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.

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 2845 1472 1462 730 717	C–H stretching C–H stretching CH_2 bending CH_2 bending CH_2 rocking CH_2 rocking	Nishikida and Coates, 2003; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
2	Low density polyethylene (LDPE)	2915 2845 1467 1462 1377 730 717	C–H stretching C–H stretching CH_2 bending CH_2 bending CH_2 bending CH_2 rocking CH_2 rocking	Nishikida and Coates, 2003; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
3	Polyethylene terephthalate (PET)	1713 1241 1094 720	C=O stretching C–O stretching C–O stretching Aromatic CH out-of-plane bending	Verleye et al., 2001; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
4	Polypropylene (PP)	2950 2915 2838 1455 1377 1166 997 972 840 808	C–H stretching C–H stretching C–H stretching CH_2 bending CH_3 bending CH bending, CH3 rocking, C–C stretching CH_3 rocking, CH_3 bending, CH bending CH_3 rocking, C–C stretching CH_2 rocking, C–CH_3 stretching CH_2 rocking, C–C stretching, C–CH stretching	Verleye et al., 2001; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
5	Polystyrene (PS)	3024 2847 1601 1492 1451 1027 694 537	Aromatic C–H stretching C–H stretching Aromatic ring stretching Aromatic ring stretching CH_2 bending Aromatic CH bending Aromatic CH out-of-plane bending Aromatic ring out-of-plane bending	Verleye et al., 2001; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
6	Polyvinyl chloride (PVC)	1427 1331 1255 1099 966 616	CH2 bending CH bending CH bending C–C stretching CH2 rocking C–Cl stretching	Beltran and Marcilla, 1997; Verleye et al., 2001; Noda et al., 2007; Jung et al., 2018
7	Polyurethane (PU)	2865 1731 1531 1451 1223	C–H stretching C=O stretching C–N stretching CH2 bending C(=O)O stretching	Verleye et al., 2001; Noda et al., 2007; Asefnejad et al., 2011; Jung et al., 2018
8	Nylon (all polyamides)	3298 2932 2858 1634 1538 1464 1372 1274 1199 687	N–H stretching CH stretching CH stretching C=O stretching NH bending, C–N stretching CH_2 bending CH_2 bending NH bending, C–N stretching CH_2 bending NH bending, C=O bending	Rotter and Ishida, 1992; Verleye et al., 2001; Noda et al., 2007; Mecozzi et al., 2016; Jung et al., 2018

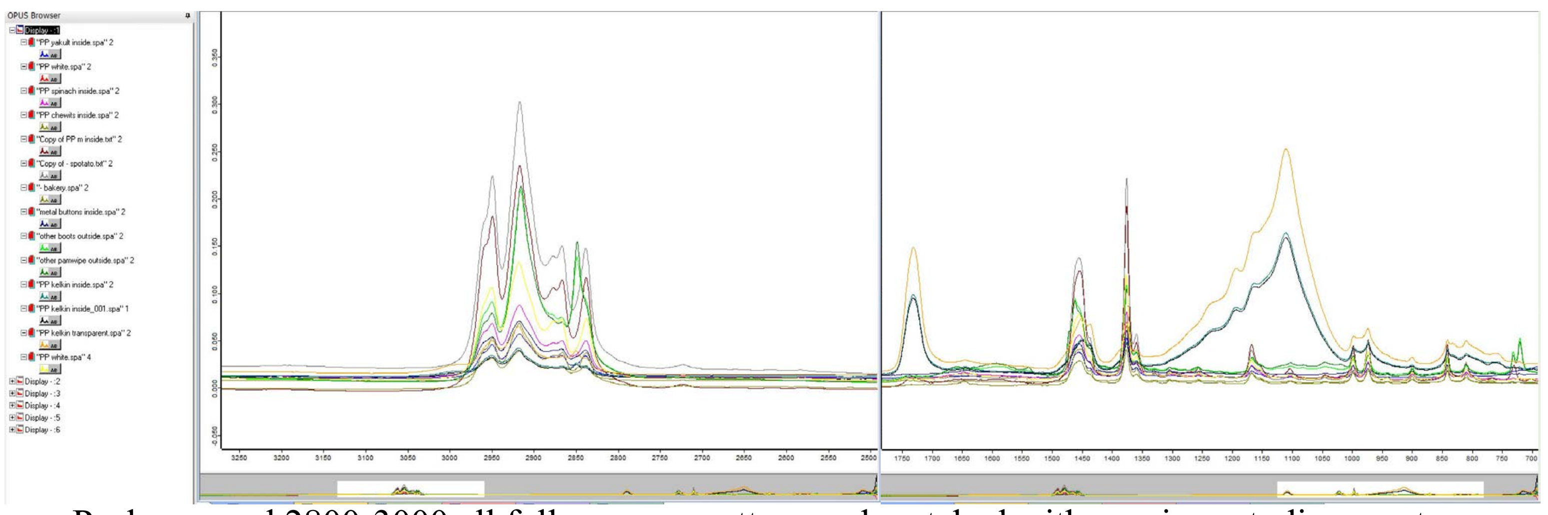
(*continued*)

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

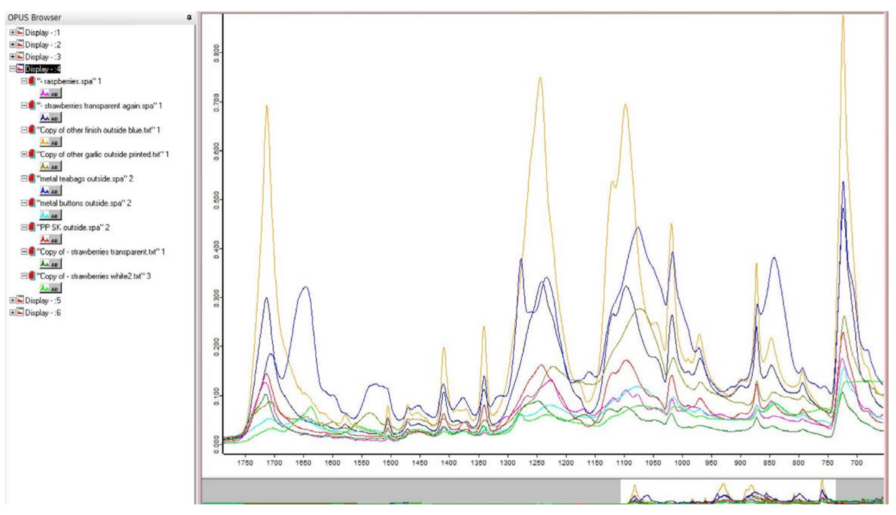
Results / Discussion

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 terephthalate (PET)



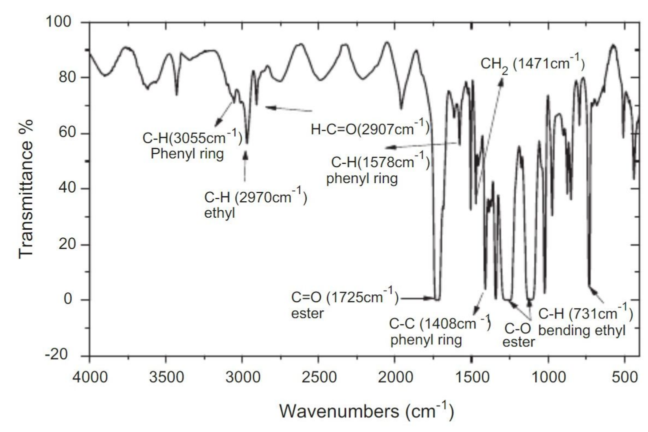
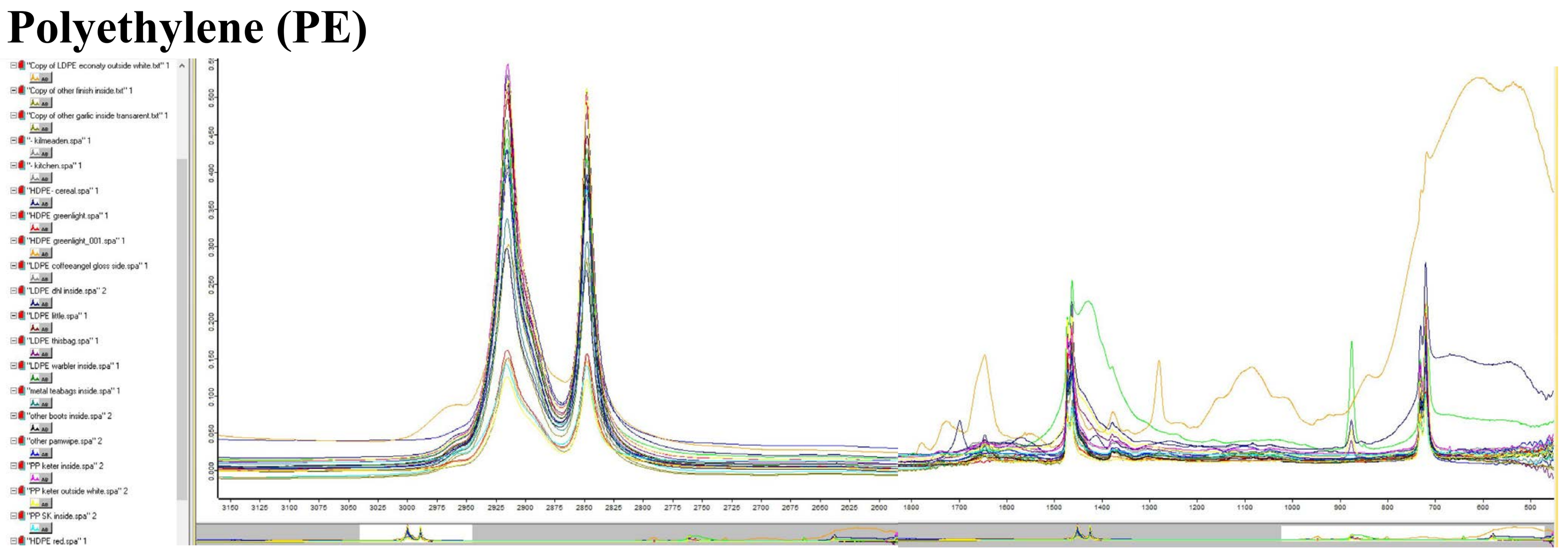


Fig. 5. FT-IR spectra of PET film before electron beam treatment.

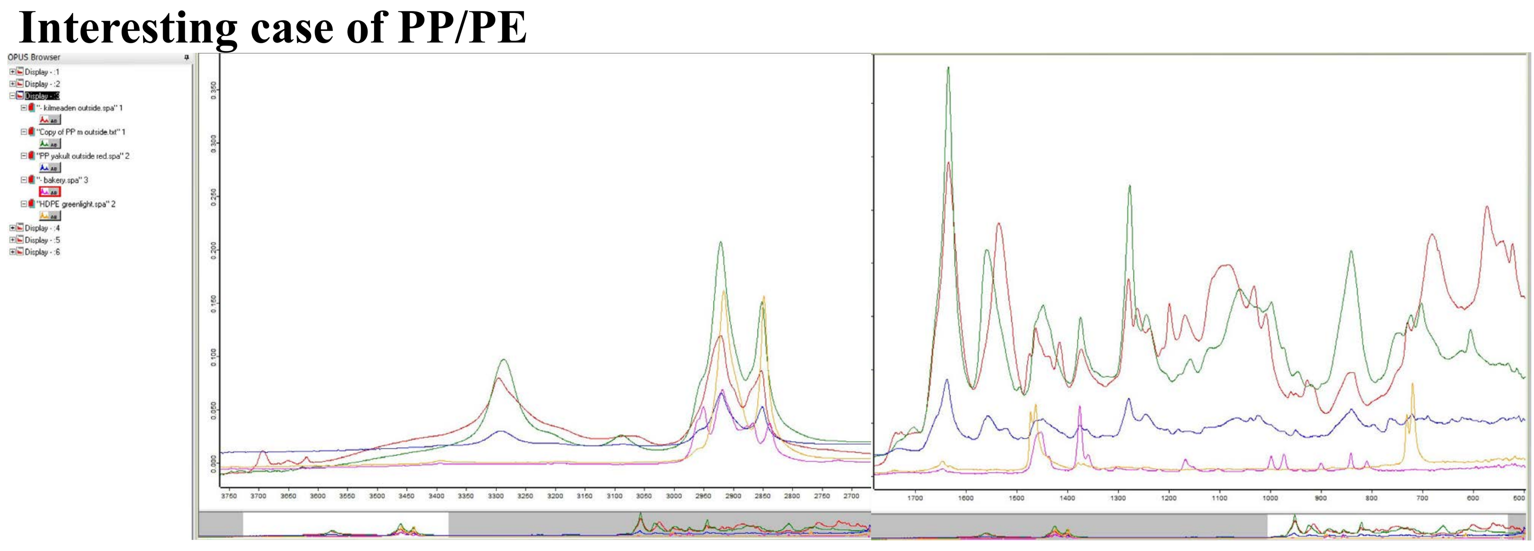
- The orange sample has most distinctive peaks, but all samples follow the same pattern
- Characteristic peaks match with that of PET from tables
- "Metal teabags outside" (blue) stands out, can be attributed to printing on outside of packaging
- Identified another mislabeled PP sample

Polyethylene (PE)



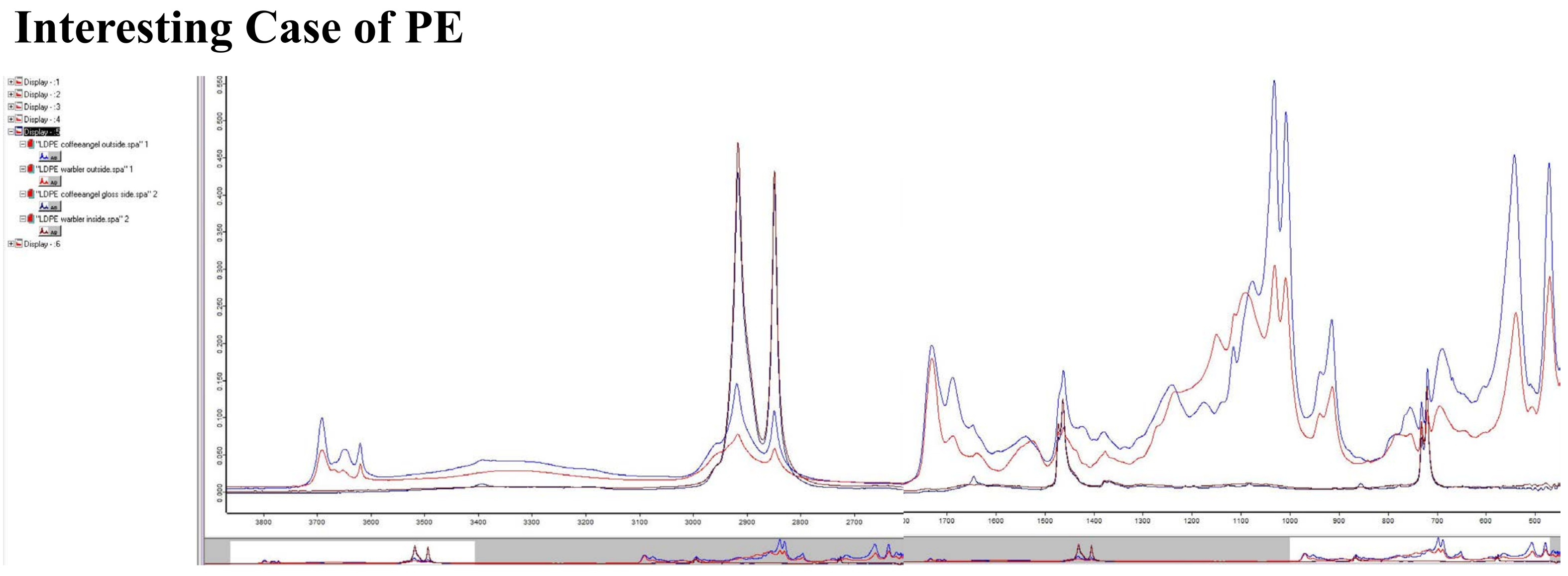
- Two characteristic peaks between 2800-3000
- A few samples stand out, but odd peaks can be attributed to ink printed on the outside of samples
- PE characteristic peaks line up with those from table
- Difficult to distinguish between low density (LDPE) and high density (HDPE)
- Able to identify mislabeled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

Interesting case of PP/PE



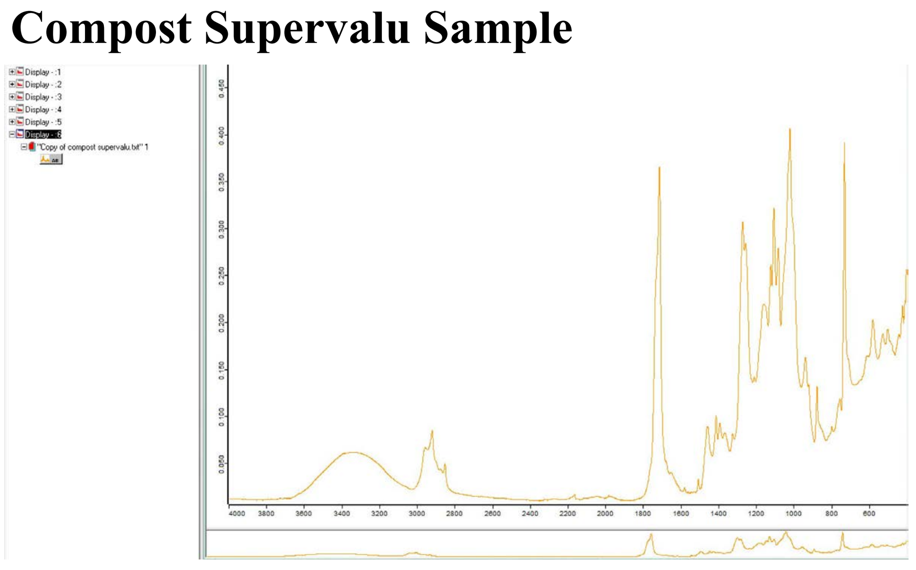
- "Bakery" was believed to be PP, "HDPE greenlight" was identified as PE
- "PP m outside," "PP yakult outside," and "Kilmeaden outside" all showed two characteristic peaks between 2800-3000, indicating PE and mislabeled PP samples
- Difficult to distinguish differences in 600-1700 range due to the number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

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

Compost Supervalu Sample



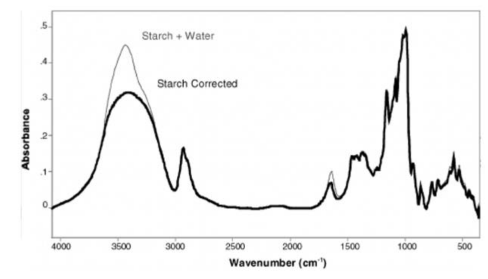
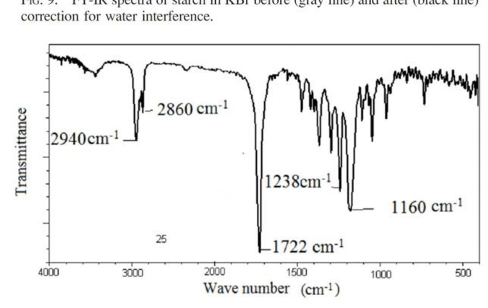


FIG. 9. FT-IR spectra of starch in KBr before (gray line) and after (black line) correction for water interference.



FTIR spectrum of the commercial polycaprolactone

- 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

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.

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