(REFEREED RESEARCH)

IMPROVING PHYSICAL PROPERTIES OF POLYAMIDE FIBERS BY USING ATMOSPHERIC PLASMA TREATMENTS

ATMOSFERİK PLAZMA İŞLEMLERİNİ KULLANARAK POLİAMİD LİFLERİNİN FİZİKSEL ÖZELLİKLERİNİN İYİLEŞTİRİLMESİ

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ABSTRACT

An inert and two non-polymerizing gases were used to produce plasma. Effects of atmospheric plasma treatment on some physical properties of polyamide fabrics were investigated. Thermal, low-strees mechanical and air permeability properties of different plasma treated polyamide fabrics were evaluated in this study. It is thought that changes in these properties are closely related to their topographycal changing thanks to plasma treatments. Thermal properties have been closely related to the amount of air trapped between the yarns and fibers. It is thought that physical and final properties of polyamide fabrics can be improved by using plasma treatments, and atmospheric plasma treatment is an alternative for ecological treatments.

Key Words: Atmospheric plasma treatment, Polyamide, Low stress mechanical properties, Air permeability, Thermal properties.

ÖZET

Plazmayı oluşturmak için bir inert ve iki polimerize olmayan gaz kullanılmıştır. Poliamid kumaşların bazı fiziksel özellikleri üzerine atmosferik plazma işleminin etkisi incelenmiştir. Bu çalışmada, farklı plazma işlemleri görmüş poliamid kumaşların ısıl, düşük kuvvet mekanik, hava geçirgenlik özellikleri değerlendirildi. Bu özelliklerdeki değişimin, plazma işlemi nedeniyle liflerde meydana gelen topografik değişiklikler ile yakından ilgili olduğu düşünülmektedir. Isıl özellikler lifler ve iplikler arasında depolanan hava miktarı ile yakından ilgilidir. Poliamid kumaşların fiziksel ve son kullanım özelliklerinin plazma işlemleri kullanılarak iyileştirilebileceğine ve atmosferik plazma işlemlerinin ekolojik işlemlere bir alternatif olduğu düşünülmektedir.

Anahtar Kelimeler: Atmosferik plazma işlemi, Poliamid, Düşük kuvvet mekanik özellikler, Hava geçirgenliği, Isıl özellikler.

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1. INTRODUCTION

To modify textile materials, plasma treatments have been used long time. They are enviromentally friendly process and a little or no-chemical are used during plasma treatments (1). Plasmas are ionized gases, and can be produced at atmospheric or low preesure. Wettability, dyeability, adhesion etc properties of textiles can be improved with plasma treatments (2-4).

During the plasma treatment, surface morphologies and functionalities of textile materials have altered because of oxidation, etching etc. As for the application of plasma treatment in polyamide fabric, most of the discussions were focused on the effectiveness of this treatment to improve adhesion (2-5). However, little discussion has been published on the mechanical properties, thermal properties and the air permeability. In this study, the effects of air, nitrogen and argon atmospheric plasma treatments on various physical properties of polyamide fabrics such as, surface properties, strength, thermal comfort, air permeability and water vapor permeability were investigated.

2. MATERIALS AND METHODS

2.1 Materials

The fabric (63 ends/cm, 70 den; 33 picks/cm, 162 den; 100 g/m^2) were scoured with acetone for 4 hours using the soxhlet extraction method. The cleaned fabrics were dried in laboratory condition for one day. The fabrics were finally cut to dimensions of 10 cm × 500 cm and conditioned according to ASTM Designation 1776 before being characterized.

Argon (purity of >99.99), air (20.9% oxygen, 79.1% nitrogen and relative humidity < 3 ppm) and nitrogen (purity of >99) as the process gases were purchased from BOS. Acetone was purchased from Merck Chemical Company.

2.2 Atmospheric Pressure Plasma Treatment

For plasma treatment, a laboratory scale atmospheric plasma reactor was utilized. The discharge is produced between four electrode (diameter = 17 mm) couples, placed within cylindrical enclosure. Distance between electrode couples is 6 cm, and electrodes can be operated selectively. One of the electrode in the couple is covered dielectric material, and the inter-electrode distance is set 2 mm. Discharge can be generated under the different power and time intervals. Atmospheric plasma device can be working continuously under the different velocity (6). Polyamide fabrics were treated different exposure times and powers at atmospheric conditions. The plasma treated fabrics samples were left in controlled climate conditions for one day before comfort tests.

2.3 Surface Characterization

Changing of fiber surface after plasma treatment was characterized with Philips XL-30S FEG Scanning Electron Microscopy.

2.4 Comfort Properties

To evaluate low stree-mechanical properties of untreated and plasma treated polyamide fabrics, their tensile and frictional properties were investigated. For their tensile strength according to ASTM D5035 and frictional properties evaluations, U-Test Tensile Tester (Turkey) and Frictorq instruments were used, respectively (6, 7). All measurements were repeated for the five equally treated specimens and averaged with analytical tolerance limited to 5 %.

The air permeability of the polyamide fabrics was studied using an air permeability tester FX 3300 (Switzerland). The result of air permeability expressed as air permeability was recorded in terms of l/m^2*s. Small air permeability values indicate poorer air permeability. All measurements were repeated for the five equally treated specimens and averaged with analytical tolerance limited to 5 %.

The thermal properties were studied using Alembeta device constructed by Hes (8-10). Thermal conductivity and thermal resistance were measured. All measurements were repeated for the five equally treated specimens and averaged with analytical tolerance limited to 5 %.

Permetest instrument was used to determine the relative water-vapor permeability (8, 11). All measurements were repeated for the five equally treated specimens and averaged with analytical tolerance limited to 5 %.

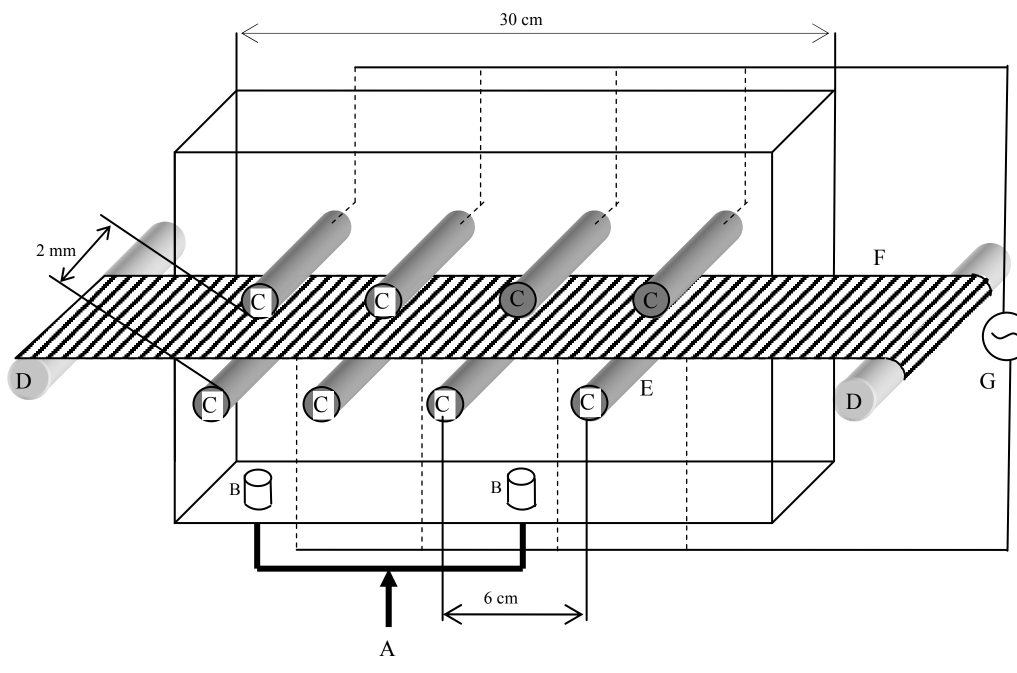
3. RESULTS AND DISCUSSION

3.1 Surface Characterization

SEM micrographs of the untreated and plasma treated polyamide fabrics are shown in Figures 1. It can be seen that after argon, air and nitrogen plasma treatment for sixty seconds, etching took place and surfaces of polyamide fibers gained rougher character than untreated fiber. The roughest surface was obtained with nitrogen plasma treatment because of may be ionisation energy of nitrogen. The largest pore on the fiber surface was obtained with argon plasma treatment, because of inertness character of argon gas.

3.2 Comfort Properties

The tensile properties are evaluated with tensile strength. Tensile strength values of the untreated and plasma treated polyamide fabrics are shown in Table 1.



Schema 1. Laboratory scale atmospheric plasma apparatus A: Processing Gas, B: Holes for gas entrance, C: Electrodes, D: Fabric wrapping mechanism, E: Quartz, F: Fabric, G and H: Electrical current

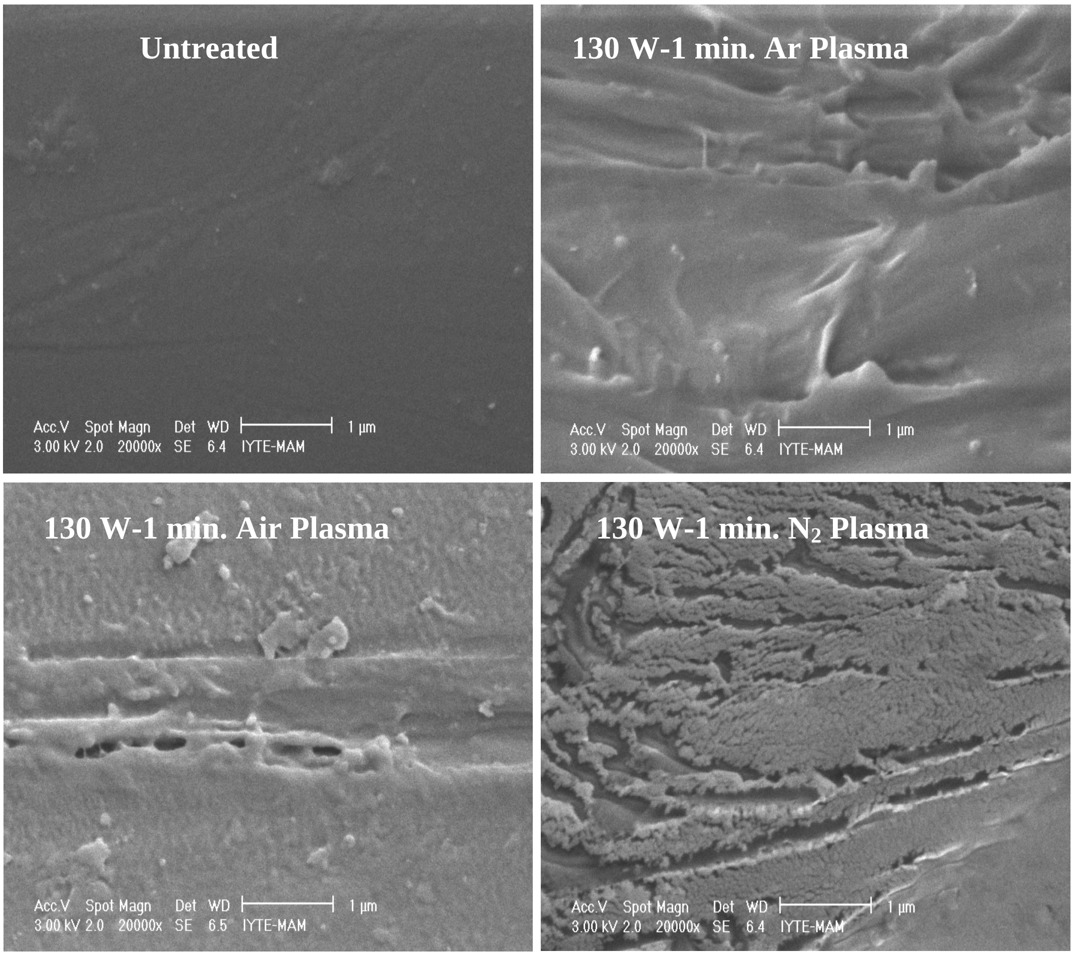


Figure 1. SEM images of untreated and after different plasma treated polyamide fabrics

Table 1. Low stress mechanical, air permeability, water vapor permeability and thermal properties of untreated and plasma treated polyamide fabrics

Process	Thermal conductivity *($x10^{-3}$ $K.m^2.W^{-1}$)*	Thermal resistance *($x10^{-3}$ $W.m^{-1}.K^{-1}$)*	Air permeability *(l/m^2*s)*	Water vapor permeability *(%)*	Kinetic friction coefficient *(-)*	Breaking strength *(N)*
Untreated	0.0401	0.0154	77.93	51.53	0.2107	101.06
50 W-20s AP	0.0401	0.0154	78.52	56.9	0.2166	93.89
50 W-40s AP	0.0401	0.0154	77.26	57.41	0.2279	94.56
50 W-60s AP	0.0401	0.0154	76.23	57.63	0.2289	96.13
100 W-20s AP	0.0401	0.0154	75.18	57.9	0.2257	94.93
100 W-40s AP	0.0398	0.0161	74.32	58.15	0.2325	95.72
100 W-60s AP	0.0395	0.0172	73.85	58.53	0.2712	97.19
130 W-20s AP	0.0396	0.0167	75.18	59.6	0.2324	94.35
130 W-40s AP	0.0395	0.0173	74.77	59.73	0.2517	95.65
130 W-60s AP	0.0379	0.0208	74.15	60.67	0.2967	96.13
50 W-20s Air	0.0401	0.0154	77.87	54.27	0.2165	95.07
50 W-40s Air	0.0401	0.0154	77.32	56.79	0.2212	95.35
50 W-60s Air	0.04	0.0154	77.23	57.12	0.2368	97.43
100 W-20s Air	0.04	0.0156	76.65	57.16	0.2216	96.11
100 W-40s Air	0.0398	0.0162	75.12	58.27	0.2368	97.37
100 W-60s Air	0.0395	0.0172	74.15	58.98	0.2462	98.60
130 W-20s Air	0.0396	0.0168	75.87	58.67	0.2267	97.77
130 W-40s Air	0.0389	0.0189	75.12	59.27	0.2612	98.76
130 W-60s Air	0.0377	0.02	74.23	61.06	0.2911	99.6
50 W-20s NP	0.0401	0.0154	77.77	54.16	0.2133	95.47
50 W-40s NP	0.0401	0.0154	76.92	55.67	0.2201	96.12
50 W-60s NP	0.0401	0.0154	75.83	58.91	0.2285	96.89
100 W-20s NP	0.0401	0.0154	76.15	58.13	0.2332	96.25
100 W-40s NP	0.0392	0.0176	74.92	59.98	0.2449	97.11
100 W-60s NP	0.0390	0.018	73.01	60.77	0.2716	98.67
130 W-20s NP	0.0381	0.0192	75.62	60.19	0.2613	96.15
130 W-40s NP	0.0372	0.0201	74.12	61.77	0.2819	98.75
130 W-60s NP	0.0362	0.0219	71.97	63.16	0.3165	99.2

After plasma treatment, tensile strength of fabrics was changed a little (between 7 % and 2 %). When treatment power and exposure times increased, difference between untreated and plasma treated fabrics decreased because of increasing interyarn and inter-fiber friction (12, 13). As you seen SEM images, rougher fiber surface was obtained after plasma treatments.

The results of the surface properties of the plasma treated fabrics, including the kinetic coefficient of friction of the fabric surface, are summarized in Table 1.

The kinetic coefficient of friction reflects the fabric roughness and crispness. After all plasma treatment, kinetic coefficient of friction values increased significantly (between 50 % and 3 %), and the increment was different plasma types. The roughest surface obtained with nitrogen plasma treatment because of lower ionisation energy of nitrogen and the highest amount of electrons.

In this study, the air permeability of the plasma treated samples was investigated and the results are summarized in Table 1. The plasma treatments decreased air permeability (the highest difference was 7.7 %), and increased air resistance of the treated fabrics. The air permeability depends on the construction characteristics of the yarn or fiber, in which a large proportion is occupied by air space. There are some factors affecting the air permeability of the fabric, e.g. the fabric structure, thickness and surface characteristics, etc (12, 14). Because plasma treatment does not influence fabric structure, changing of the air permeability depends on the fabric thickness and surface characteristics. As discussed before, plasma treatment alters the surface morphology, and it is possible to say that plasma treatment induces a certain degree of roughness (4). These changes act as a boundary to hinder the air flow through the fabric, thus resulting in a reduction in the air permeability of the fabric.

Table 1 shows the thermal properties of fabric expressed as the thermal conductivity and thermal resistance of the polyamide fabrics with variation in treatment time, power and gas. After plasma treatment while thermal resistance increased (approximately 43 %), thermal conductivity decreased (approximately 8 %). The thermal properties of a textile fabric depend, to a great extent, on the air trapped within it. As mentioned before, etching on the fiber surface occurred during plasma treatment, surface roughness increased thanks to etching effect, as shown Figure 1. When surface roughness increased, the amount of air trapped between the yarns and fibers may increase (15). In addition, the air permeability results indicate that plasma treated fabrics have poorer air permeability; therefore, the air trapped inside the fabric will not escape easily. This implies that plasma treated fabric has better insulation and help to prevent heat loss in the fabric when compared with untreated fabric.

Untreated and plasma treated polyamide fabric water vapor permeability values are given in Table 1. After plasma treatment, water vapor permeability of polyamide fabrics increased (the hghest increasing was approximately 23 %), and these results demonstrated liquid transfer properties and also wettability of the polyamide samples. Changing of surface may cause to reduce the capillary pressure, and also an increase of the functional groups on the fiber surface may cause to increase wettability (2). Moreover, increased vapor transfer provides better comfort feeling.

4. CONCLUSIONS

Argon, air and nitrogen plasma treated polyamide woven fabrics were evaluated for comfort properties. For this reason, their low-stress mechanical properties, air permeability, water vapor permability and thermal properties were investigated. After plasma treatments, all measured properties changed and so, comfort proerties of polyamide fabrics were improved. During the plasma treatments, fiber surface morphologies were altered, and surface roughness increased. All measured properties were changed because of increasing surface roughness. Insulation properties, which depend on amount of air trapped between yarns and fibers, of plasma treated fabrics increased because of decreasing thermal conductivity and air permeability. The plasma treatment showed a significant influence on the properties of the polyamide fabric, and the most effective gas for plasma treatment was nitrogene. All plasma treatments, the prolonged exposure time and increased plasma power in the treatment affect the mechanical properties, air permeability, water vapor permeability and thermal properties. To conclude, wear-ability and comfort properties of the polyamide fabrics had better after plasma treatments.

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