Using Titanium Dioxide Nanoparticles as Additives in Plastic in Order to Reduce Plastic Waste

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Valencia High School April 26th, 2019

Object/ Problem Statement

Ideal Model:

The Actual Model:

By 2050, there will be 12 billion metric tons of plastic in landfills [1]. There are 7 different types of plastic, each with different characteristics, represented by a numbered system. Each plastic from these groups has different characteristics. The plastics from groups 5, 6, and 7 are the hardest to recycle due to their high oxidation rate; which makes them more susceptible to absorbing contaminants. The ideal product for a solution to this problem would be a plastic that is highly resistant to oxidation. Using titanium dioxide nanoparticles as additives could make the plastic ultraviolet light resistant and thermal resistant.

Figure 1

Introduction

Plastics begin to absorb contaminants after going through a process called oxidation. During oxidation heat, light, and polarity can lead to the increased breakdown of the material. Plastics can become brittle and have a visible change in color when their barriers are broken, making them more vulnerable to the absorption of contaminants (Figure 2). By enhancing the plastics resistance to these factors, it will also have a higher resistance to

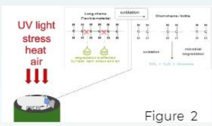


Figure 2

oxidation. Using TiO2 nanoparticles- which are particles at the size of 1-100 nm and thus has different physical and chemical properties than the macroscale- as an additive is most effective because of the high surface area to volume ratio making them more chemically reactive and have a high resistance to heat. Plastic additives is a growing market that is projected to rise to $57.8 billion dollars by 2020. The competition for this product would be other plastic manufacturer companies who create additives for their plastics. The target market is the actual companies that buy the plastic for industrial purposes. From a business standpoint, TiO_2 nanoparticles are a good material to use because they are able to be mass produced and do not cost a lot to make.

Methods

Heating Test:

Figure 3

The control bioplastic (clear) and nanoparticle bioplastic (white)

Figure 4

Both bioplastics placed on a hot plate for 8 min.

UV Light Test:

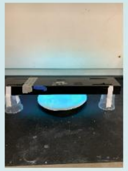


Figure 5

Both plastics were placed under UV light set up for 24 hours

Figure 6

The nanoparticle bioplastic turned blue after being exposed to UV light

Figure 7

A ruler, clamps, and digital spring scale was used to do a stress strain test on the plastics

Two bioplastics were made. One with TiO_2 nanoparticles, and one without for a control variable. The ingredients were mixed together on a hot plate and spread on a sheet of aluminum foil to dry overnight [2].

Results

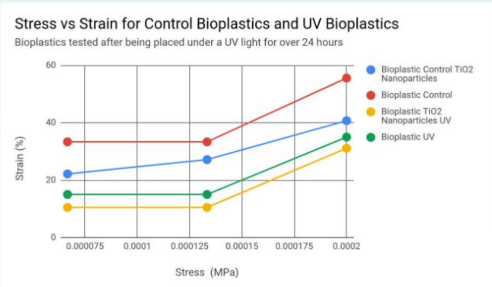
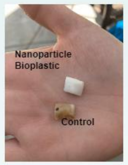


Figure 8

Figure 9



Bioplastics after heat test

Figure 10

Nanoparticle bioplastic before/ after UV light test

As the plastic was being pulled, its change in length was measured at every 2 newtons until the plastic broke. The data from the two trials was averaged and the increasing trends show that the non-nanoparticle bioplastics, when strained, deformed more than the bioplastics with nanoparticles. (Figure 8).

Discussion

The hypothesis being researched in this lab was whether using titanium dioxide nanoparticles as an additive in plastic would enhance its properties- such as thermal resistance and ultraviolet resistance- in order to prevent the contamination of plastic after oxidation. After testing the titanium dioxide nanoparticles in combination with bioplastic, the results showed that after being heated to high temperatures the bioplastic without nanoparticles burned much faster than the bioplastic with nanoparticles (Figure 9). This demonstrated that the nanoparticles worked successfully as a thermal resistive additive. Next the bioplastics were tested under UV light for over 24 hours. After this light exposure, the bioplastic with no nanoparticles had no visible change while the bioplastic with nanoparticles turned from a white color to a blue color (Figure 10). This was because after being exposed to UV light the bioplastic did not experience oxidation, but instead a reduction which resulted in oxygen vacancies. After this process occurs "[the] blue TiO_2 consists of Ti3+ state with high oxygen defect density that can absorb the visible and infrared as well as ultraviolet light due to its low energy bandgap"[3]. A bandgap is the difference between the valence and conduction band. The limitations of this study was the fact that only bioplastic as a model was able to be tested as it was the only plastic that could be made without already existing additives. The bioplastics overall structure is different from other plastics such as polypropylene and polystyrene, so more plastics should be tested in order to determine if similar results can be produced with the nanoparticles. Another limitation was that the stress strain test lacked precision and thus was not reliable. More trials should be conducted in order to verify its repeatability. A limitation of TiO_2 nanoparticles is their possible environmental effects; however, there are options for hazard reduction [4].

Conclusion

One of the most trying issues of today's society is its rapid growth of plastic waste. By enhancing plastic's resistance properties, recycling facilities will be able to more effectively clean these plastics, due to less contaminants. The data from the lab demonstrated that TiO_2 successfully functioned as a thermal and UV light resistant additive in bioplastic.

Acknowledgements

Thank you to Naeem Mady from Intertek for taking the time to work with us and offering to become our mentor for this project.

References

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