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Pre-treatment of beech wood by cold plasma

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Abstract: *Pre-treatment of beech wood by cold plasma*. Adhesive joints of wood could be strengthened by plasma treatment of the surface. The low-temperature discharge plasma has been used to improve the wetting and adhesion properties of wood. The contact angle of water drop showed a steep decrease after activation by RF plasma in air and the surface energy and its polar component of beech wood were increased with time of plasma activation.

Keywords: polyester foil, furniture finishing, plasma treatment

INTRODUCTION

The bonding of wood after discharge plasma surface modification is of considerable interest with the respect to construction of the strongest wood adhesive joints (1-3). Great efforts have been made in developing various kinds of furniture using wood or plastics veneers in adhesive joints wood-adhesive-veneer. The low-temperature discharge plasma has been used to improve the wetting and adhesion properties of wood. The pre-treatment of wood surface using discharge plasma is attractive for various wood applications mainly because of their lower cost. However, we have identified a significant increase of polar component of wood surface energy after modification by low-temperature plasma. Polar component of surface energy is associated with the presence of acid-base forces (electron donor–acceptor bonds). The treatment of wood exhibited a substantial aging effect, but the modified surface never recovers to its initial hydrophobic state. The enhancement of wood wettability is a necessary condition to promote a better adhesion with a water-based adhesives and coatings, which is currently being studied. The radio-frequency (RF) discharge plasma at reduced pressure is currently an efficient method for modification of surface and adhesive properties of wood, and is considered as the ‘green’ ecologically friendly method (4-7). For a common industrial wood application various woods have to possess a large set of various surface characteristics, including polarity (hydrophobicity or hydrophilicity), dyability, scratch resistance, tailored adhesive properties, antibacterial resistance etc. Nanoscale changes to the surface of wood materials enable the changes in materials surface, while maintaining the desirable bulk material properties. In our experimental work we have been focused to study of surface and adhesive properties of beech wood (*Fagus sylvatica*) modified by RF discharge plasma.

EXPERIMENTAL

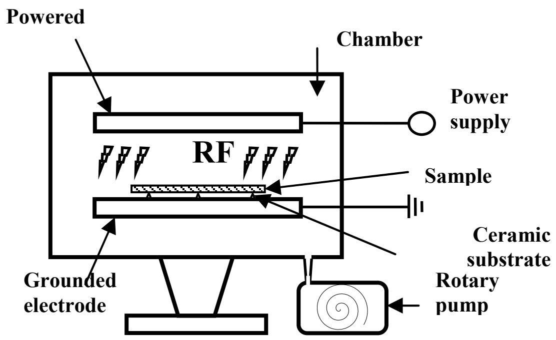
Materials

Beech wood plates with dimensions 50 × 15 × 5 mm (TU in Zvolen, Slovakia), ChS Epoxy 510, Telalit T 410 (Spolchemie, Czech Republic), set of 5 testing liquids (water, ethylene glycol, formamide, diiodmethane, 1-bromonaphthalene), dichlorometane.

Modification method

In this paper the beech wood surface was pre-treated by RF discharge plasma. There are two reasons why in the case of wood to apply discharge plasma modification. Firstly, discharge plasma in air itself significantly increases hydrophilicity of the wood, because of formation various polar groups (e.g. hydroxyl, carbonyl, carboxyl, etc.), and, the wood macromolecules are also cross-links (up to a few microns) what leads to the increase in scratch resistance and to the improvement in barrier properties of the wood material. Second reason for the plasma use is an increase of adhesion in adhesive joint between wood substrate, that is important for industrial applications due to growth of wood wettability.

The modification of wood by the capacitively coupled RF plasma was performed in a laboratory RF plasma reactor (Scheme 1) working at reduced pressure 80 Pa consists of two 240-mm brass parallel circular electrodes with symmetrical arrangement, 10 mm thick, between which RF plasma was created.



Scheme 1 Scheme of radio-frequency plasma generator

The electrodes of RF plasma reactor are placed in a locked-up stainless steel vacuum cylinder. The one is powered and the other one is grounded together with steel cylinder. The voltage of RF plasma reactor is 2 kV, frequency 13.56 MHz, current intensity was 0.6 mA, and the max. power of the RF plasma source is 1200W. The wood samples were modified by RF plasma at the power 300W. The improvement of hydrophilicity and/or hydrophobicity of the wood, its surface properties, the improvement of strength of adhesive joint of wood/wood composites with epoxy adhesive were studied for the determination of the appropriate structure of the plasma modified wood surfaces. The surface energy of beech wood was determined using contact angles measurements with selected testing liquids set using SEE (Surface Energy Evaluation) device completed with a web camera (Advex, Czech Republic), and necessary PC software.

The drop of the testing liquid (V = 20μl) was placed with a micropipette (Biohit, Finland) on the polymer surface, and a contact angle of the testing liquid was measured. The contact angle of testing liquid drop on the wood surface was measured instantly after its placing. The surface energies of wood were evaluated by Owens-Wendt-Rabel-Kaelble (OWRK) equation (7).

RESULTS AND DISCUSSION

The contact angle of water drop on the beech wood surface was measured immediately after drop deposition. The contact angles of water decreased with time of the activation by RF plasma. The contact angles of water showed a steep decrease from 66^o (pristine sample) to 40^o

after 120s activation of wood by RF plasma in air. The decrease of the contact angles of polar testing liquid (water) can be explained by an increase of the hydrophilicity of beech wood surface due to the treatment by RF plasma in air. The hydrophilicity of the surface depends on the formation of polar oxygenic functional groups on wood surface during the plasma modification in air. After saturation of the polymer surface with polar groups the hydrophilicity was stabilized.

The surface energy and its polar component of beech wood increased with time of plasma activation. The surface energy of beech wood treated 120s by RF plasma in air increased from 66 (pristine sample) to 78 $mJ.m^{-2}$, and the polar component of the surface energy increased from 17.4 (pristine sample) to 27.2 $mJ.m^{-2}$ (120 s). If the longer activation time was applied the changes od surface energy and its polar component were very small. This fact relates to saturation of wood surface with oxygen-containing functional groups due to modification by RF plasma.

The shear strength of adhesive joint beech wood modified by RF plasma in air – epoxy adhesive vs. activation time increased non-linearly from 5.2 MPa (pristine wood) up to 7.8 MPa (120s activation by RF plasma).

CONCLUSIONS

The contact angles of water deposited on beech wood surface showed a steep decrease after activation by RF plasma in air. The surface energy and its polar component of beech wood increased with time of activation by plasma. The surface energy of beech wood treated by RF plasma in air increased from 66 (pristine sample) to 78 $mJ.m^{-2}$, and the polar component of the surface energy increased from 17.4 to 27.2 $mJ.m^{-2}$. The shear strength of adhesive joint of beech wood using epoxy adhesive increases non-linearly with activation time from 5.2 to 7.8 MPa.

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Streszczenie: *Modyfikacja drewna bukowego zimną plazmą*. Połączenia klejowe w drewnie mogą być wzmocnione za pomocą aktywacji plazmowej powierzchni klejonych. Użyto zimnej plazmy w celu polepszenia zwilżalności i własności adhezyjnych drewna. Kąt zwilżania po aktywacji plazmą o częstotliwości radiowej znacząco się zmniejszył, zwiększyła się natomiast energia powierzchniowa.

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