Dinoop Lal S. “Photodegradation of polystyrene by nano titanium dioxide and photosensitizers.” Thesis. Research & Postgraduate Department of Chemistry, St. Thomas’ College (Autonomous), Thrissur, University of Calicut, 2020.

Chapter 8
Summary and Conclusion

Photodegradation could be considered as a suitable technique for the demolition of plastic debris compared to various other techniques practiced worldwide. The advantage of photodegradation over other remedial measures implemented for the waste plastic treatment is that the process is ecofriendly and cost effective. Photodegradation of plastics takes place naturally in the presence of sunlight but with a delayed time period which makes the process practically worthless. The entire plot of this thesis, focusing on the acceleration of PS photodegradation using various photocatalysts becomes relevant in this aspect. The metal oxide semiconductor TiO_2, as a photocatalyst showed better efficiency for the photodegradation of PS compared to ZnO under UV radiation. Throughout the study, we could arrive into the conclusion that the photocatalytic efficiency of TiO_2 and ZnO could be improved by modifying or coupling with various photosensitizers for the effective photodegradation of PS. Modifications have been done by associating TiO_2 and ZnO with PANI and GO. TiO_2 has been coupled with benzophenone derivatives and triphenylmethane dyes and doped with transition metals such as Fe, Cu and Ag. All these materials improved the photocatalytic efficiency of TiO_2 and ZnO for the photodegradation of PS under UV radiation. The compounds PANI, GO and triphenylmethane dyes and metals Fe, Cu and Ag were not acceptable photosensitizers in their uncoupled state. They could act as effective photosensitizers only when coupled with TiO_2 or ZnO. Derivatives of benzophenone however are better photosensitizers even in their uncoupled state.

The question “Which photocatalyst is the best for the photodegradation of PS?” has to be addressed at this point. This question however could only be answered accounting the mode of application of PS-photocatalyst composite system. From our investigations, PS-TiO_2-GO exhibited superior photocatalytic activity for UV initiated PS degradation compared to the other composites. PS-TiO_2-GO composites were mechanically stronger and thermally more stable compared to PS-TiO_2. This favours the use of PS-TiO_2-GO composite replacing pristine PS in several applications demanding better thermal stability and mechanical strength. Packing containers, toys or machine parts, for example, are made up of this composite. The products made out

of this composite undergo better degradation when thrown into the environment after their usage. TiO_2-GO, even though a better photocatalyst, cannot be considered as suitable filler for every application replacing other photocatalysts. The BDV values of PS-TiO_2-GO composites were lower compared to PS-TiO_2. This implies that the composite cannot be used for high voltage insulation applications. PS-TiO_2-PANI as well as PS-TiO_2-metal composites also showed lower BDV values even though they underwent appreciable extent of photodegradation. These composites also cannot withstand higher voltage similar to GO. Even though PS-TiO_2-metal can be used for food packing, PS-TiO_2-PANI and PS-ZnO-PANI are not suitable since the contact of PANI with edible materials is unhealthy. The PS-benzophenone derivative composites are transparent and mechanically stronger than pristine PS. The composites can substitute PS in applications where transparency is in demand. It should also be however noted that the compound 2-hydroxy-4-methoxybenzophenone does not sensitize PS for photodegradation as evident from the results obtained.

Practical significance of this work

- Photodegradation studies using an artificial UV lamp which has the power 30W and wavelength 253 nm have been conducted in this study. The photodegradation of PS was effective under this condition. It is estimated that UV radiation from sun striking the earth is around 32 W. This signifies that the efficiency of PS photodegradation, inside UV chamber, is certainly possible under natural sunlight too. Some of the composites of TiO_2 or ZnO with PANI or metals have the ability to be photocatalytically active even under visible light, as discussed in chapter 1. Exposure of PS under sunlight may increase the extent of photodegradation for such composites.
- Photodegradation might occur much easier and faster in our environment where the conditions are much harsher. Environmental weathering of the polymer may further assist its degradation process.
- Incorporation of optimum amount of photocatalysts also makes PS mechanically stronger and thermally more stable promising a wide range of applications.
- Photocatalysts can be loaded into PS during the moulding process and can be brought into commercial applications without much time consuming and complicated processes.

Eco friendliness in the photocatalysed degradation of PS and the relevance of this work

- Photodegradation occurs naturally under direct sunlight without any further requirements, making the process costless.
- No toxic gases are liberated during the process.
- The photocatalysts and sensitizers employed in this work, such as TiO_2, ZnO, GO, Fe, Cu and Ag are non-hazardous materials.
- Even though the photosensitizers like PANI, benzophenone derivatives and triphenylmethane dyes may be hazardous, their presence in PS doesn't matter much as they are loaded in very minute quantities.
- Photodegradation of PS composites would be effective in water bodies too. Interaction of water molecules with the catalysts or PS furnishes more OH• under sunlight that enhances photodegradation.

Way forward

UV-visible spectra of some of the PS composites especially composites consisting of PANI, GO, metals and dyes showed absorption in the UV as well as in the visible region. A thorough literature survey also supports the fact that these photosensitizers have the ability to extend the photocatalytic activity of TiO_2 and ZnO into the visible region. Replacing the UV light source with the visible light of sun can further extend the scope of PS photodegradation studies.

The electrical, mechanical and thermal properties of the PS-composites showed variations according to the type of photocatalysts used. A detailed study of various properties of these PS composites may explore the possible usages of these composites in several applications.