Plasma, UV Radiation and Ozone for Microplastics Degradation: Optical Characterization of Polystyrene, Polyethylene and Polypropylene Degradation using FTIR and Raman Spectroscopy

M. Ćurčić[1*], P. Kolarž[1], B. Hadžić[1], I. Stajčić[2], Z. Lazarević[1], D. Maletić[1], M. A. Urošević[1], A. Ilić[1]

[1]*Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia*

[2]*Institute Vinca, University of Belgrade, P.O. Box 522, 11001 Belgrade, Serbia*

**milicap@ipb.ac.rs*

Plastics, particularly the types of plastics typically used in packaging, are materials known for their very long lifespans, despite often being produced for short-term use. Polystyrene (PS), polypropylene (PP) and polyethylene (PE) constitute the majority of single-use plastics, and their disposal can lead to environmental release, either directly through littering or indirectly due to the poor process controls. Microplastics, defined as particles larger than approximately 100 nm but smaller than 5 mm in diameter, have been detected worldwide. Recently, comprehensive data on their prevalence and distribution in natural environments have been increasingly reported in the scientific literature. The development of techniques for the intended degradation of microplastics is yet another topic of current interest. However, in the field of monitoring microplastics, conventional sampling techniques for the detection and quantification of amounts of plastic particles are primarily adept at detecting microplastics and larger particles. As a result, there is a notable paucity of data on the environmental concentrations of nanoplastics, i.e., particles smaller than approximately 100 nm. This data gap underscores the necessity to develop the advanced nanoplastics detection and quantification methods, to better handle the distinct and potentially significant environmental and health risks posed by their diminutive size. In light of these concerns, as well as the need for additional detailed studies of various degradation methods, we conducted experiments involving three types of microplastics—polystyrene, polyethylene, and polypropylene—subjecting them to extreme degradation conditions. Through separate exposures to plasma, UV radiation, and ozone, we aimed to break down the microplastics into smaller particles, potentially converting them into nanoplastics and further degrading them to a state where they are entirely destroyed. One of the main advantages of our approach is that it allows a comparison of the actual effects of various treatments; otherwise, with the combined treatments, the effects of each one might not be clearly discernable. The final objective of this study is to investigate whether these extreme degradation conditions can effectively reduce the size of microplastics and potentially significantly contribute to its elimination. The study results allow a better understanding of microplastics degradation processes and provide a pathway to assist in mitigating their environmental impact.

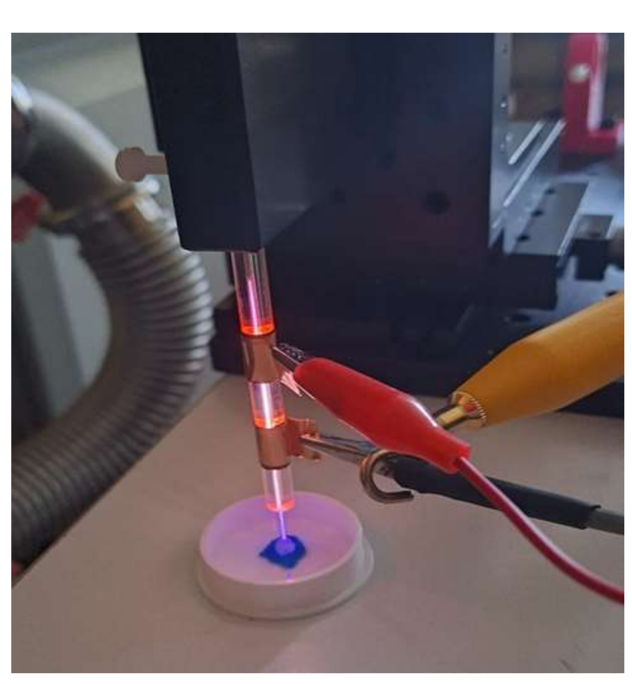
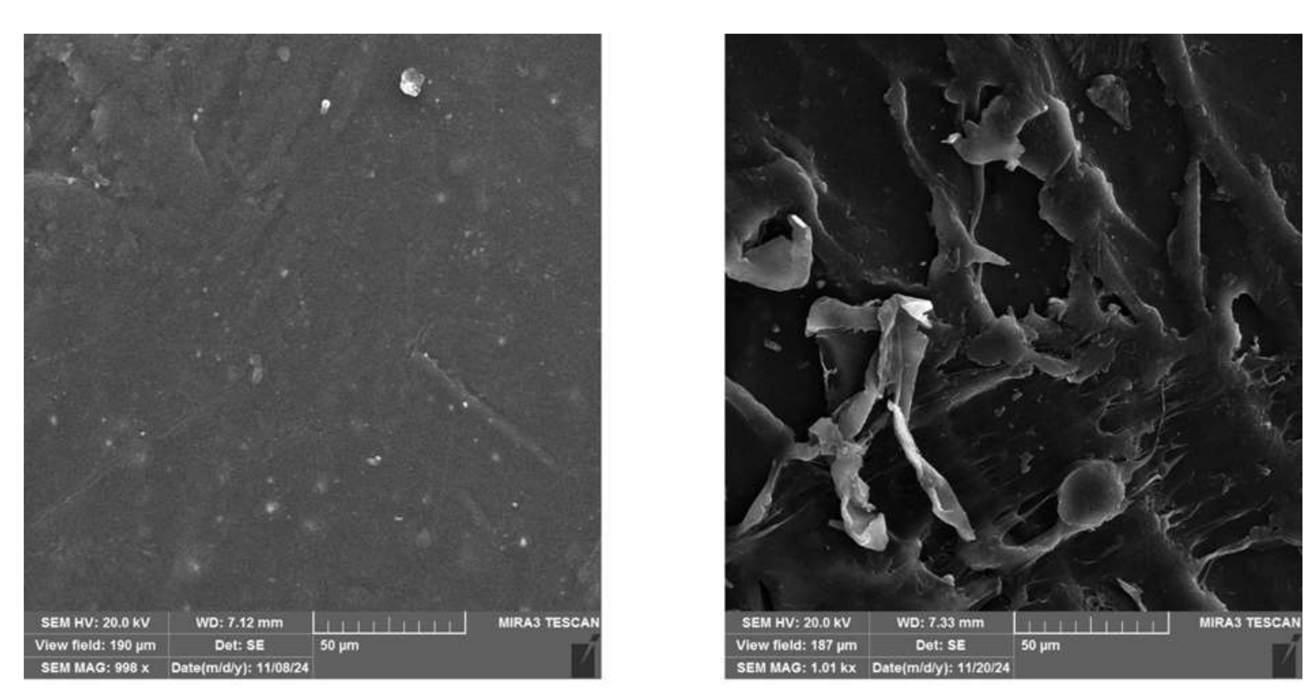


Figure 1. Setup used for plasma treatment.



a) b)

Figure 2. FESEM images: a) PS before degradation and b) PS after degradation plasma.

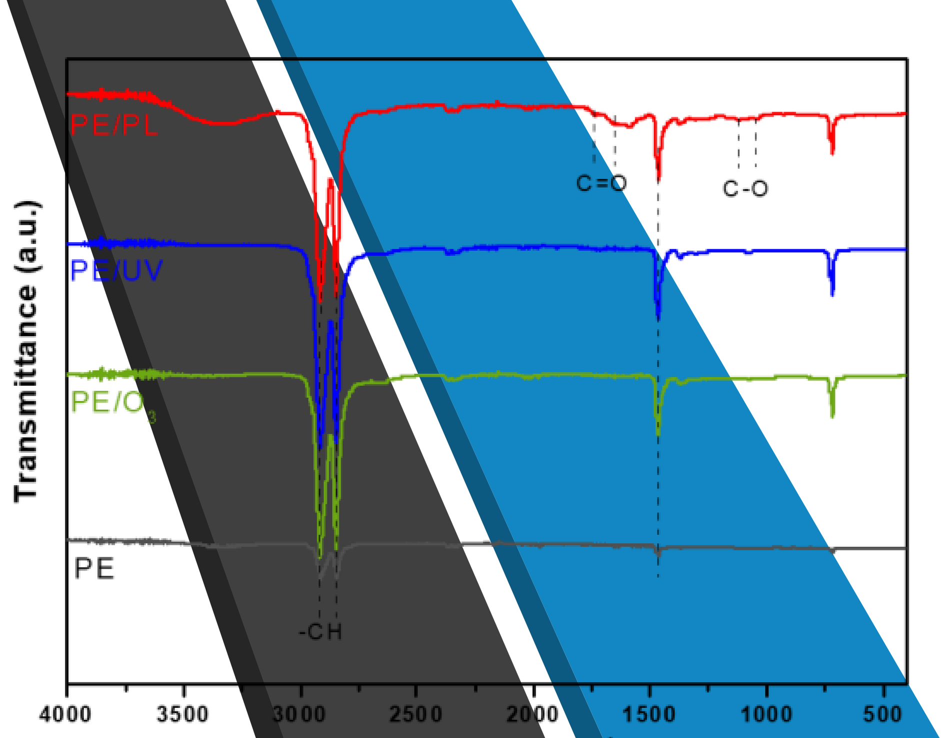


Figure 3. FTIR spectra of PE and PE/Plasma, PE/O3, PE/UV.

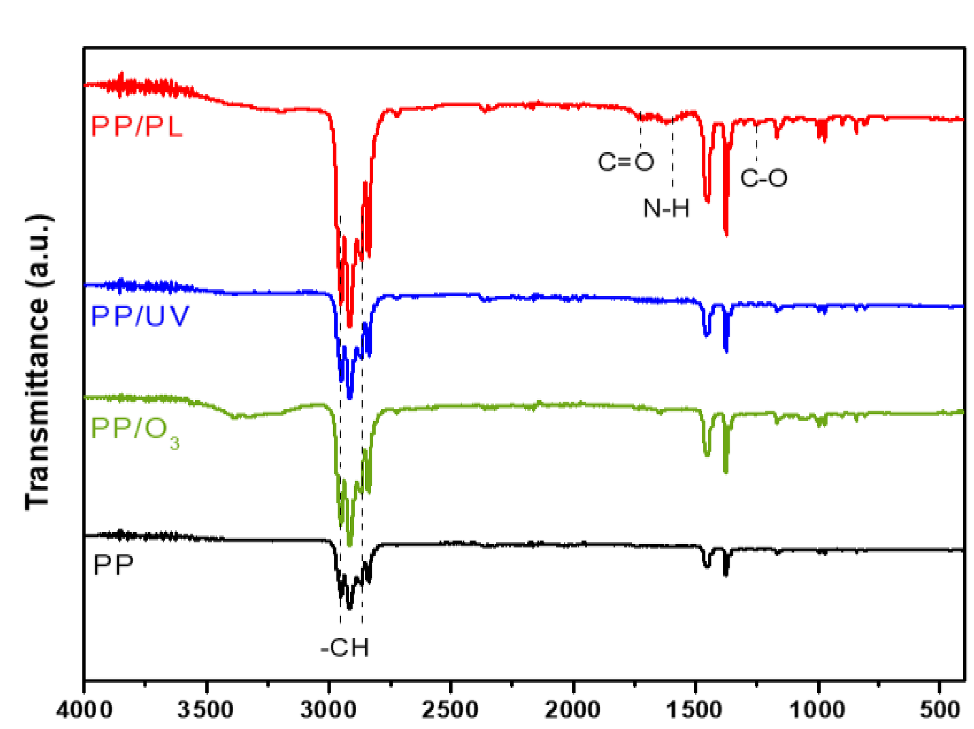


Figure 4. FTIR spectra of PP and PP/Plasma, PP/ UV, PP/O3.

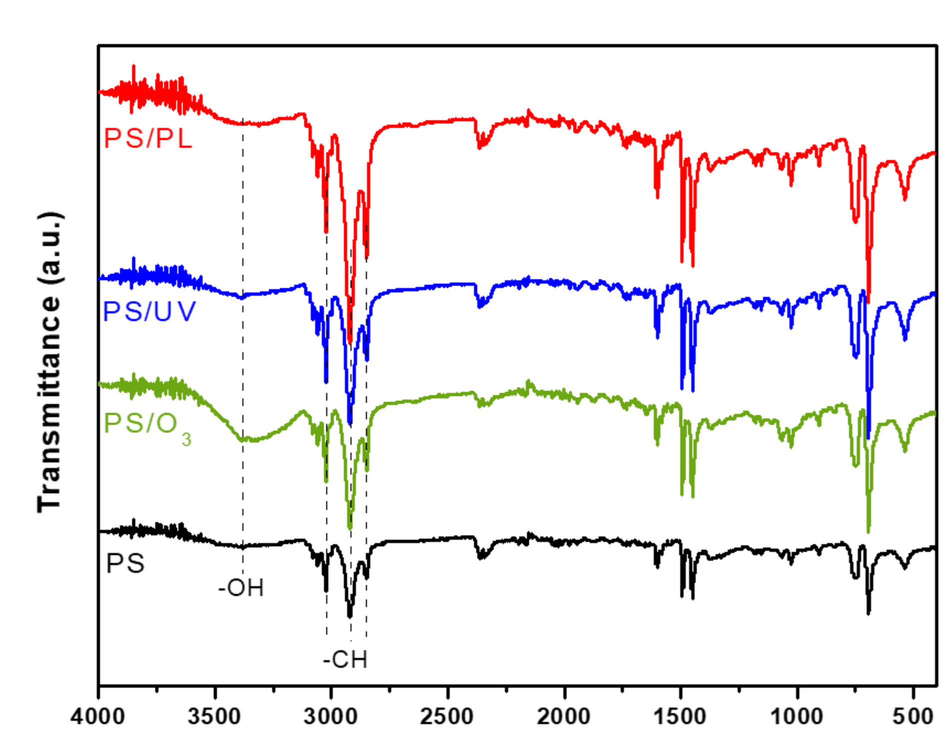


Figure 5. FTIR spectra of PS and PS/Plasma, PS/UV, PS/O3.

Acknowledgements

This work has been supported by The Science Fund of the Republic of Serbia, Green program of cooperation between science and industry, grant no. 5661.