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Environmental Nanotechnology for Microplastic Removal: Insights into Laser-Induced Photodegradation

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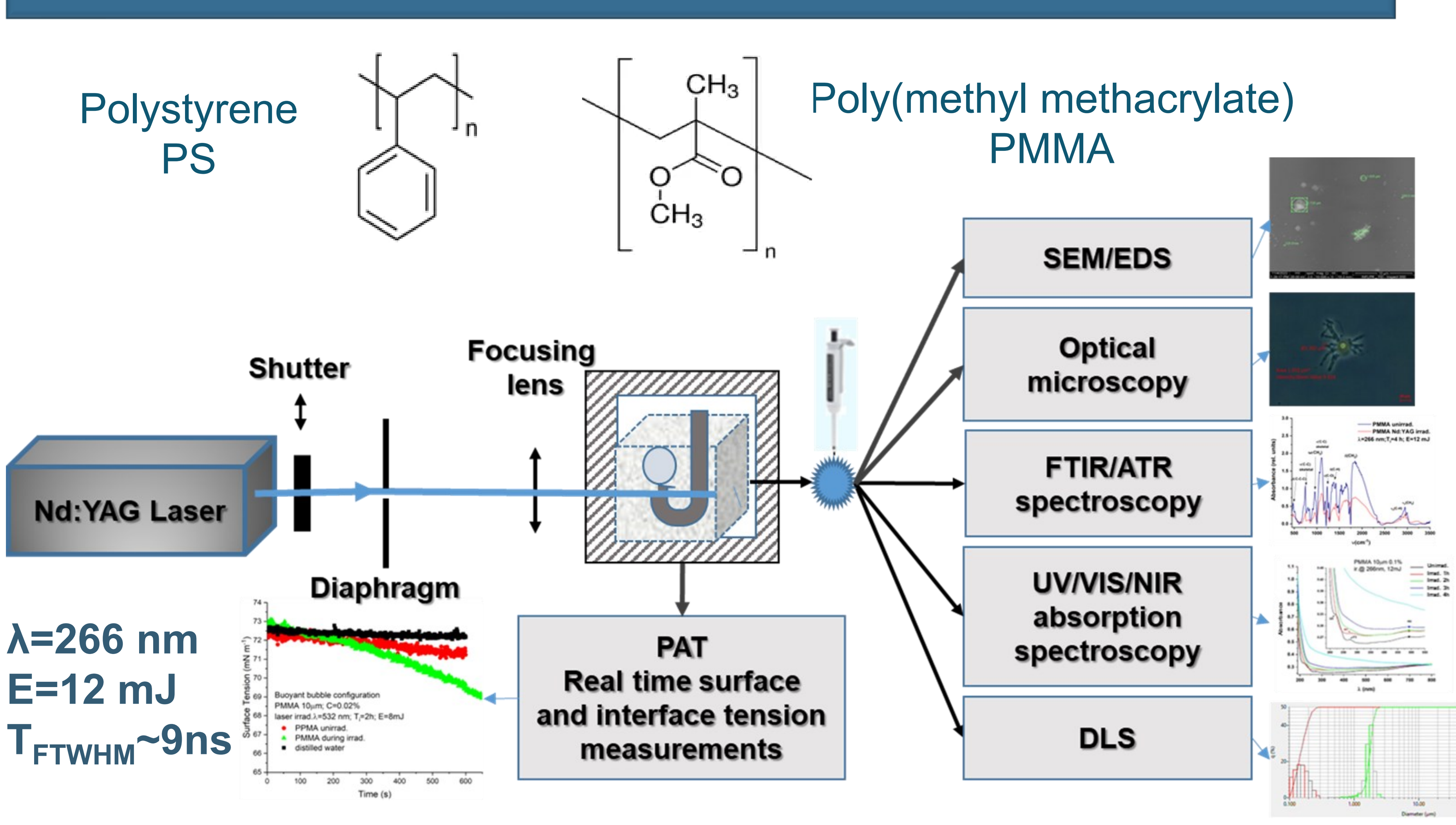
INTRODUCTION & AIM

- The consumption of plastics increases environmental pollution due to their low biodegradability, inappropriate use, and inefficient disposal;
- Exposure of plastic materials in the environment promotes physical, chemical, and biological degradation processes;
- Plastic degradation leads to accumulation of very small plastic fragments in the environmental ecosystems;
- Microplastics (MPs) vary in size between 0.1–5 mm. The smaller group of nanoplastics (NPs) are particles that range from 1 to 100 nm in size;
- Laser-driven photodegradation, a promising solution to mitigate MPs pollution by their mineralization into CO_2 and H_2O or converting them into valuable byproducts [1];
- Many challenges in the field of micro- and nano-plastics research must be addressed [2].

This study explores the effects of UV laser irradiation on poly(methyl methacrylate) (PMMA) and polystyrene (PS) micro/nanoparticles in water to evaluate their degradation potential.

METHOD



CONCLUSION

Research toward effectively laser photodegrading MPs is still in its early stages. During the laser irradiation of MPs, various by-products are formed, whose characteristics might exhibit significant levels of pollution and toxicity. Recycling these offers pollution control and resource reuse. However, environmental impacts must be assessed to avoid harm. Sustainable, greener conversion methods are essential for truly effective and eco-friendly MPs management.

ACKNOWLEDGEMENT

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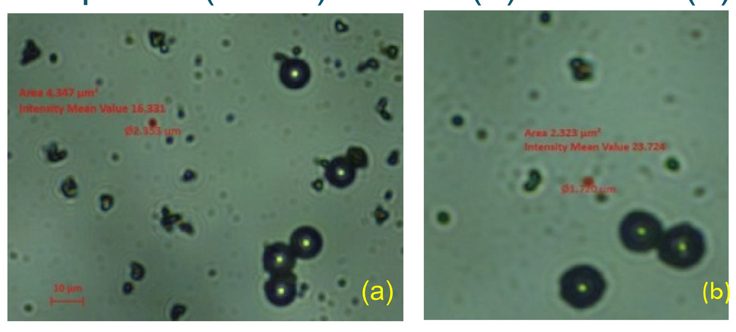
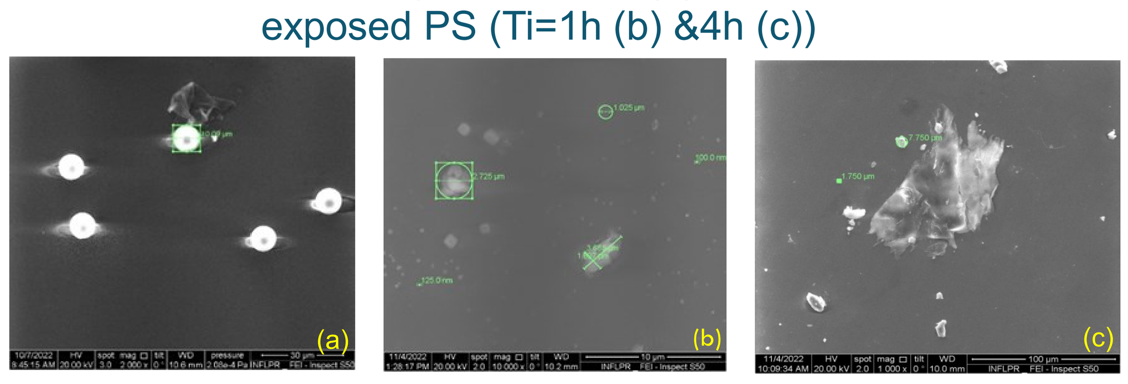
RESULTS & DISCUSSION

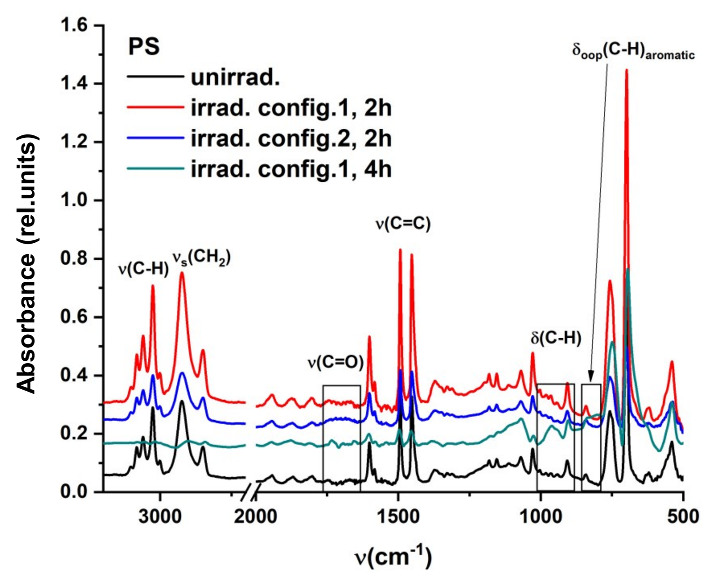
Optical microscopy images (40x) of laser exposed (Ti=4h) PMMA (a) and PS (b)



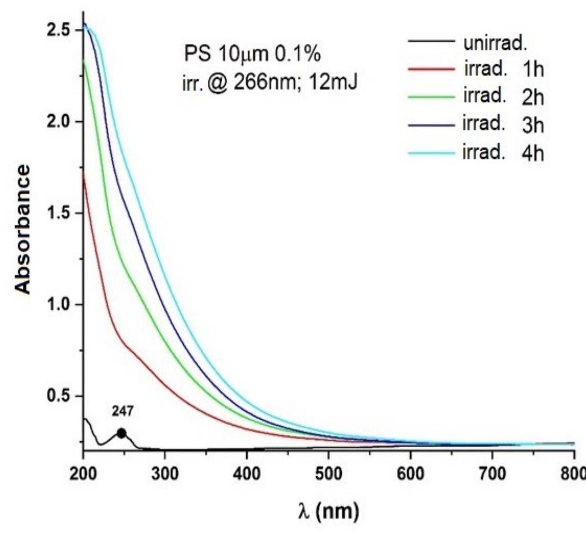
SEM images of native (a) & laser exposed PS (Ti=1h (b) &4h (c))



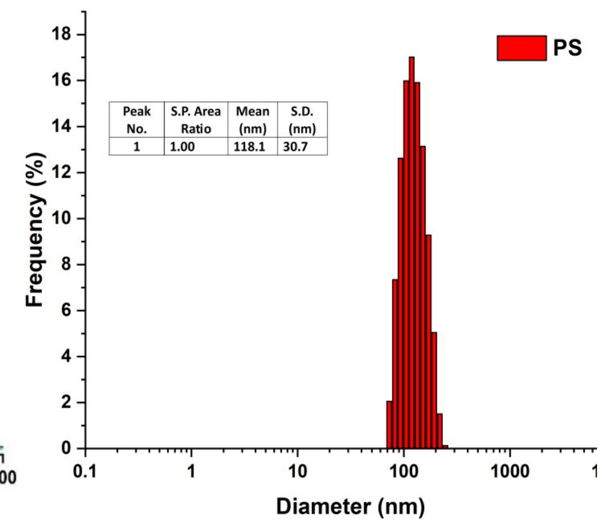
The FTIR spectrum of PS



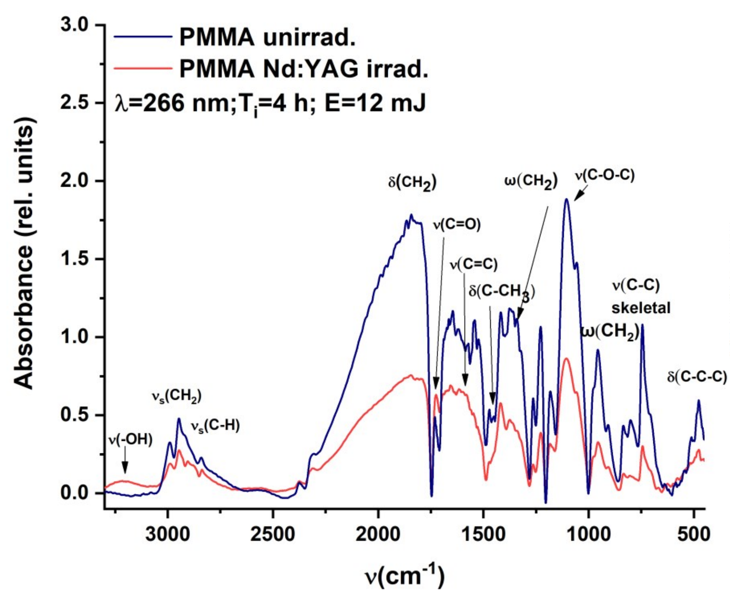
The UV-Vis absorption spectra of PS in aqueous solutions



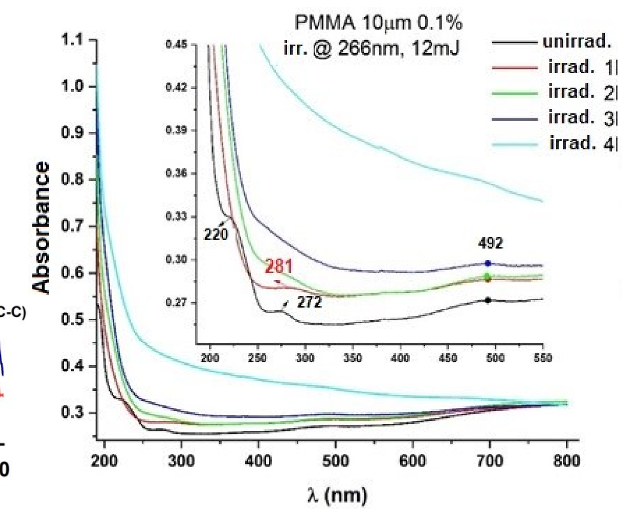
Particle size distribution of unirradiated PS



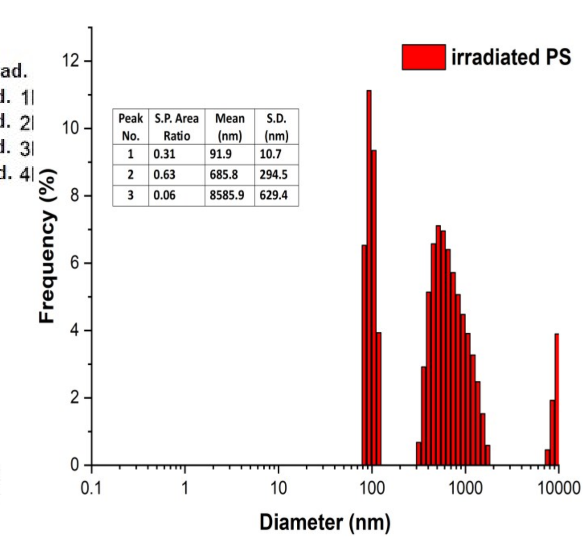
The FTIR spectrum of PMMA



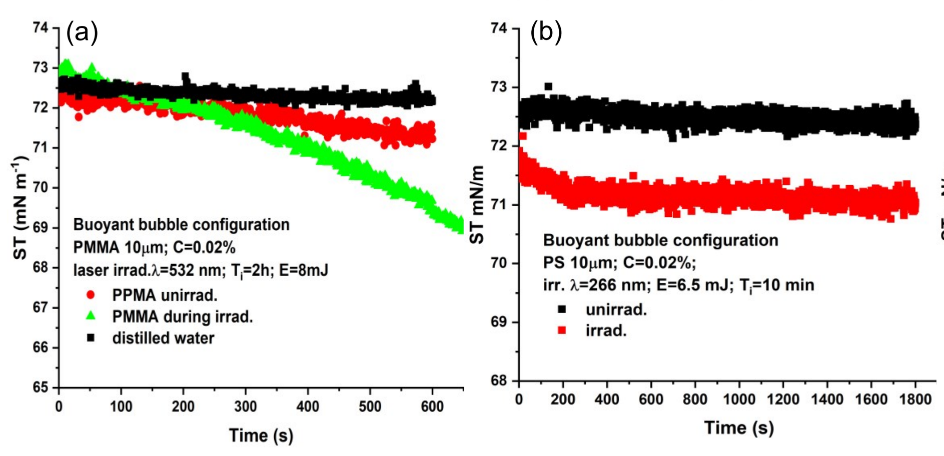
The UV-Vis absorption spectra of PMMA in aqueous solutions



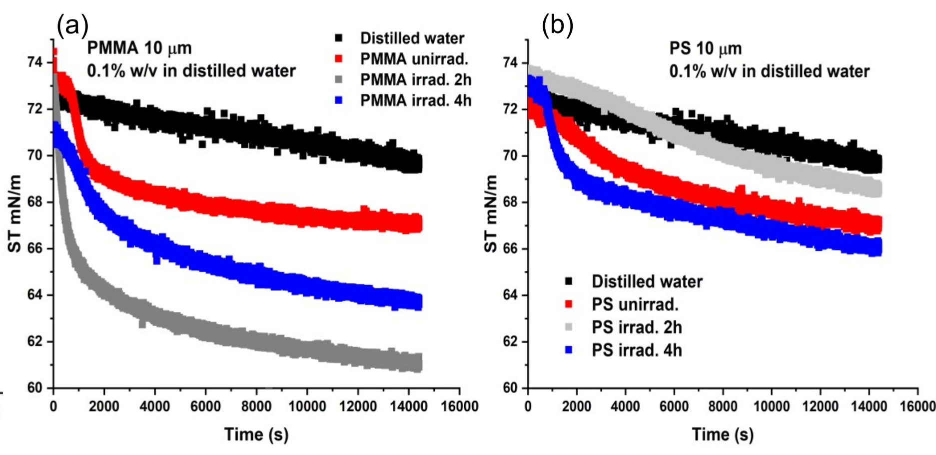
Particle size distribution of irradiated PS



Variation of surface tension at the air-water interface for MPs in emerging bubble configuration. Dynamic interface tension measured during irradiation of PMMA (a) and PS (b) .



Variation of surface tension for laser exposed MPs dispersed in distilled water: PMMA (a) and PS (b)



- SEM and optical microscopy confirm the MPs breaking and formation of micro-/nanoparticles randomly distributed in water. EDS analysis indicated increased percents of oxygen for laser exposed PMs, which suggest material oxidation.
- Advanced laser induced photodegradation was obtained for PMMA 10 µm (0.1% w/v) exposed to 12 mJ laser radiation for 4 h. FTIR analysis suggest that this undergone through the C=O bonds breaking. In the same irradiation conditions, the photodegradation of PS takes place through the formation of intermediate peroxides, and the formation of carbonyl compounds.
- Fragments of lower dimensions were evidenced by DLS in irradiated samples. Exposure of PS-NPs to UV laser radiation induces changes in surface functional groups, reducing electrostatic repulsive forces and thereby accelerating particle agglomeration.
- DIT results revealed that photodegradation involves diffusion and reorganization at the air-water interface.

REFERENCES

1. Ramírez-Escárcega, K.J.; Amaya-Galván, K.J.; García-Prieto, J.C.; Silerio-Vázquez, F.D.J.; Proal-Nájera, J.B. *Journal of Environmental Chemical Engineering* **2025**, 13:115594;
2. Paiman SH, Md Noor SF, Ngadi N, Nordin AH, Abdullah N. *Chemical Engineering Journal*. **2023**;467:143534.