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RF N_2/Ar GAS MIXTURE PLASMA INDUCED MODIFICATION OF ACOUSTICAL PROPERTIES OF TEXTILE FABRICS MADE OF NATURAL CELLULOSE FIBERS (COTTON, HEMP)

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Abstract. Low temperature plasma is one of the most frequently used treatment for surface modifications of textile fibers. Application of plasma has many advantages for the textile processing relative to other chemical wet processes in terms of cost saving, water saving and eco friendliness. In the present work, we have examined modification of acoustical properties of fabrics made from natural cellulose fibers (cotton, hemp) by plasma treatment in radio frequency (RF) N_2-Ar gas mixtures plasma. It has been observed that the noise absorption coefficient is increased at medium and higher frequency due to the plasma treatment at certain values of reduced electric field.

1. INTRODUCTION

Plasma is a mixture of electrons, positive and negative ions, free radicals and excited molecules. In general, all of these species can interact with the surface of textiles samples (Arefi-Khonsari et al. 2008). Plasma treatment can change the surface properties of materials with no impact on the bulk properties. The depth of surface treatment is less than 100 nm. Plasma treatment affects the mechanical, chemical and microstructural properties of fiber surface, causing the changes in various physical properties of textiles, such as sound absorption coefficient, which has been already observed for the polyester and jute fabrics (Youngjoo et al. 2010). In previous work we already estimated that there is an increase of SAC of the treated cellulose fiber materials (cotton, hemp) almost in the whole frequency range due to the argon plasma treatment (Pavlović et. al 2019).

2. EXPERIMENTAL SETUP

The cotton/hemp knitted fabrics was treated in the RF capacitively coupled plasma (CCP) reactor filled by the N_2 – Ar gas mixture. The plasma reactor, which was described previously in detail (Pavlović et al. 2018, Pavlović et al. 2019) is presented here only shortly. The reactor was placed in the cylindrical 304 stainless steel chamber. In the center of the cylinder a copper electrode was placed. In order to control gas or gas mixture purity, a vacuum system equipped with gas mass flow controllers was used. The high voltage RF generator at standard 13.56 MHz frequency was applied for RF discharges. The argon gas was fed through mass flow controller at gas flow of 2 sccm and nitrogen gas flow was changed from 10 to 60 sccm. The pressure of the argon gas in the chamber was about 0.7 Torr, 1.1 Torr and 1,6 Torr, respectively, and the maximal voltage was 1200 V peak to peak. The power used during plasma discharges was in the range from 60W to 100 W. The treated samples of materials were placed in the plasma reactor by using specially designed feedthrough connector and the treatments lasted for 20 minutes (this was an estimated optimum). In order to measure and control plasma conditions, the optical emission spectroscopy (OES) was employed. The measurements of the sound absorption coefficient (SAC) of the examined materials were performed before and after plasma treatments. We used a standard two-microphone impedance tube which has been designed as per the ISO 10534-2:1998 standard (Acoustics-Determination of sound absorption coefficient and impedance in impedance tubes-Part 2: Transfer-function method). The diameter of the tube (29 mm) was set up for measuring SAC in the high frequency range (up to 5200 Hz).

3. RESULT AND DISCUSION

The SAC spectra for both untreated and the plasma treated sample, in the frequency range from 0 Hz to 5200 Hz, are presented in Fig 1. SAC spectra for treated sample in pure argon plasma is presented, too. As can be seen from Fig 1, as in the case of samples treated by Ar gas plasma, there is an increase of SAC of the samples treated in N_2-Ar plasma almost in the whole frequency range, but it is the highest in the medium and high frequency values, in the range from 3000 Hz to 4500 Hz. The increase in SAC of the samples treated in N_2-Ar gas mixture plasma at high frequencies is even much more pronounced as compared to the samples treated in pure argon gas plasma. We have found that the maximal increase of SAC can be obtained for medium values of nitrogen gas concentration in the gas mixture (at gas flows of 30-40 sccm) or reduced electric field E/N, which was in the range from 200 to 700 Td. It is also noticed that at the highest values of the observed range of the nitrogen gas concentration (at gas flows of 50 sccm, 60 sccm) in the gas mixture plasma, there are almost no any effect on the SAC values of the treated samples.

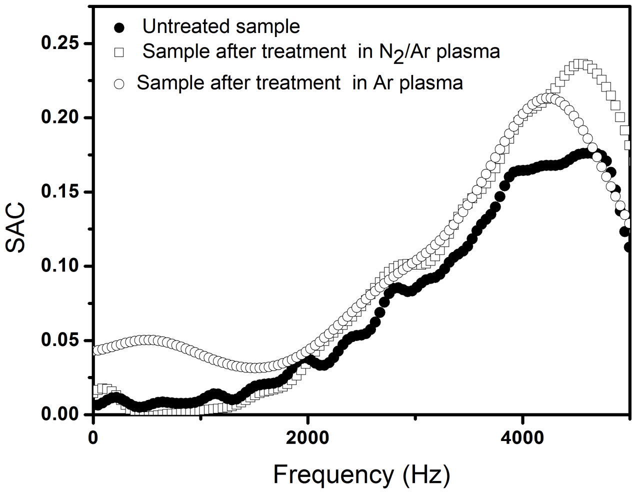

Figure 1: Sound absorption coefficients of the representative sample of treated materials.

In order to investigate and closely explain such behavior of SAC values of the samples treated under different applied values of nitrogen concentration in plasma gas mixtures, we performed an OES diagnostics of RF plasma discharge. The optical measurements were performed in the spectral range from 300 nm to 795 nm. The intensities of spectral lines obtained from relaxation of excited states of neutral argon atoms and of excited argon ions was obtained. The relative intensity of the argon spectral lines for different flow ratios with nitrogen are given in table 1. From table 1. it can be concluded that the argon spectral lines are the most intense in the case when the percentage of nitrogen in the gas mixtures is the lowest. When the participation of nitrogen is greater, relative intensities of the spectral lines decrease as the reduced electric field E/N decreases.

In our previous paper regard to the argon plasma modification of cellulose fabrics, we concluded that such treatments cause the bond-breakage in the fiber polymer macromolecules producing the free radical parts in polymer chains (Pavlović et. al 2018). Free electrons in the argon plasma can perform such bond-breakage, especially at higher energies, due to an increase of cross sections for the processes which can break carbon-hydrogen, carbon-oxygen and carbon-carbon bonds.

When the participation of nitrogen is greater, it increases the number of excited and energetic plasma species which leads to increase the number of bond-breaking processes on the fiber surface. Consequently, the SAC value of the fabrics increases. Also, when the participation of nitrogen more increases, the reduced electric field E/N decreases which leads to decrease the number of bond-breaking processes on the fiber surface. We can conclude that there is an optimal value of the concentration of the nitrogen gas in the mixture providing the enough number of excited atoms, molecules, ions and free electrons in the plasma chamber which take place in reaction processes with polymer surface, which causes bond breaking in the fiber polymer macromolecules, increasing the fibers elasticity. This optimum is obtained experimentally for medium values of nitrogen gas concentration in the gas mixture.

λ (nm)	Rel. Intensity Rel. flow ratio (2/10)	Rel. Intensity |Rel. flow ratio (2/30)	Rel. Intensity Rel. flow ratio (2/60)
750.38	1	0.3173	0.3601
751.46	0.3644	0.0450	0.1942
763.51	0.4045	0.2535	0.1036
772.42	0.2356	0.0479	0.0633

Table 1: Relative intensity of argon atom spectral lines for different flow ratios in the mixtures with nitrogen

4. CONCLUSIONS

The aim of this work was an investigation of modifications of the acoustical properties of fabrics made from natural cellulose fibers (cotton, hemp) by N_2-Ar gas mixtures plasma treatment. According to the obtained experimental results and previously published results, it can be concluded that modification of cellulose fabrics in the RF N_2-Ar gas mixtures plasma at optimal nitrogen concentration in the gas mixture can cause the greater increase in SAC values, especially at high frequencies, comparing with fabric samples treated in pure argon plasma. The main reason for such distinction is the increase of the number of excited and energetic plasma species which leads to increase the number of bond-breaking processes on the fiber surface.

References

Arefi-Khonsari, F., Tatoulian, M.: 2008, Advanced Plasma Technology, Editors: d`Agostino, R., Favia, P., Kawai, Y., Ikegami, H., Sato, N., Arefi-Khonsari F., Wiley-VCH Verlag GmbH&Co.KgaA.

Pavlović, S. S., Stanković, S. B., Žekić, A., Nenadović, M., Popović, D. M., Milosavljević, V. V., Poparić, G. B.: 2019, *Cellulose*, **26**, 11, 6543.

Pavlović, S. S., Milosavljević, V. M., Cullen, P. J., Stanković, S. B., Popović, D. M., Poparić, G. B.: 2018, 29th Summer School and International Symposium on the Physics of Ionized Gases - SPIG, August 28 – September 1, Belgrade, Serbia, Contributed Papers, **254**.

Youngjoo, N., Gilsoo, C.: 2010 *Fibers and Polymers*, **11,** 782.