Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 83, 2013: 283-287
(Ann. WULS - SGGW, For. and Wood Technol. 83, 2013)

Modification of a polyester-based foil by cold plasma for furniture applications

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Abstract: *Modification of a polyester-based foil by cold plasma for furniture applications*. The surface free energy of polyester foil is an insufficient in some applications, e.g. bonding of foils for furniture applications with polyurethane dispersions in a vacuum pressing. The plasma treatment significantly improves surface properties. Experiments proved an increase of the surface energy, peel strength and change of the chemical composition of the foil surface.

Keywords: polyester foil, furniture surface finishing, plasma treatment

INTRODUCTION

Polyester foils are frequently used in many industrial applications, e.g. in the automotive industry for the cars construction and also in the furniture industry due to their excellent mechanical and thermal properties. The surface free energy of polyester is insufficient in some applications, e.g. bonding and printing. The application of cold plasmas for pre-treatment of polymeric surfaces [1-4] is a dry, ecological method of the modification, which can tailor polymers in order to modify their surface energy and adhesion to other materials. It is well known that the modification of polymers by cold plasma leads to changes in surface and adhesive properties. Depending on the processing gases used, different functional groups are formed in a very thin surface layer of the polymer [5].

EXPERIMENTAL

Materials

In our experiments, we used oriented PET foils (Tenolan OAN, Czech Republic) with thickness 0.2 mm for the modification by discharge plasma. The PET foils were treated in acetone in order to eliminate the additives influencing their surface properties. The adhesive joints of modified PET were prepared by using ware-based dispersion Dispercoll U 53 (Bayer, Germany).

Plasma modification

The modification of the PET foils by a Diffuse Coplanar Surface Barrier discharge (DCSBD) plasma was performed in a laboratory plasma generator at atmospheric pressure in N_2 or O_2 gases of the technical purity.

Characterization methods

Surface free energy

The surface free energy of PET was determined via measurements of the contact angles of a set of testing liquids: re-distilled water, ethylene glycol, formamide, methylene iodide, and α-bromo naphthalene) with a SEE (Surface Energy Evaluation) system (Advex, Czech Republic). The drops of testing liquid (V = 3 μl) were placed on the PET foil surface with a micropipette (Biohit, Finland), and the dependence $\theta = f(t)$ was extrapolated to $t = 0$. The surface free energy of the polymer as well as its polar and dispersive components were evaluated by the Owens-Wendt-Rable-Kaelble (OWRK) method modified by a least squares method [3].

Strength of the adhesive joint

The peel strength of the adhesive joint (P_{peel}) of the plasma modified PET foil to oak wood using polyurethane adhesive was determined by peeling of the adhesive joint (peel tests) at a 180° angle using a 5 kN universal testing machine Instron 4301 (Instron, England).

XPS

The XPS spectra were recorded using a VG Scientific ESCALAB 250 system equipped with a micro-focused, monochromatic Al K_α X-ray source (1486.6 eV) and a magnetic lens which increases the electron acceptance angle and hence the sensitivity. The spectra were acquired in the constant analyzer energy mode, with pass energies of 150 and 20 eV for the survey and narrow regions, respectively. The Avantage software, version 2.2, was used for digital acquisition and data processing. The spectral calibration was performed by setting the main C1s peak at 285 eV. The O/C atomic ratios were determined by considering the integrated peak areas of C1s and O1s, and their respective Scoffield sensitivity factors corrected for the analyzer transmission function.

RESULTS AND DISCUSSION

Surface free energy

The surface free energy of the PET foils modified by DCSBD in O_2 and N_2 plasma at atmospheric pressure vs. the activation time is shown in Figure 1. The surface free energy of PET during modification by DCSBD plasma in O_2 and N_2 (Figure 1, plot a, b) significantly increased in comparison with the untreated polymer.

Figure 1, plot a) shows that the surface free energy of PET modified by DCSBD plasma in O_2 increases from an initial value of 47.8 $mJ.m^{-2}$ for untreated PET to 82.6 $J.m^{-2}$ for 20 s of the plasma modification. Figure 1, plot b) shows the surface free energy of PET modified by DCSBD plasma in N_2. These values are lower than those of PET modified by the same method in O_2. Figure 1, plot a) shows that the surface free energy of PET modified by DCSBD plasma in O_2 increases from an initial value of 47.8 $mJ.m^{-2}$ for untreated PET to 82.6 $J.m^{-2}$ for 20 s of the plasma modification. Figure 1, plot b) shows the surface free energy of PET modified by DCSBD plasma in N_2. These values are lower than those of PET modified by the same method in O_2.

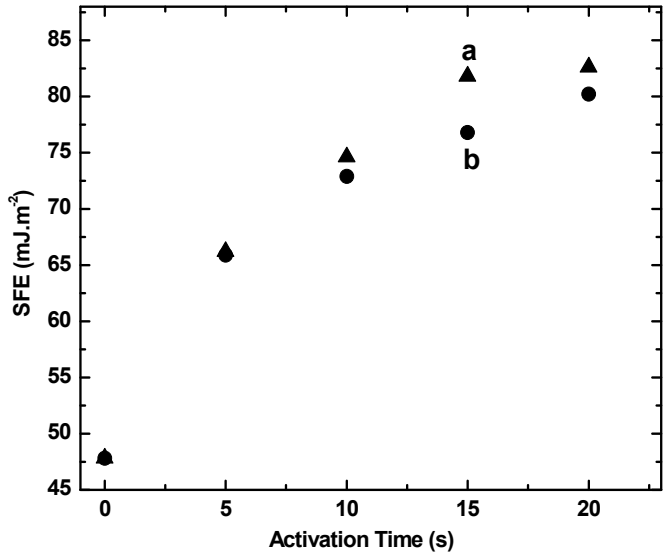

Fig. 1 Surface energy of PET foil modified by DCSBD plasma:
in O_2 (a) and in N_2 (b) vs. activation time

Strength of adhesive joint

The peel strength of the adhesive joints of PET foils, modified by DCSBD plasma in nitrogen (Fig. 2, plot b), in oxygen (Fig. 2, plot a) to polyacrylate vs. time of activation is shown in Figure 2. The peel strengths of PET to polyacrylate after modification by DCSBD plasma significantly increased, and these increases were higher for the samples modified in oxygen. The peel strength of the adhesive joint increased from 77 $N.m^{-1}$ (unmodified PET) to 180 $N.m^{-1}$ (DCSBD, 10 s, N_2), and 237 $N.m^{-1}$ (DCSBD, 10 s, O_2). These results indicate that the plasma irradiation considerably improves the adhesive properties of PET for DCSBD plasma.

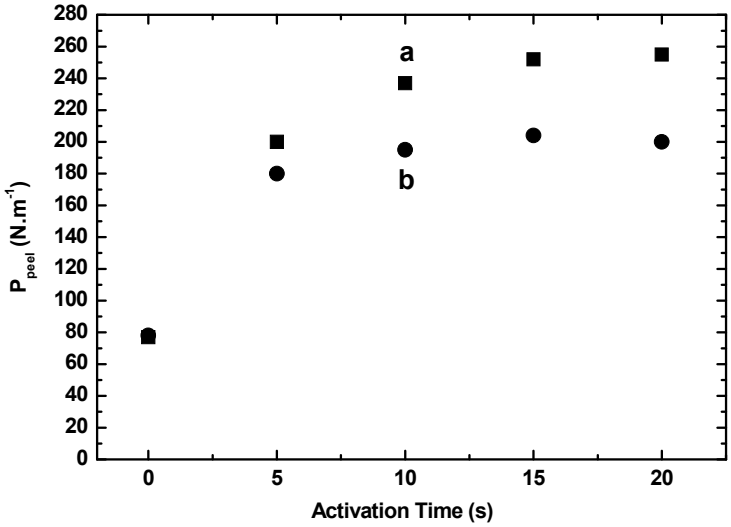

Fig. 2 Peel strength of adhesive joint of PET modified by DCSBD plasma:
a – O_2, b – N_2 to oak wood vs. activation time

XPS

The XPS survey scans and C1s and O1s peaks of the untreated PET, as well as the survey scans and C1s, O1s and N1s peaks of the modified PET are shown in Table 1. XPS showed an increase in oxygen and nitrogen content in PET surface layers after modification by DCSBD plasma in N_2 or O_2.

Tab. 1 XPS element amount, O/C, N/C, and (N + O)/C ratio of PET treated by DSBD plasma

Parameter	PET untreated	DSBD, N_2, 5s	DSBD, N_2, 10s	DSBD, O_2, 5s	DSBD, O_2, 10s
C1s	75.59	68.23	70.06	76.51	76.67
O1s	24.41	30.12	25.95	23.49	23.33
N1s	0	1.65	3.99	0	0
O/C	0.323	0.35	0.370	0.416	0.441
N/C	0	0.036	0.057	0	0
(N+O)/C	0.323	0.388	0.427	0.416	0.441

CONCLUSIONS

1. The surface free energy of PET modified by DSBD plasma significantly increased, and this increase was higher for O_2 compared to N_2;
2. The peel strength of PET, modified by DCSBD plasma to oak wood using polyurethane adhesive significantly increased, and this value was higher in the case of O_2 than in the case of N_2.
3. XPS showed the increase in oxygen and nitrogen content in PET surface layers after modification by DSBD plasma in N_2 or O_2.

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Streszczenie: *Plazmowa modyfikacja folii poliestrowej do zastosowań w meblarstwie*. Energia powierzchniowa folii poliestrowej jest niewystarczająca w niektórych zastosowaniach, takich jak opłaszczowanie przy pomocy dyspersyjnych klejów poliuretanowych. Aktywacja plazmowa znacząco poprawia własności powierzchni. Badania wykazały wzrost energii powierzchniowej, wytrzymałości na odrywanie oraz zmiany składu chemicznego folii.
Acknowledgements: *Authors are grateful to financial supports by the Ministry of Education of the Slovak Republic project No. 26220220091 by Research & Development Operational Program funded by ERDF, project of the Slovak Academy of Sciences Grant VEGA 2/0185/10 and project of the Technical University in Zvolen VEGA 1/0581/12.*

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