



Classifying Different Types of Plastic using FTIR Spectroscopy

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Introduction

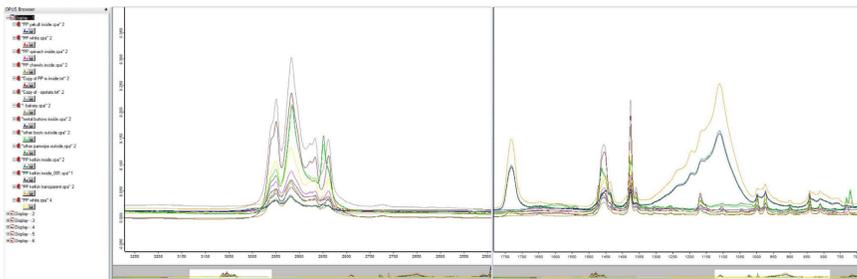
FTIR or Fourier transform infrared is a method of infrared spectroscopy. Infrared radiation passes through a given sample and while a partial amount of that radiation is absorbed, some still passes through it. The basic idea is that chemical bonds between different elements will absorb light at different frequencies, meaning that each different chemical structure will have its own unique spectrum. Previous publications have identified spectra for many different types of plastic to build a database for a variety of unique compounds, including many different types of plastic that were analyzed in this experiment. This is a quick and relatively inexpensive way to identify different materials, and could be helpful in plastic sorting and recycling. The main goals of this project were to see if FTIR is effective when these plastics become multilayered and have exterior printing and if they are still easily identifiable.

Methodology

- Samples were collected from an array of different every-day plastic packagings
- Samples were run through a spectrometer to get FTIR spectra that averaged 64 scans per sample
- Scans were then uploaded to Bruker's OPUS software to view the spectroscopies
- Labeled samples were compared with each other to establish a baseline for different plastic types through comparison of spectra peaks
- Graphs of labeled sample types were compared with those of unknown types to classify them as different plastic types
- Graphs were compared with tables of characteristic peaks based on wave numbers for reference to plastic types
- Unknown samples with no match to marked samples were sorted into similar graph structures and compared with peak assignments from tables to determine plastic type

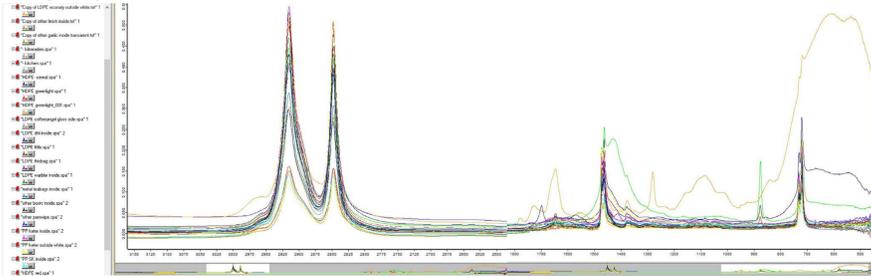
Results / Discussion

Polypropylene (PP)



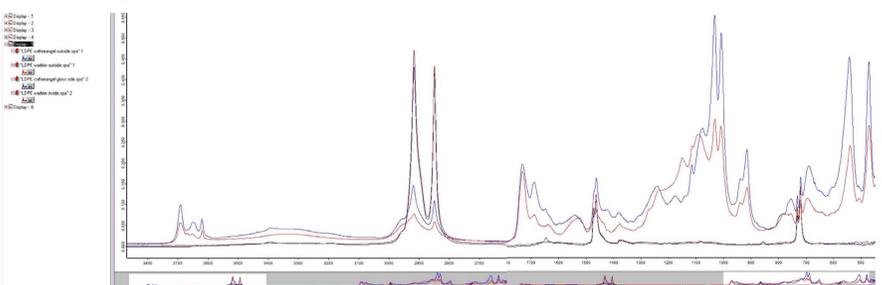
- Peaks around 2800-3000 all follow same pattern and matched with previous studies spectra
- Few stand out around 1700 and between 1000-1300, indicates multilayered film
- PP characteristic peaks all line up with those mentioned in table

Polyethylene (PE)



- Two characteristic peaks between 2800-3000
- A few samples stand out, but odd peaks can be attributed to ink printed on the outside of samples
- PE characteristic peaks line up with those from table
- Difficult to distinguish between low density (LDPE) and high density (HDPE)
- Able to identify mislabeled plastic types - samples labeled PP were actually PE

Interesting Case of PE



- Outside samples had many more peaks than inside samples
- Two peaks between 2800-3000 still indicate PE, as well as characteristic peaks at 1450 and 700
- Peaks from outside samples can be attributed to printing process and chemical complexity of pigments

Conclusions

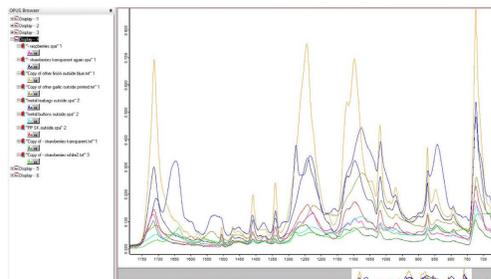
Most samples were able to be identified as either polypropylene or polyethylene with relative ease. Polyethylene terephthalate was a bit more difficult to decipher due to its more complex structure, however it was still identifiable. Even with impacts from different pigments, the overall structure of these was still in tact and characteristic peaks were still visible through most samples. This was an effective method for identifying many different samples and correcting those that had been previously identified as the wrong plastic.



Table 3. FTIR characteristic peak assignments for various types of MPs.

S. No.	Polymer	Characteristic peaks (cm ⁻¹)	Assignment	Reference
1	High density polyethylene (HDPE)	2915	C-H stretching	Nishikida and Coates, 2003; Noda et al., 2007; Alesio et al., 2009; Meccozzi et al., 2016; Jung et al., 2018
		1472	CH ₂ bending	
		1462	CH ₂ bending	
		720	CH ₂ rocking	
		717	CH ₂ rocking	
2	Low density polyethylene (LDPE)	2915	C-H stretching	Nishikida and Coates, 2003; Noda et al., 2007; Alesio et al., 2009; Meccozzi et al., 2016; Jung et al., 2018
		2845	C-H stretching	
		1467	CH ₂ bending	
		1462	CH ₂ bending	
		1377	CH ₂ rocking	
3	Polyethylene terephthalate (PET)	1713	C=O stretching	Verleye et al., 2001; Noda et al., 2007; Alesio et al., 2009; Meccozzi et al., 2016; Jung et al., 2018
		1241	C-O stretching	
		1094	C-O stretching	
		720	Aromatic CH out-of-plane bending	
		717	CH ₂ rocking	
4	Polypropylene (PP)	2950	C-H stretching	Verleye et al., 2001; Noda et al., 2007; Alesio et al., 2009; Meccozzi et al., 2016; Jung et al., 2018
		2915	C-H stretching	
		2038	C-H stretching	
		1455	CH ₂ bending	
		1377	CH ₂ bending	
		1166	CH ₂ rocking, CH ₃ rocking	
		997	C-C stretching	
		972	CH ₂ rocking, CH ₃ bending	
5	Polystyrene (PS)	3024	Aromatic C-H stretching	Verleye et al., 2001; Noda et al., 2007; Alesio et al., 2009; Meccozzi et al., 2016; Jung et al., 2018
		2947	C-H stretching	
		1601	Aromatic ring stretching	
		1492	Aromatic ring stretching	
		1451	CH ₂ bending	
		1027	Aromatic CH out-of-plane bending	
		694	Aromatic ring out-of-plane bending	
		537	Aromatic ring out-of-plane bending	
		1427	CH ₂ bending	
		1331	CH bending	
6	Polyvinyl chloride (PVC)	1331	CH bending	Beltran and Macilla, 1997; Verleye et al., 2001; Noda et al., 2007; Jung et al., 2018
		1099	C-Cl stretching	
		966	CH ₂ rocking	
		616	C-Cl stretching	
		516	C-Cl stretching	
7	Polyurethane (PU)	2865	C-H stretching	Verleye et al., 2001; Noda et al., 2007; Alesio et al., 2009; Meccozzi et al., 2016; Jung et al., 2018
		1731	C=O stretching	
		1531	C-N stretching	
		1451	CH ₂ bending	
		1223	C=O stretching	
8	Nylon (all polyamides)	3298	N-H stretching	Rotter and Shiba, 1992; Verleye et al., 2001; Noda et al., 2007; Meccozzi et al., 2016; Jung et al., 2018
		2932	CH stretching	
		2858	CH stretching	
		1654	C=O stretching	
		1538	NH bending, C-N stretching	
		1464	CH ₂ bending	
		1372	CH ₂ bending	
		1274	NH bending, C-N stretching	
		1199	CH ₂ bending	
		687	NH bending, C=O bending	

Polyethylene terephthalate (PET)



- The orange sample has most distinctive peaks, but all samples follow the same pattern
- Characteristic peaks match with that of PET from tables
- "Metal teabags outside" (blue) stands out, can be attributed to printing on outside of packaging
- Identified another mislabeled PP sample

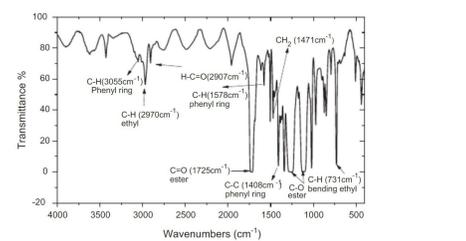
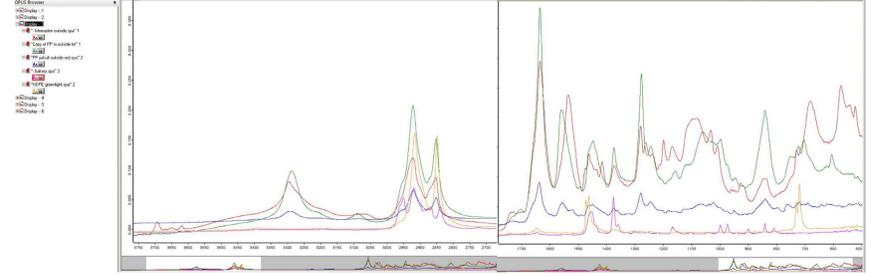


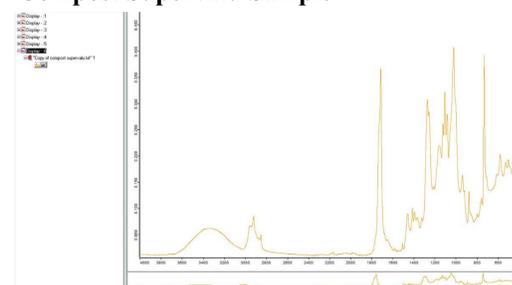
Fig. 5. FT-IR spectra of PET film before electron beam treatment.

Interesting case of PP/PE



- "Bakery" was believed to be PP, "HDPE greenlight" was identified as PE
- "PP m outside," "PP yakult outside," and "Kilmeaden outside" all showed two characteristic peaks between 2800-3000, indicating PE and mislabeled PP samples
- Difficult to distinguish differences in 600-1700 range due to the number of bonds in ink structures

Compost Supervalu Sample



- Only compostable sample and did not match with anything else
- Matches well with starch and polycaprolactone spectra, indicating multi layered or a blend of the two

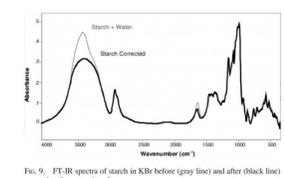
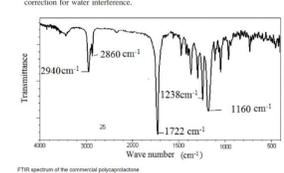


Fig. 9. FT-IR spectra of starch in KBr before (gray line) and after (black line) correction for water interference.



FTIR spectrum of the commercial polycaprolactone

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