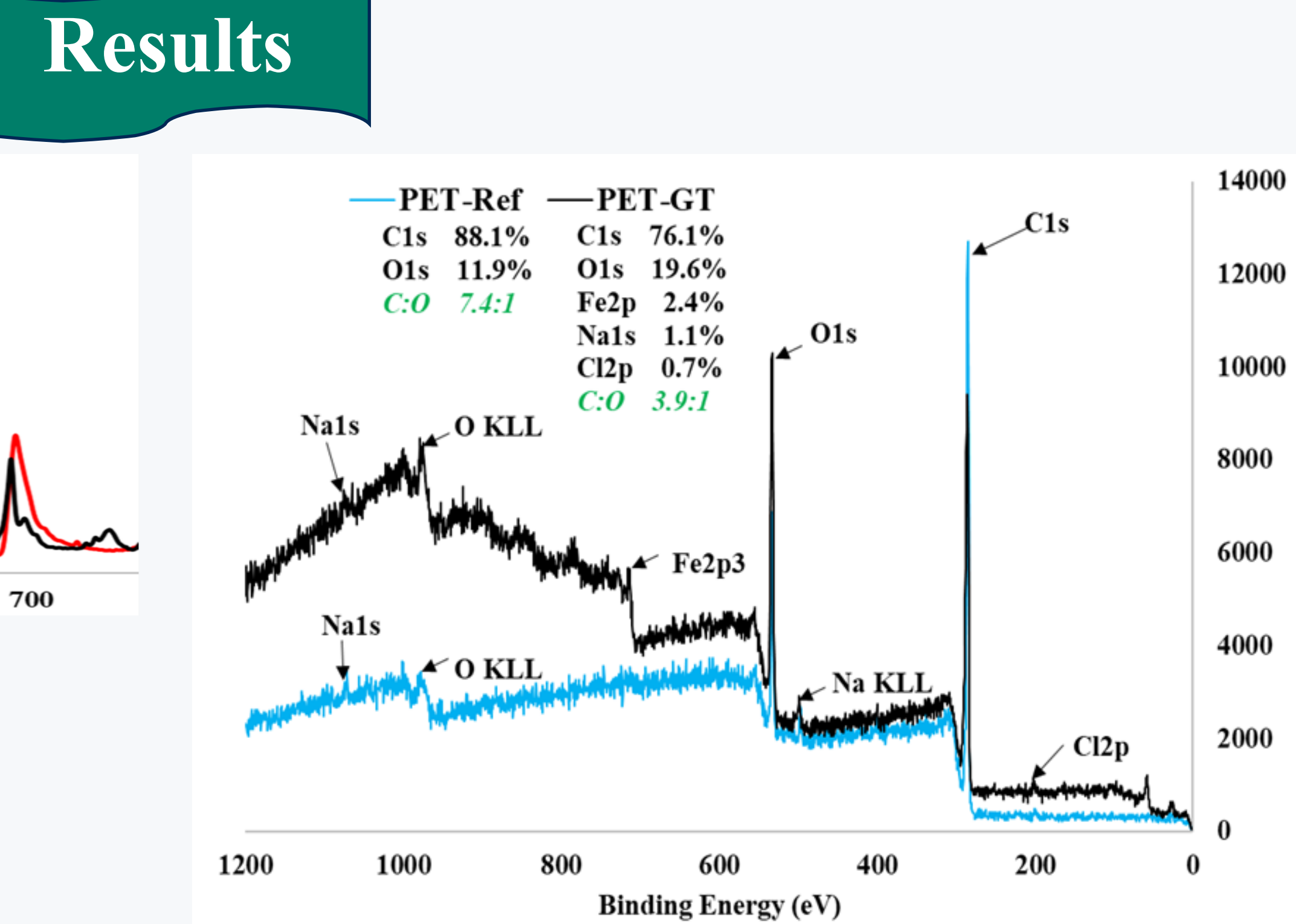


Figure 3. XPS survey spectra of untreated PET-MP (blue) and PET-MP-GT (black). Inset: Surface elemental compositions.

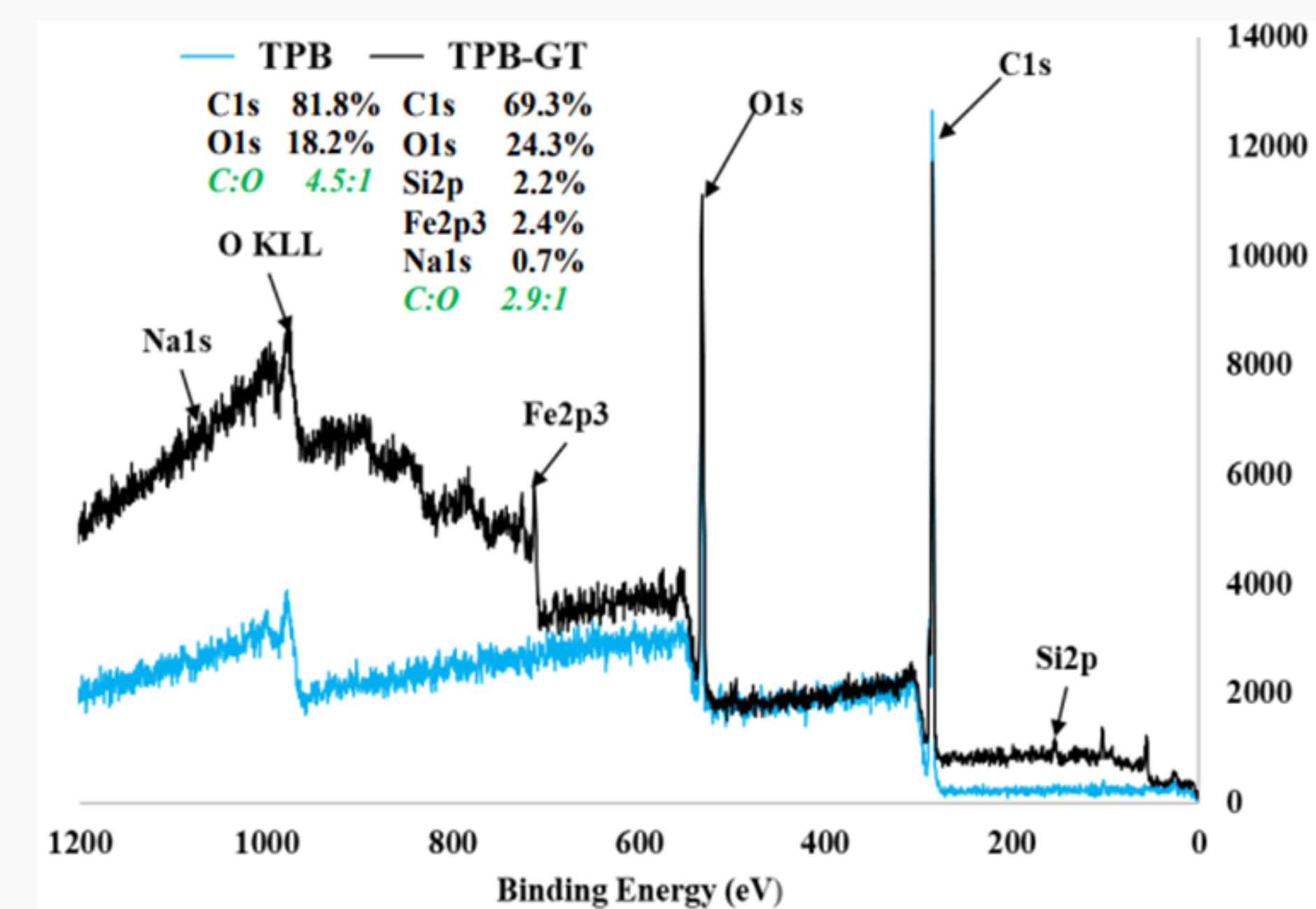


Figure 4. XPS survey spectra of untreated TPB-MP (blue) and TPB-MP-GT (black). Inset: Surface elemental compositions.

Table 1. Binding energies (eV) and intensities, in parenthesis, (c/s) for C1s, O1s and Fe2p electrons in PET-MP, PET-MP-GT, TPB-MP and TPB-MP-GT.

	PET-MP	PET-MP-GT	TPB-MP	TPB-MP-GT
C1s				
C-C, C-H	284.8 (5081)	284.8 (2632)	284.8 (3918)	285.0 (3723)
C-O	286.0 (900)	286.3 (2169)	286.0 (1160)	286.3 (923)
O-C=O	289.0 (690)	288.8 (981)	288.8 (943)	288.8 (775)
O1s	532.2 (1849)	533.3 (2531)	532.0 (2265)	532.1 (2367)
Fe2p				
2p3/2		712.6 (1187)		711.1 (269)
2p1/2		727.0 (1171)		727.0 (241)

Methodology

Microplastic samples included PET-MPs and TPB-MPs. As presented in Figure 1 (below), samples were exposed to Goethite (GT), ferric hydroxide oxide, to simulate natural interactions between minerals and microplastics. Figure 2 depicts FT-IR spectra of PET-MPs and TPB-MPs, which was used to identify polymer type & functional groups. Figures 3-4 visualize XPS spectra of PET-MP and TPB-MP, respectively. XPS analysis determined surface composition and environments before and after GT adsorption. As well, XPS revealed the presence of chemical changes, specifically via analysis of electron binding energy energies, as portrayed in Figures 3-5 and Table 1.

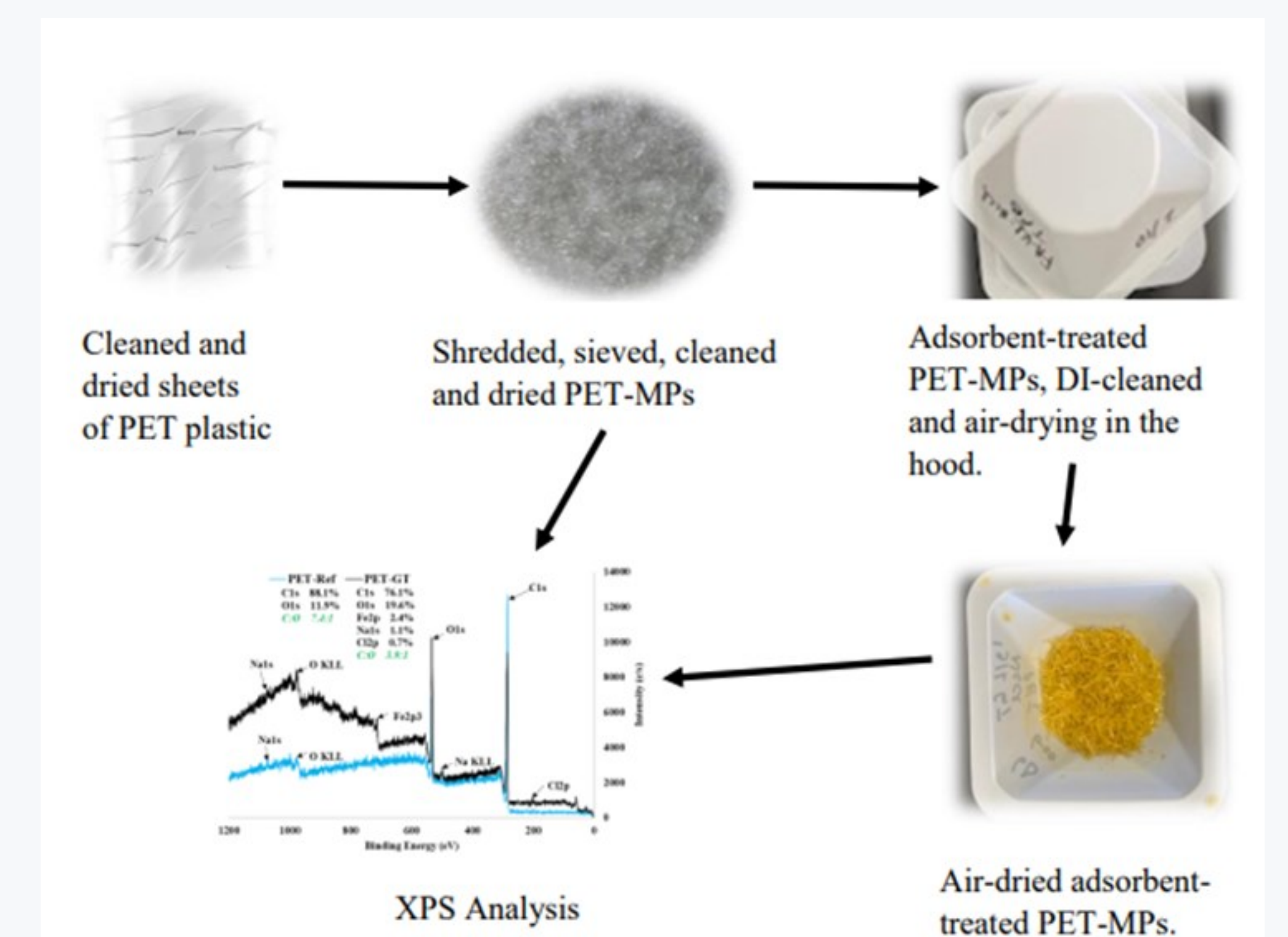


Figure 1. Schematic of the experimental procedure showing the preparation of PET-MPs and the drying of the GT-treated PET-MPs before XPS analysis.

References

Scan here for reference list.

