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Test report

Aging test of monofilament fishing line

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Monofilament fishing line (nylon and PBSAT)	Week 39

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ABSTRACT
Two types of monofilament fishing line were received. One line was made of nylon (polyamide-6) and the other was PBSAT (polybutylene succinate co-adipate-co-terephthalate). Both materials were aged for 1000 hours in a weathering test, simulating outdoor condition. The degradation of the materials was characterised by FTIR spectroscopy, mechanical testing, light microscopy, and scanning electron microscopy. The analyses reveal that both materials show signs of degradation already after 200 hours of exposure. PBSAT degrades faster than nylon and thus shows a stronger reduction in mechanical strength and material integrity. In addition, PBSAT is changing its chemical structure more significantly during degradation compared to nylon, as revealed by FTIR.

The test results relate only to the items tested

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1 Experiment

Two types of monofilament fishing line were received. One line was made of nylon (polyamide-6) and the other was PBSAT (polybutylene succinate co-adipate-co-terephthalate). From both lines, 36 pieces of approx. 35 cm length were cut for the weathering test, yielding 72 samples in total. One set of 6 pieces from each material was kept aside as reference. The other pieces were fixed on to the sample holders of the weather-o-meter in groups of 6. The weathering was done according to ISO 4892-2 (outdoor) using an Atlas Xenotest 440 weather-o-meter. The total exposure time was 1000 hours and the parameters for the weathering cycle are summarized in Table 1.

Table 1: Weathering cycle according to ISO 4892-2 (2013).

Exposure period	Irradiance		Black-standard temperature [°C]	Chamber temperature [°C]	Relative humidity [%]
	Broadband UV300-400 [W/m²]	Narrowband [W/m² nm)]			
102 min dry	60 ± 2	0,51 ± 0,02 (@340 nm)	65 ± 3	38 ± 3	50 ± 10
18 min water spray	60 ± 2	0,51 ± 0,02 (@340 nm)	-	38 ± 3	-

During the weathering test one set of samples (6 pieces) from each material was removed after 196h, 431h, 626h, 817h, and finally after 1000h for further analysis.
Tensile testing of the fishing lines samples was performed using a Zwick/Roell Z250 universal test machine and three parallels from each set of samples were analysed.
FTIR spectra were recorded using an Agilent Cary 670 equipped with an ATR crystal.

2 Results and discussion

2.1 Tensile test

Figure 1 shows the stress-strain curves of both nylon and PBSAT samples when new (non-aged) and after 1000 hours of exposure.

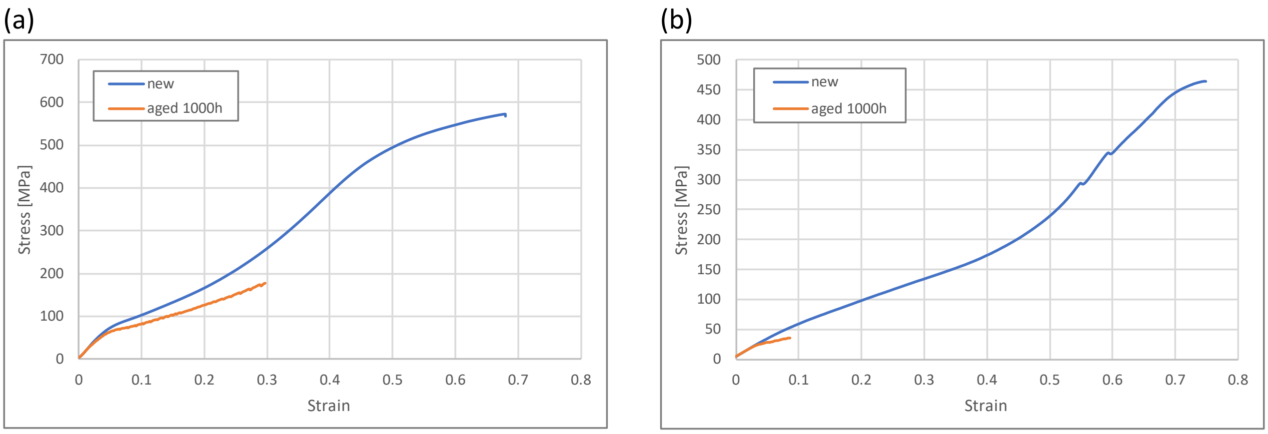


Figure 1: Stress-strain curve of nylon (a) and PBSAT (b). The strain is the engineering strain ($\Delta L/L_0$ where L_0 is the initial grip-to-grip distance). The stress is the engineering stress (force divided by initial cross-sectional area).

The strain at break is reduced after aging, i.e. the material loses ductility, which is an expected sign of degradation. This aging effect is strongest for the PBSAT fishing line. The change in tensile strength and strain at break are shown in Figure 2a and b, respectively. Before aging, the tensile strength of nylon is about 23% higher than the one of PBSAT. Already after 200 hours exposure the tensile strength of both materials starts to decline, and the deterioration is strongest for PBSAT. However, after 600 hours exposure the values for nylon seem to level off whereas those of PBSAT continue to decline.

(a) (b)

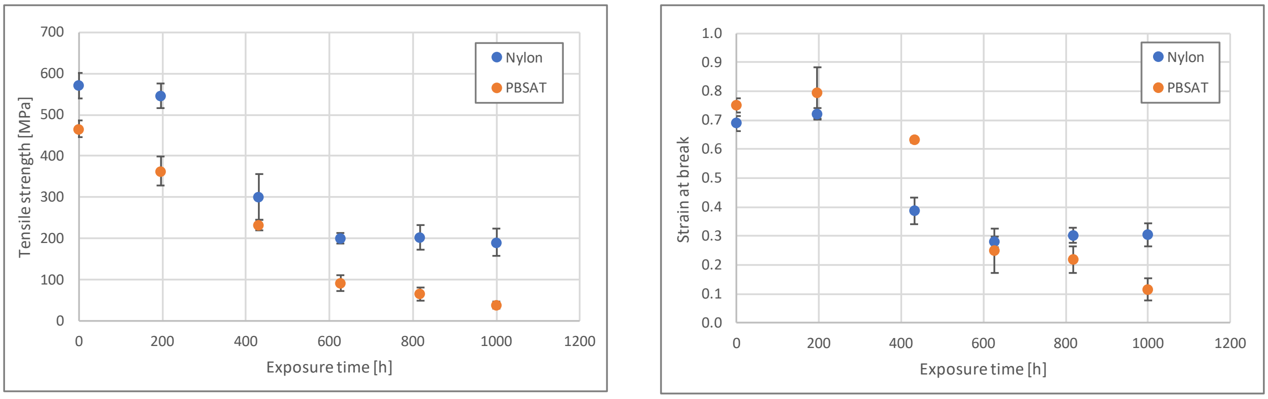


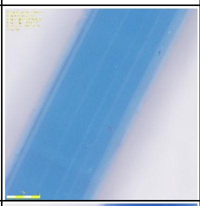
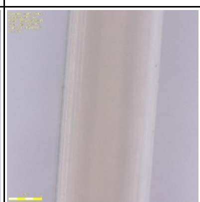
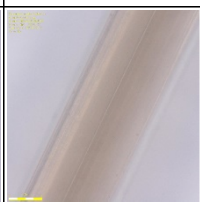
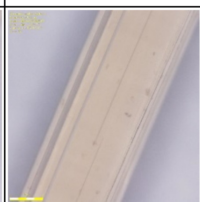
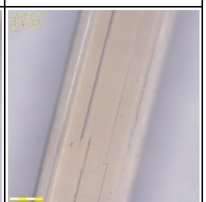
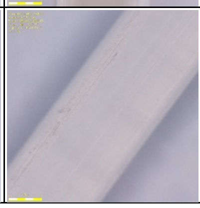
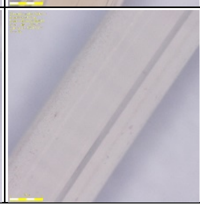
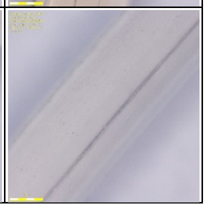
Figure 2: Change of tensile strength (a) and strain at break (b) during aging.

Before aging, the elongation at break is about 9% higher for PBSAT compared to nylon, indicating that this material has a slightly higher ability for plastic deformation. For both materials the elongation at break increases slightly during the first 200 hours of exposure and then declines significantly. Like the tensile strength, the elongation at break for nylon seems to level off after about 600 hours exposure whereas PBSAT continues to decline.

2.2 Light microscopy

Table 2 shows light microscopy images of the two materials at different times during the aging test. It can be seen easily, that both materials lose their colour quickly. Already after around 200 hours of exposure the blue colour is faded away and the materials become colourless to slightly yellowish. Also, the formation of cracks at the surface can be observed, which starts at around 600 hours of exposure and is more prominent for the PBSAT sample.

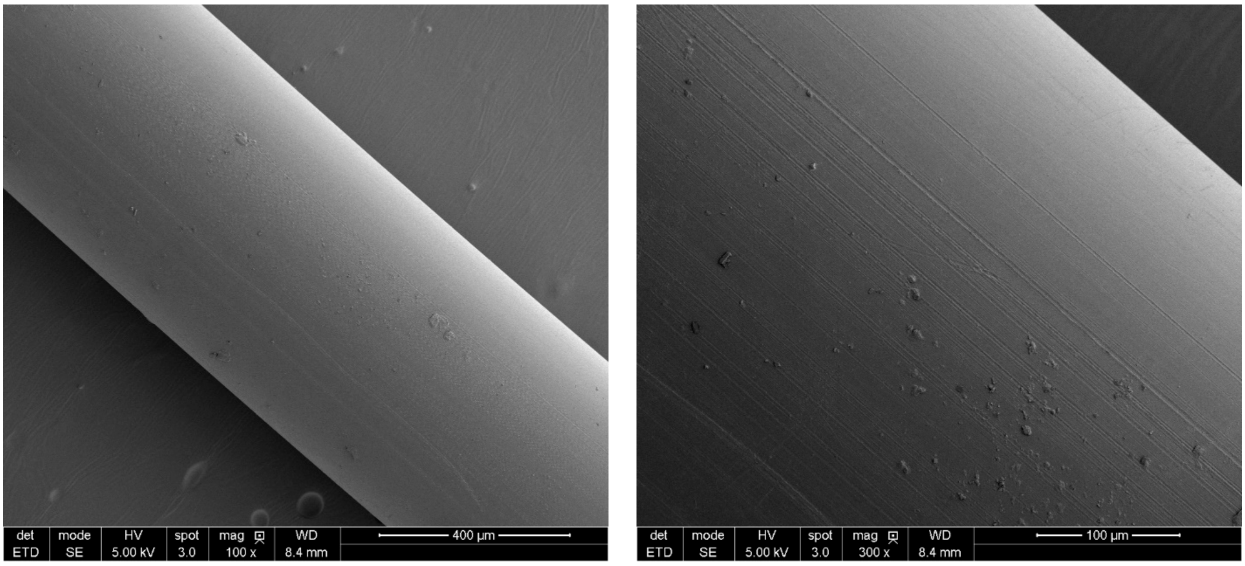
Table 2: Light microscopy images of nylon and PBSAT samples at different points during the aging test.

	new	196h	431h	626h	817h	1000h
Nylon						
PBSAT						

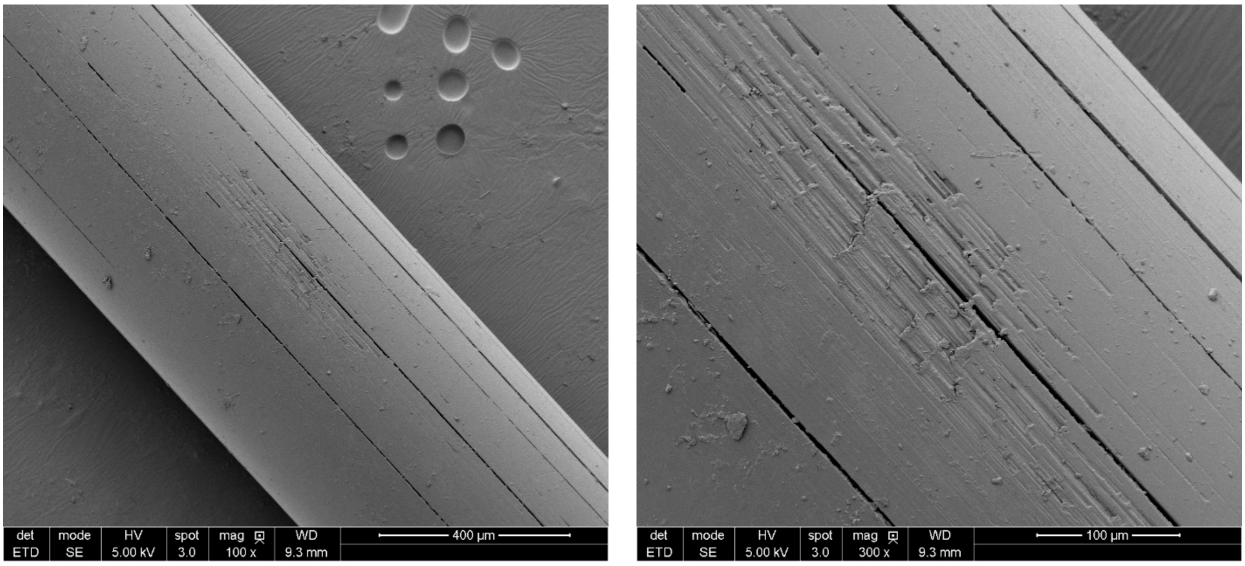
2.3 Scanning electron microscopy (SEM)

Figure 3 shows SEM micrographs of the nylon sample before and after 1000 hours aging. The new nylon line has a smooth surface showing only some scratches originating most likely from the manufacturing process. After 1000 hours of exposure the surface of the nylon line shows long cracks along the fibre axis and the line starts to fragmentate, showing large areas where material is broken off (Figure 3b).

(a)



(b)



(b)

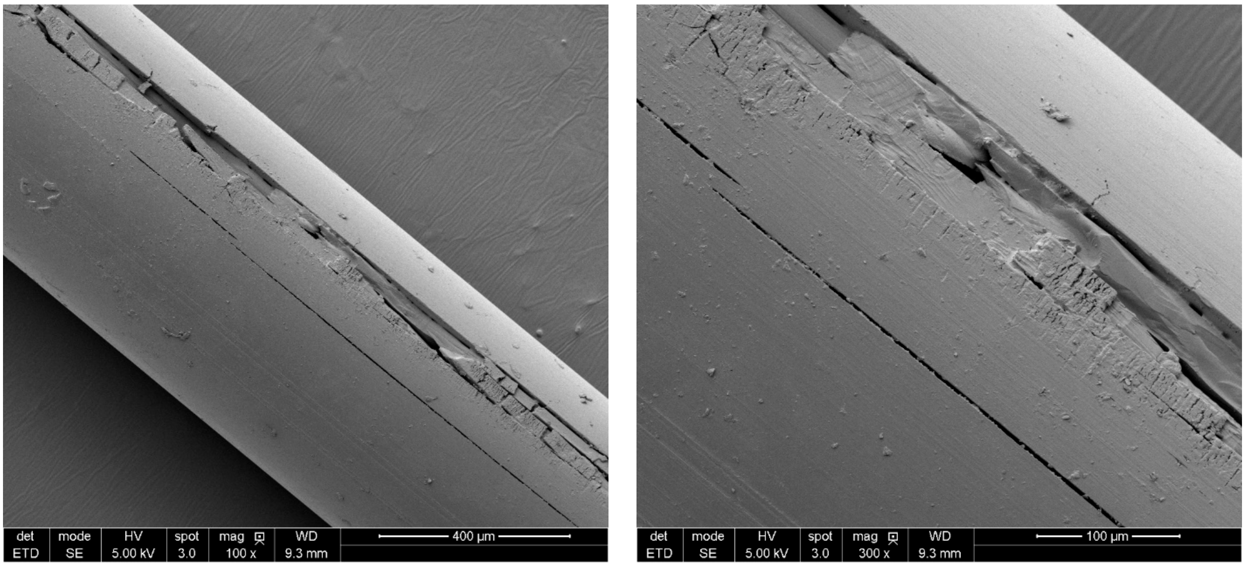
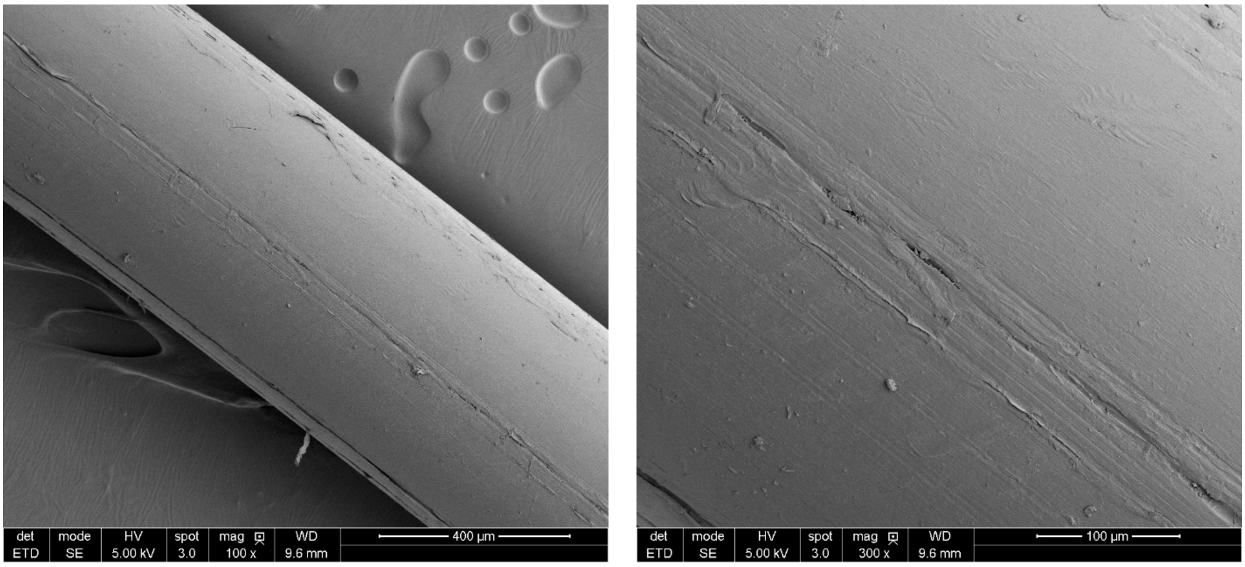


Figure 3: SEM micrographs of the nylon fishing line sample before (a) and after 1000 hours aging (b).

The surface of the non-exposed fishing line made of PBSAT is slightly rougher compared to the nylon sample and it shows already some cracks along the fibre axis (Figure 4a). After 1000 hours of exposure the degradation of the fishing line is clearly visible. The material has started to fragmentate and large pieces from the surface have started to break off (Figure 4b).

(a)



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(b)

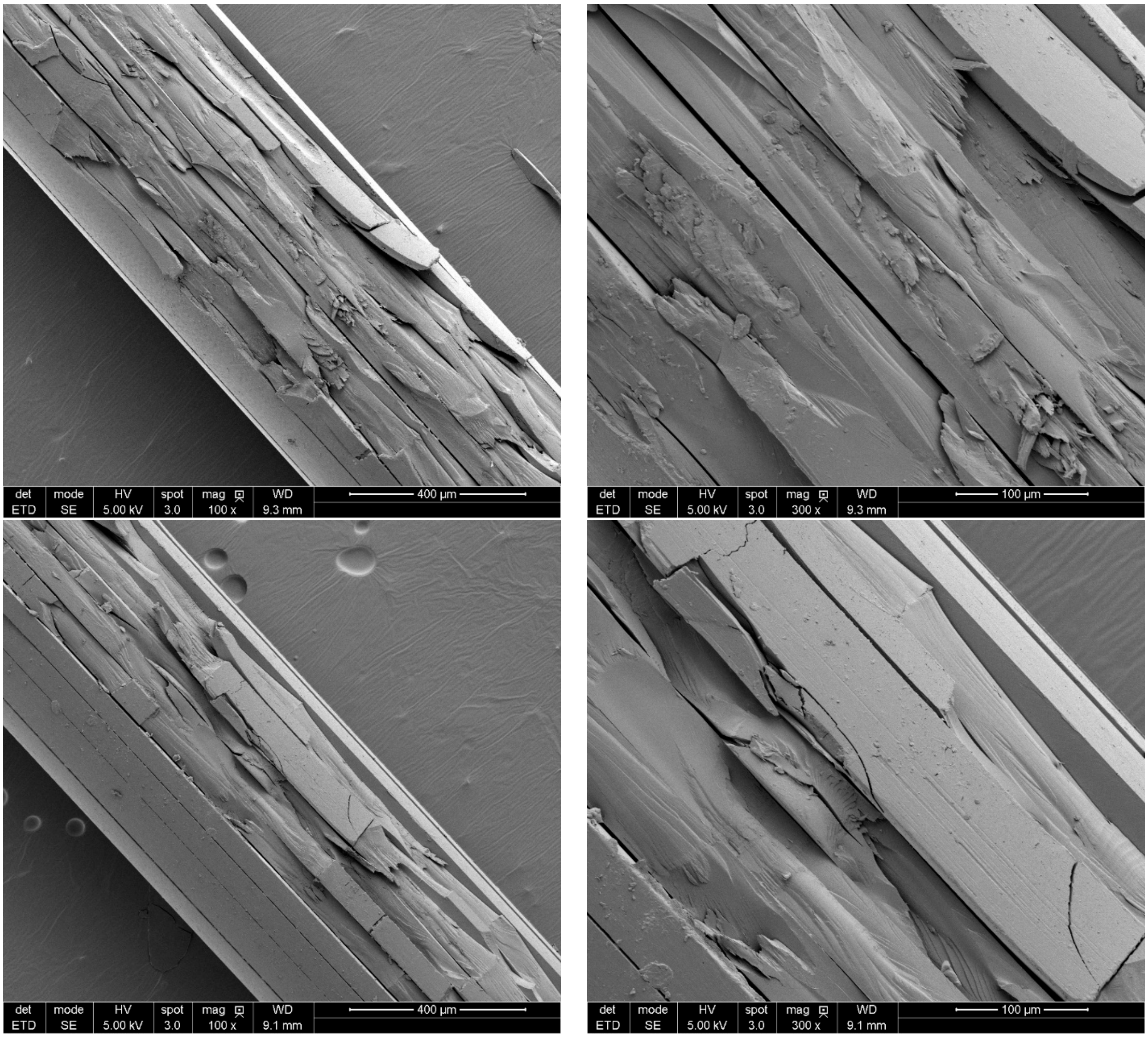
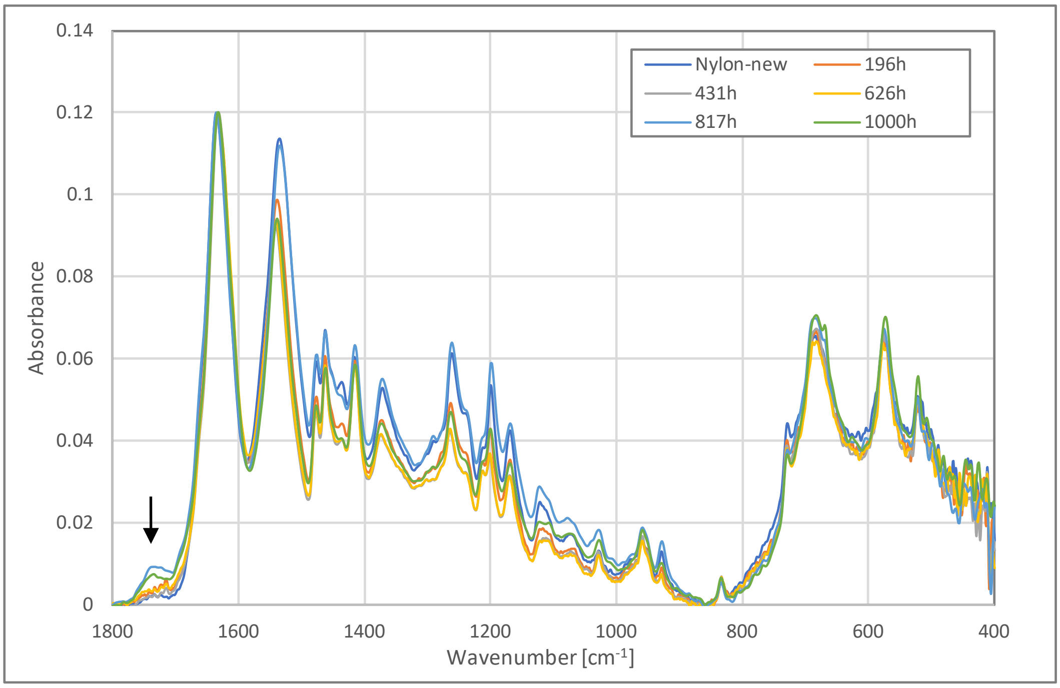


Figure 4: SEM micrographs of the PBSAT fishing line sample before (a) and after 1000 hours aging (b).

2.4 FTIR

Figure 5a shows the FTIR spectra of the nylon samples. The aging leads to an oxidation of the material and introduces carbonyl groups, which appear in the spectra as a peak at around 1730 cm^{-1} (indicated by an arrow). Besides that, there are no significant changes observed in the spectra. The FTIR spectra of the PBSAT samples are shown in Figure 5b. The main changes in the spectra during aging are the reduction of the two peaks at 1245 and 1267 cm^{-1} (stretching vibrations of C–O) and the reduction of the peak at 731 cm^{-1} (bending vibration of CH-plane of a benzene ring), both indicated by an arrow. In addition, the peaks between 750-1200 cm-1 are all slightly reduced. These peaks are related to stretching vibrations of C-O bonds as well as to bending vibration at the surface of adjacent hydrogen atoms on a phenyl ring. The findings indicate that the chemical structure of PBSAT is changing more significantly during degradation compared to nylon.

(a)



(b)

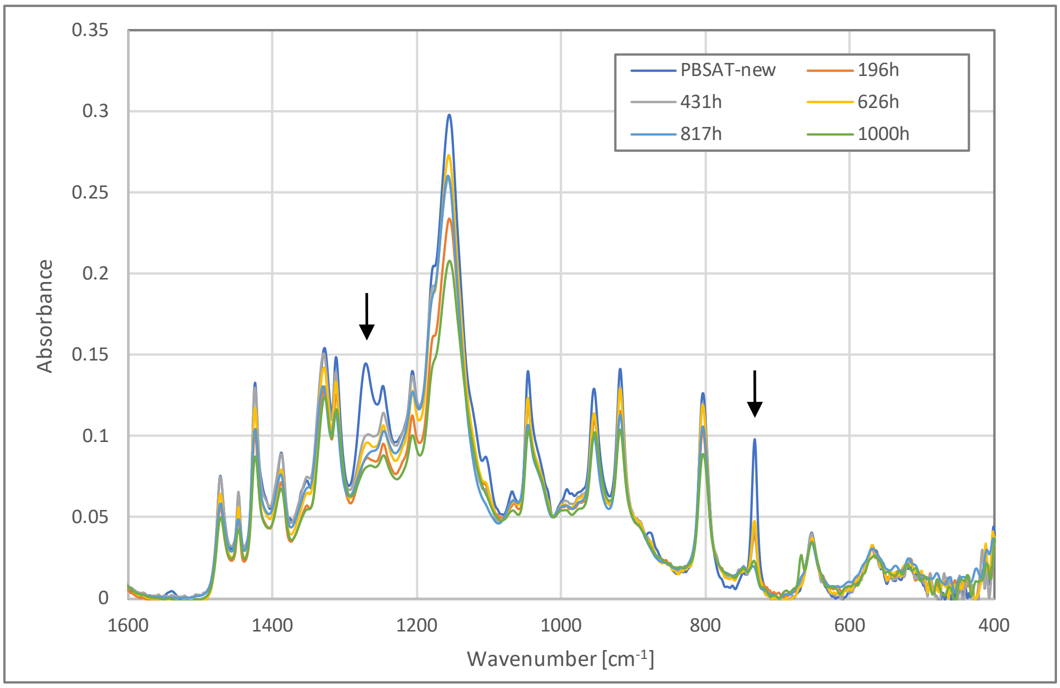


Figure 5: FTIR spectra of nylon (a) and PBSAT (b).

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