Accelerated Weathering-Induced Surface Degradation of Polyethylene Terephthalate and Melamine Etherified Resin Nonwoven Fabrics

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Keywords: *Accelerated weathering, Plastic degradation, Physico-chemical properties, Polyethylene terephthalate, Melamine etherified resin, Surface chemistry, Environmental aging*

Introduction

Plastic degradation caused by environmental stressors ultimately leads to the formation of microplastics and, subsequently, nanoplastics, which are among the most persistent and harmful environmental pollutants, posing risks to ecosystems and human health. Because **degradation and fragmentation begin primarily at the plastic surface, a detailed understanding of surface-related physicochemical changes is essential for elucidating degradation pathways of plastic materials. Accelerated weathering** tests provide an **effective method for studying plastic degradation under realistic environmental conditions by simulating ultraviolet (UV) radiation, temperature fluctuations, moisture, and oxygen exposure.** These controlled tests condense years of natural weathering into weeks or months, enabling **systematic evaluation of degradation mechanisms**. ***Monitoring changes in surface chemistry, morphology, wettability, and surface charge allows identification of rate-limiting processes and structure–property relationships that govern polymer stability.***

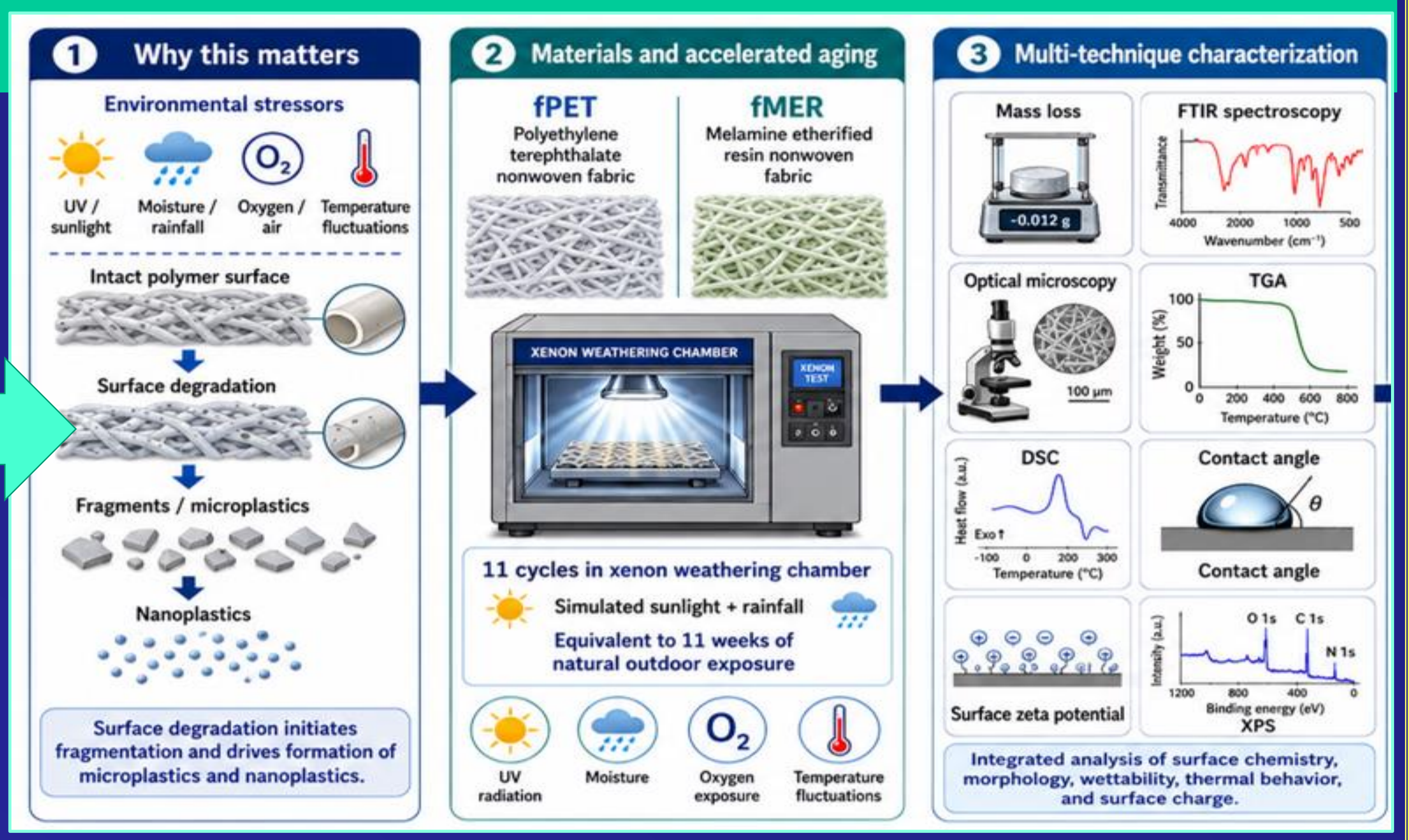

Figure 1: Overall study approach.

Results & Discussion

Polyethylene terephthalate (fPET) and melamine etherified resin (fMER) nonwoven fabrics were investigated to elucidate the evolution of their physicochemical properties under accelerated aging conditions. For the first time, these materials were subjected **to accelerated aging in a xenon weathering chamber for 11 cycles**, each cycle comprising simulated sunlight and rainfall, **corresponding to a total of 11 weeks of natural outdoor exposure**. Degradation-induced changes were comprehensively **evaluated using a multi-technique approach**, including mass loss measurements, infrared spectroscopy, optical microscopy, thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), contact angle analysis, surface zeta potential measurements, and high-resolution surface chemical characterization by X-ray photoelectron spectroscopy (XPS).

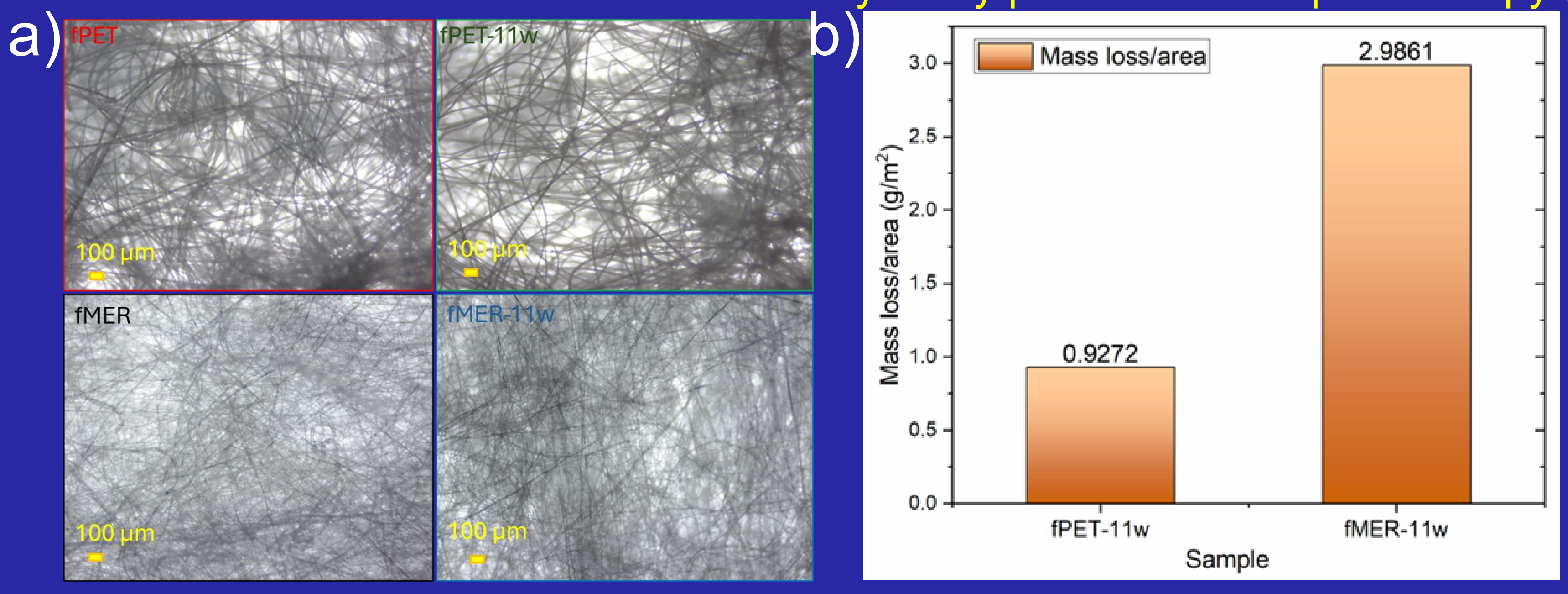

Figure 2: a) optical microscopy and b) mass loss of fPET and fMER after accelerated weathering aging.

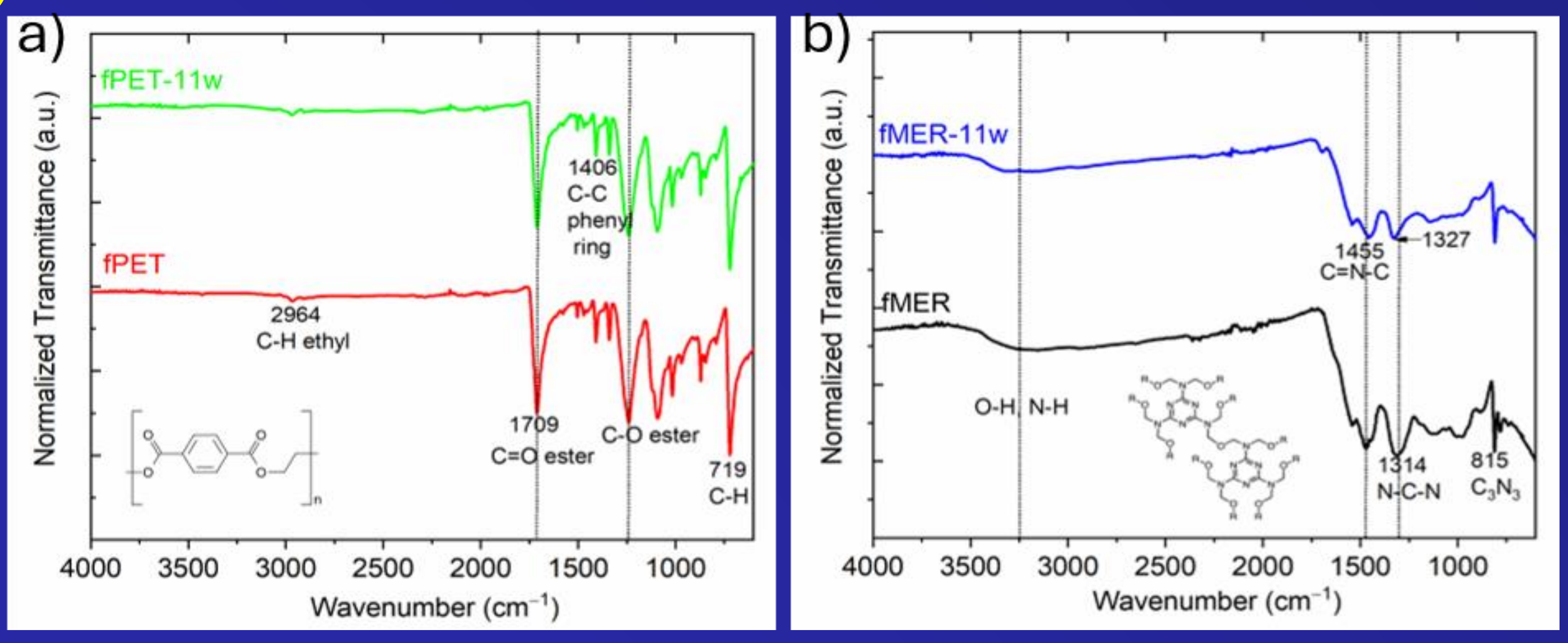

Figure 3: Infrared spectroscopy of native and aged a) fPET and b) fMER.

Table 1: Atomic composition of native and aged fPET.

Sample/atomic composition (at.%)	C ↑	O ↓	N	Na	Si	P	Ca
fPET	**75.4 ± 1.7**	**23.0 ± 1.8**		0.6 ± 0.3	0.6 ± 0.3	0.5 ± 0.3	
fPET-11w	**69.3 ± 1.0**	**26.3 ± 0.9**	2.6 ± 0.6		1.6 ± 0.8		0.3 ± 0.1

Table 2: Atomic composition of native and aged fMER.

Sample/atomic composition (at.%)	C	O ↓	N ↑	Si	S	Ca	Cl
fMER	58.6 ± 1.7	**6.6 ± 0.9**	**32.7 ± 2.0**	0.8 ± 0.4			1.4 ± 0.5
fMER-11w	61.1 ± 3.9	**19.1 ± 0.6**	**17.8 ± 3.9**	1.4 ± 0.5	0.2 ± 0.1	0.24 ± 0.1	0.1 ± 0.1

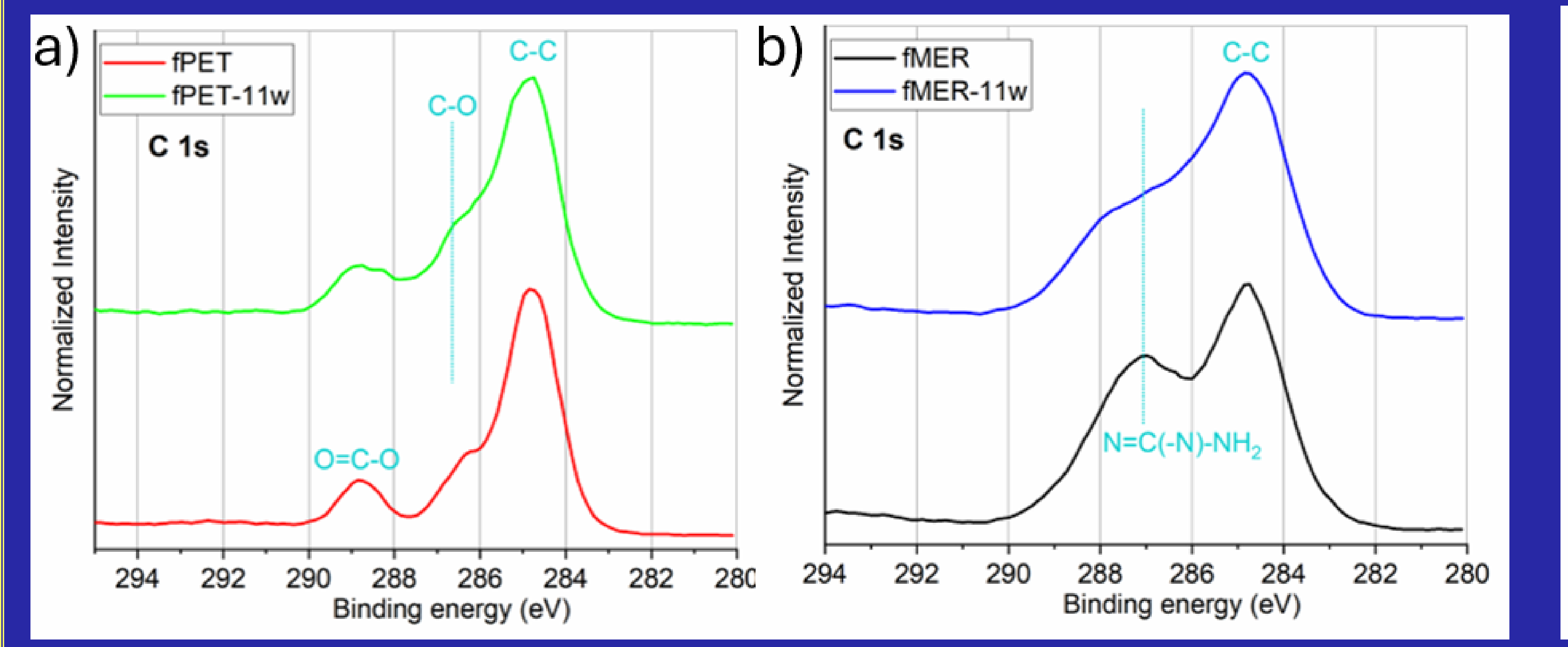

Figure 4: High-resolution C 1s spectrum for a) fPET and b) fMER before and after aging.

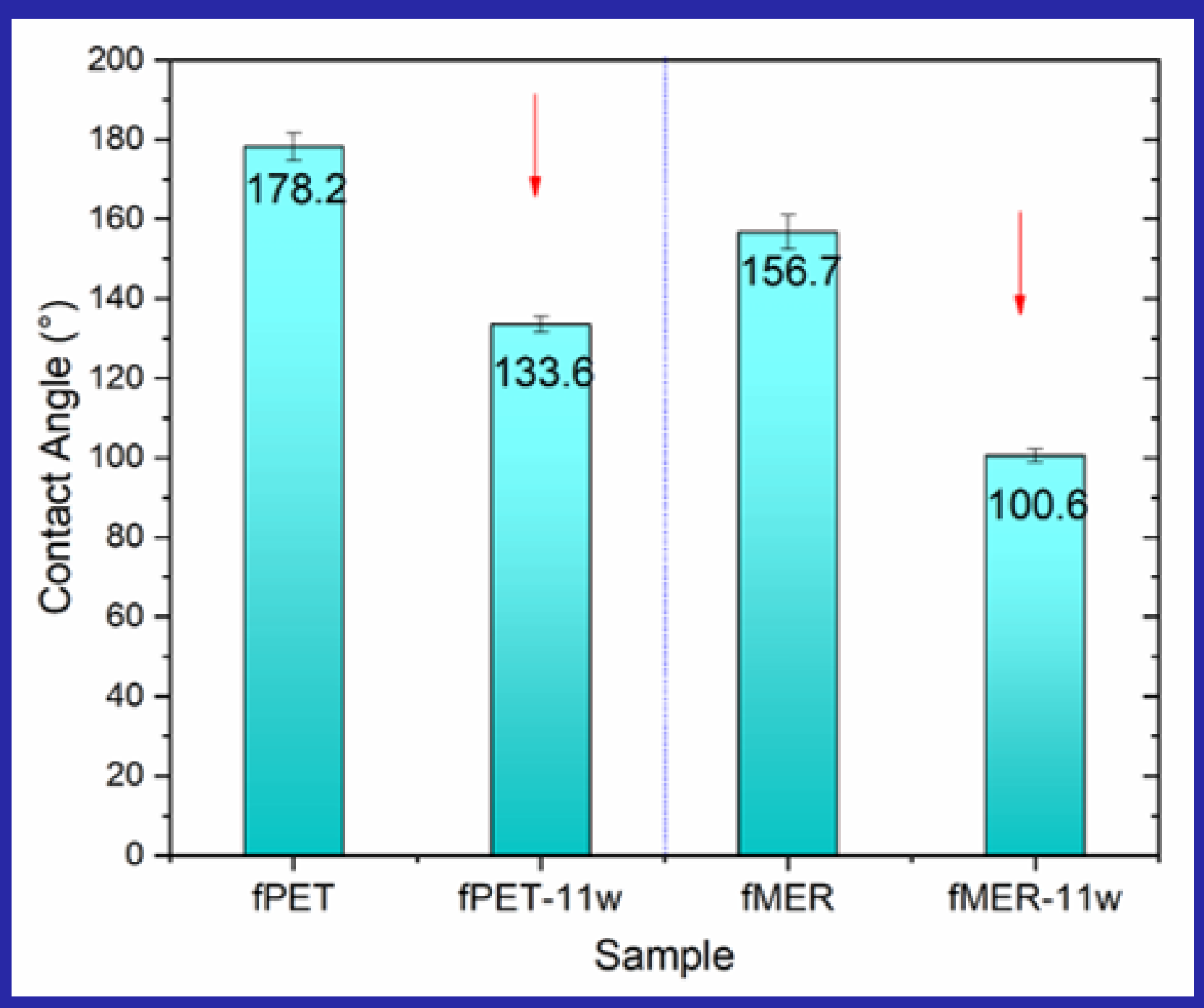

Figure 5: Changes in wettability before and after aging.

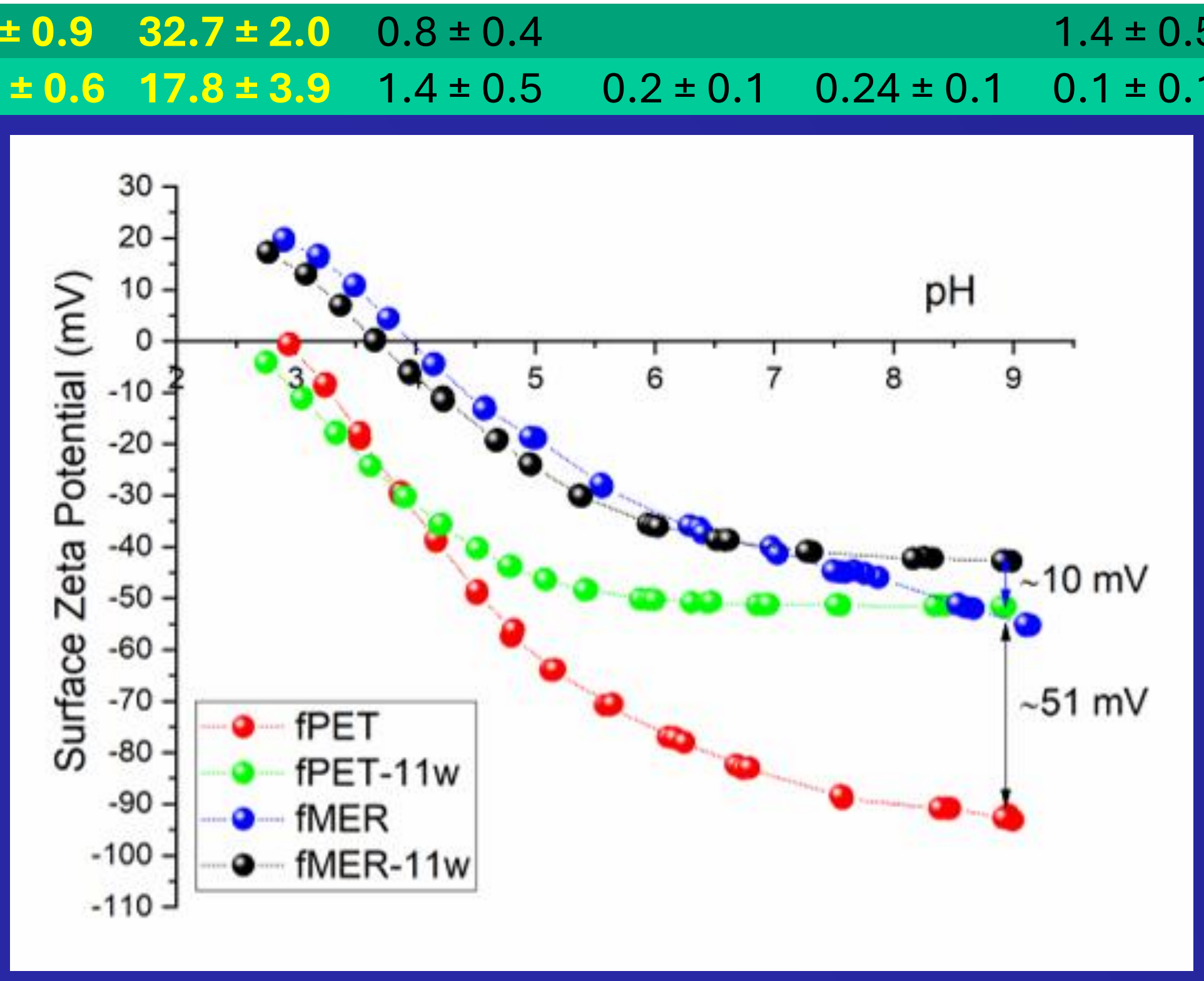

Figure 6: Surface zeta potential as a function of pH reveals changes in surface characteristics after aging.

Conclusions

fPET – main conclusions

- Contact angle decreased, indicating increased surface wettability and polarity.
- Measurable mass loss confirmed early-stage material degradation.
- XPS showed no significant change in atomic composition, suggesting limited chemical alteration at the surface.
- fPET degradation was mainly reflected in physical surface changes and increased polarity.

fMER – main conclusions

- Contact angle decreased, indicating increased surface wettability and polarity.
- Measurable mass loss confirmed degradation of the material during aging.
- XPS revealed a decrease in nitrogen content, suggesting degradation of nitrogen-containing melamine structures.
- IR spectral changes indicated modifications of functional groups after weathering.
- fMER showed a material-specific degradation pathway involving both surface and chemical changes.

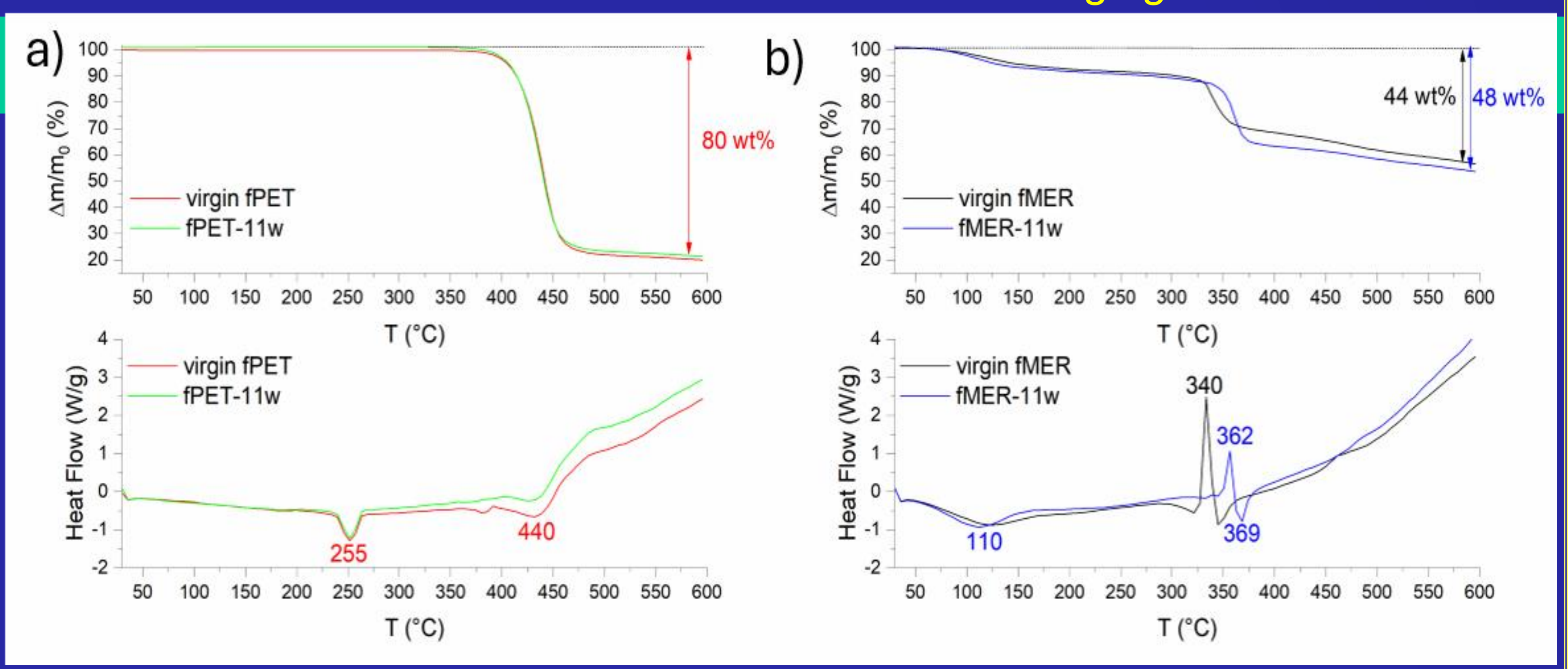

Figure 7: Thermogravimetric analysis and DSC results for a) fPET and b) fMER.

The authors acknowledge the financial support from the Slovenian Research Agency (Research Programmes: P2-0118, P2-0412, P2-0082 and P2-0421 and Project J7-3149 and the Grant Agency of the Czech Republic under Project No. 21–45726 L.