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Plasma effect on the chemical structure of cellulose fabric for modification of some functional properties

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Abstract

The present paper describes efficiency of the low-pressure plasma process for improving of deposition process on chemical-physical activated cellulose fabric surfaces. The surface of cellulose substrates was pre-treated with O_2 plasma followed by acrylic acid (AAc) as monomer in plasma polymerisation process with surface of cotton fabrics in continuous treatment process was used (O_2/AAc). AAc as monomer was applied on the fabric surface using PE-CVD process. Modifications of cellulose fibres were studied in respect to surface effects by means of SEM microscopy while the chemical effects of plasma treatment were studied using X-ray photoelectron spectroscopy. Results indicate that the surface of the cotton fibres was cleaner and smooth with micro-fibrils visible along to fibre axis after treatment with AAc, what is in correlation with results of hydrophilic properties of O_2/AAc treated samples. According to XPS spectra results, oxygen plasma is certainly changed the chemical surface structure of tested cotton fabrics whereby the deposition of the AAc nano-layer on the fibre surface was enabled.

Keywords: cellulose fabric, plasma treatment, surface modification, chemical structure, XPS, SEM

1. Introduction

Low-temperature plasma treatment is one of the most versatile techniques in material surface modification. It has been widely used in many applications of textile area for targeted surface modifications mainly include the improving of dyeability, printability wettability, soil resistance of natural textile materials such as cotton [1-5] and silk [6], flame, water- and oil-repellent [7], antimicrobial efficacy, antibacterial and antifungal properties [8,9], physical properties [10], etc. It should be noted that the multifunctional pronounced effect could be achieved if the plasma treatment combined with a variety of other agents, primarily a variety of organic and inorganic particles of micro- and nano-sizes.

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In recent years, all the more pervasive use of carboxylic acids that serve as precursors for some final processing application such as metal ions in achieving of antibacterial protection [11,12]. Carboxylic acids are polar compounds and in favorable conditions they can form hydrogen and covalent bonds with cellulose, creating active centers, and this is the reason why they are used in this study too. In addition, under certain conditions, plasma can encourage the polymerization of the surface layer and the formation of the polymer film, which can affect on the binding of metal ions as antimicrobial agents, for example [13-15]. Carboxylic acids are well known for their antibacterial properties, and combine it with some other means of achieving multifunctional effects that are of great importance for materials with both economic and environmental aspects. Plasma technology, when developed at a commercially viable level, has strong potential to offer in an attractive way achievement of new functionalities in textiles [16].

Paper present a part of the research related to the treatment of acrylic acid applied to the cotton as polymerizing agent in the low-pressure plasma system in a continuous treatment process whereby the dry sample was pre-treated with O_2 plasma. The focus is on the application of plasma and its possible dual role: on the one hand, it is the surface functionalization of the cellulose substrate, and on the other hand, plasma should serve as a medium for the final deposition of antimicrobial agents.

The effects of plasma treatments were analyzed by SEM microscopy and XPS spectroscopy to determine the fiber surface and chemical changes. For the testing the impact of plasma on hydrophilic properties of fabric surface, simple drops test was used in experiment.

2. Experimental

2.1. Materials, devices and reagents

Plain weave cotton fabric was industrially prepared (desized and scoured). In the Tab. 1, physical characteristics of the pre-treated and raw cotton fabrics are presented. Raw cotton fabrics were additionally pre-treated with sodium hydroxide to partially remove hydrophobic compounds from the fibre surfaces. Single-thread yarn of cotton fibres approximately equally fineness have been used in experiment.

Table 1. Characteristics of raw and pre-treated (scoured) cotton fabrics with NaOH used in experiment.

Sample	Weight of unit area (gm^{-2})	Thickness (mm)	Fabric density (threads. cm^{-1}) warp/weft	Linear yarn density (tex) warp/weft
Raw cotton fabric	119.4	0.32	23/19	29.4/25.0
Cotton fabric scoured with NaOH	130.6	0.35	25/20	29.4/25.0

Treatments were done using Low-pressure Plasma Systems type Tetra 30 PC LF-40kHz. Oxygen (purity 99.99%) as non-polymerizing gas was used for surface activation of the samples. Acrylic acid p.a. as a polymerizing vapour using *Plasma Enhanced Chemical Vapour Deposition process* (PE-CVD) was applied.

2.2. Plasma treatments

Plasma surface activation was made on woven fabrics with low-pressure (LP) - plasma TETRA 30 PC LF laboratory system. Plasma system consist of square vacuum chamber volume of 34 L with four trays arranged symmetrically inside the chamber between five planar electrodes located at a constant distance and capacitively coupled through a matching network to a 40 kHz LF-generator (1.0 kW capacity). The standard part of plasma system is standard rotary vane pump; suction power of approx.16 m^3/hour (from Leybold) with electromagnetic valve to prevent that oil vapor gets back into the vacuum chamber were used. Oxygen gas of high level of purity was applied in the process. All process parameters are fully PC controlled.

Surface Activation by Oxygen (O_2) Non-polymerizing Gas