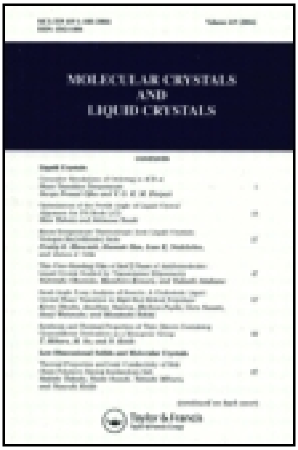

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Hydrophobic Wood Surfaces Generated by Non-Equilibrium, Atmospheric Pressure (NEAPP) Plasma-Enhanced Coating

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Hydrophobic Wood Surfaces Generated by Non-Equilibrium, Atmospheric Pressure (NEAPP) Plasma-Enhanced Coating

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NEAPP plasma-enhanced process is used to convert high molecular weight, liquid phase polymeric materials that were previously deposited on wood surfaces as thin layers, into hydrophobic, solid state networks. The entrapment of polymeric structures in the surface layers of wood samples and controlled plasma-processing performed in the next step allowed the generation of totally reduced water penetration and still a controlled surface energy.

Keywords: plasma processing; polymer liquid crystals; surface energy

INTRODUCTION

Plasma-aided manufacturing has many applications, including surface modification of materials to produce desired properties and disinfection. Plasma is the fourth state of the matter and can be defined broadly as a collection of an equal number of oppositely charged carriers with a net zero electric charge.

Cold plasmas are produced in matter with low energy contents; the degrees of ionization are small, the atomic and molecular charged and neutral species have low energies while the electrons have relatively high energies. These electrical discharges are non equilibrium plasmas and, owing to the low energy levels of the species composing the plasma, they alone are suitable for modifying organic matter.

Cold plasma is a simple procedure using no solvents, no heat or catalyst and is an entirely dry process using a small amount of reacting agent (solid, liquid or gas). It is easy to control the plasma

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parameters (RF power and reaction time) and forms an extremely thin discontinuous or continuous in the nanometer-micrometer thickness range, depending on the plasma parameters, on the surface. However, this layer can be very hydrophobic and can act as a barrier keeping water out.

Most plasma reactors used to date function in low pressure, requiring vacuum systems and therefore are limited to batch-type processes. A significant advancement in the field is the development of atmospheric pressure plasma reactors. Our project utilizes a unique atmospheric pressure array electrode reactor (AER) that was developed by F.S. Denes's plasma chemistry group at the Cener for Plasma-Aided Manufacturing. The AER design permits plasma-exposure of different types of substrates (including metals, synthetic or natural polymerers) under static or continuous flow conditions.

Many types of chemicals can be used in atmospheric pressure cold plasma. In the present case, a thin layer of paraffin oil was applied to the surface of pine and the wood was exposed to air-cold plasma generated under atmospheric pressure.

The deposition of HMWLP (e.g., paraffin oil) is performed using brushing technique. Our original Array Electrode reactor (AER), recently developed and patented at C-PAM-University of Wisconsin was employed under static conditions for the crosslinking of HMWLPs. Active plasma species for the development of surface modification processes were generated from air. Other plasma gases including, methane, ammonia, and SiCl4 are under current investigation.

The objectives of this research is to use of static or dynamic NEAPP for the conversion of high molecular weight liquid-phase polymers (HMWLP) pre-deposited onto wood surfaces, into three dimensional (crosslinked) hydrophobic networks and the plasma modified wood surfaces is analyzed using SEM, water permeation under open environment conditions and contact angle measurements.

EXPERIMENTAL

The deposition of HMWLP (e.g., paraffin oil) was performed on pine wood using brushing technique. Our original Array Electrode reactor (AER), recently developed and patented at University of Wisconsin was employed under static conditions for the crosslinking of HMWLPs. Active plasma species for the development of surface modification processes were generated from air.

The plasma conditions were as follows:

RF power dissipated to the electrodes: 100 W
Frequency of the driving field: 2 KHz

Plasma exposure time: 30 seconds
Gas: Air

RESULTS AND DISCUSSION

A drop (1 μ) of deionized water was added to the surface of both control and plasma modified wood and the water contact angle (WCA) was measured after 1 minute. Figure 1 shows the result of this test. After one minute the contact angle on the control sample was 91° whereas the contact on the plasma treated sample was 112.1°.

Figure 2 shows the SEM of the control and plasma treated (30 sec) surfaces of the pine. It can be seen that the visible wood structure has been covered with a layer of cross-linked polymer losing all of the details of the wood structure.

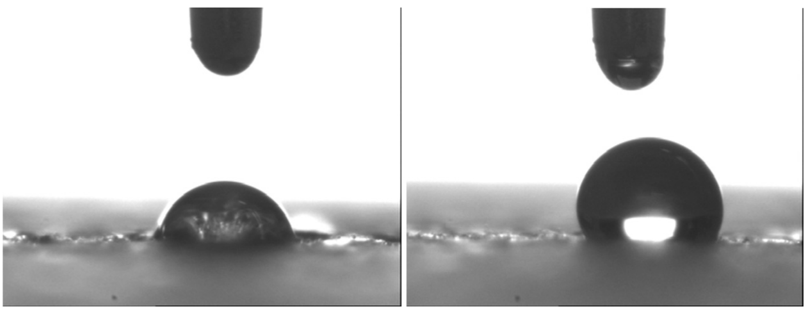

FIGURE 1 Contact angle measured after one minute. Control–WCA:91°; 30s Plasma–WCA: 112.1°.

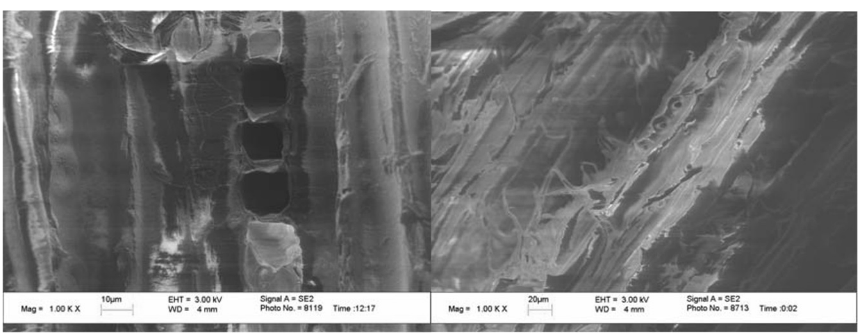

FIGURE 2 SEM of control (left) and plasma treated (right) pine wood.

CONCLUSIONS

- Pre-deposited paraffin oil was successfully converted into a solid state 3D, thin layer network in the wood sample surface layers;
- It was demonstrated that even 30 seconds plasma exposure is enough to generate a very hydrophobic surface and reduced water permeation;
- SEM analyses clearly indicate a good surface coating of wood substrate surfaces;
- Contact angle values were found in the range of 95–106 depending on the plasma treatment time. It is noteworthy that increased plasma exposure periods reduce the contact angle values while still water permeation is not allowed.
- This approach will allow further post-plasma surface modification when adhesion or printability is targeted.