Shielding properties study of the fabrics obtained by magnetron spraying

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Abstract. The article deals with the method of the modification of polyester fabrics used to create a coating that protects against electromagnetic radiation. As a method of modifying the technical properties of the polyester material, treatment in a magnetron spraying unit is proposed. Aluminum and titanium are used as sprayed materials. The use of the studied samples of metallized tissue leads to the significant decrease in the levels of electromagnetic fields.

1. Introduction

The development of the electronic industry and widespread use of electronic equipment in communications, computing, automation, biomedicine and other applications have led to problems such as electromagnetic interference of electronic devices and health problems. For these reasons, the demand for articles that protect people from radiation is growing.

The effect of electromagnetic radiation on living organisms depends on the category of radiation—ionizing or non-ionizing. The first type has a high energy potential, which acts on the cells atoms and leads to the change of their natural state. This can be deadly, as it causes cancer and other diseases. Non-ionizing radiation includes electromagnetic radiation in the form of radio waves, microwave radiation and electrical oscillations. Although the structure of the atom can not change, but its impact can lead to irreversible consequences [1].

The long-time radiation of electromagnetic waves causes rapid development of pathological processes in the human body. Many of them make enter lesion on the genetic level. This is due to the fact that the electromagnetic field has a high level of biological activity, which negatively affects on all living organisms. The protection against electromagnetic radiation is possible by coating a conductive medium that can generate and transport free charges. Electromagnetic shielding (protection) is the process of limiting the penetration of electromagnetic fields into space by blocking them with a barrier made of a conductive material. It is usually applied to fencing enclosures and cables separating electrical devices from the outside world and the environment respectively.

The shielding is a very popular method of protecting electrical equipment and people from radiated electromagnetic energy. Materials or a cover that protect the body, environment or area from harmful electromagnetic radiation are called a shield. The typical example of the local impact of electromagnetic radiation on the human body is electromagnetic waves coming from an electronic clock or mobile phone [2-4].
2. Materials and methods

The cellphone is an electric device. The communication with the other subscribers, sending messages, data transmission and idle standby are more or less accompanied by the generation of electromagnetic waves. The highest level of radiation comes from the transmitting antenna. The radiation from a telephone is the electromagnetic, this is the microwave waves that engulf the body human while using gadget. The maximum specific power of this radiation is measured by the "electromagnetic field Meter AR3120".

The waves can affect on any materials-organic or inorganic. In addition they can affect a human body and his health. To protect a person from harmful electromagnetic radiation effects, the fabrics with shielding effect properties are used.

Textile polyester materials can be used as such fabrics [4, 5]. Recently, attention has been paid to lightweight and flexible materials, such as textiles coated with a conductive layer. The conductive layer usually is made from metals. These materials due to their flexibility, durability, ease of manufacture and use are considered promising for the protection of electromagnetic radiation [6, 8].

This work is aimed to the development of modification technology of polyester material to protect against electromagnetic radiations, which have a harmful effect on human brain.

As a method for modifying the technical properties of the polyester material, treatment in a magnetron spraying installation was chosen. The operation of the magnetron sprayer is based on the properties of the cathode region of the anomalous glow gas discharge, in which the cathode is sprayed under the action of ion bombardment. The magnetic field applied in the cathode area perpendicularly to the electric field allows reducing the working pressure of the plasma-forming gas without reducing the intensity of ion bombardment and improving the conditions of transportation of the sprayed substance to the substrate. This is due to the decrease in scattering caused by collisions with gas molecules. A low-temperature plasma zone appears between the cathode and the substrate. The particles are precipitated in the form of a thin layer, and also partially dispersed and precipitated on the working chamber sprayed walls. By using a DC discharge (DC-magnetron), various metals and their alloys (vanadium, chromium, Nickel, titanium, copper, silver, stainless steel, brass, bronze, etc.) can be sprayed, also their chemical compounds can be obtained by adding appropriate reactive gases (oxygen, nitrogen, etc.) to the plasma-forming gas (argon) [7]. The adhesion of metal layers with a substrate in films obtained by magnetron method is significantly higher than that of the same films obtained by thermal vacuum spraying, at comparable spraying rates. This is due to the higher energy of condensing particles during magnetron spraying and additional activation of the substrate surface by plasma.

The magnetron spraying method practically does not pollute the environment. This method does not use any chemical materials, so there is no need in wastewater treatment, which should compensate for the costs associated with increased energy consumption of equipment due to the need for a sufficiently deep vacuuming and using of a magnetron. Equipment installation requires no special engineering communication: wastewater treatment plants, steam generators and steam pipelines, chemical plants, etc. This allows using this equipment even in small factories.

Since the fabric processing occurs under mild conditions, the fabric keeps the softness, air and moisture permeability and strength characteristics.

The spraying of a metal layer causes electrical conductivity in a fabric. Unlike other methods of applying thin-film coatings, the magnetron spraying method allows precisely adjusting the thickness of the metal layer, and hence its resistance, which is very important when creating structures with certain conductivity. In the present work, as a conductive layer, the layer of a certain metal is applied onto the fabric. The thickness of this layer plays an important role, as too large a layer will lead to loss of the textile material properties.

To achieve the required effect, various metals such as aluminum, titanium were used. As objects of study polyester fabric "XV8555 IA" selected. The composition of raw materials: 57% - viscose, 43% - acetate, weight per 1 cm² = 0.008 g, color is black.

To determine the values of the electromagnetic and electric fields the device AR3120 was used to detect magnetic fields and measure electromagnetic induction.
For research, the polyester fabric was subjected to pre-metallization in the installation CS-1000 Sputter & Deposition PVD System. This method of metallization of fabrics has not yet been used in the textile industry.

3. Results and discussion

The mass of the applied metal per square centimeter of fabric was determined by the method of firing in a muffle furnace at a temperature of 300 °C for one hour. The results of the experiment to determine the mass of the metal applied on the fabric are presented in table 1.

| №  | Name of samples                                      | Crucible weight, g | Sample weight, g | Weight of sample with crucible after firing, g | Ash weight, g |
|----|------------------------------------------------------|--------------------|------------------|------------------------------------------------|--------------|
| 1  | Aluminum coating on one side                          | 27.592             | 0.425            | 27.701                                          | 0.109        |
| 2  | Aluminum and titanium coating on one side             | 28.028             | 0.48             | 28.130                                          | 0.152        |
| 3  | Aluminum and titanium coating on both sides           | 24.696             | 0.625            | 24.789                                          | 0.293        |
| 4  | Polyester fabric "XV8555 JA" without coating         | 26.688             | 0.289            | 26.699                                          | 0.031        |

Analyzing the results of the experiment presented in table 1, it can be concluded that the mass of the applied metals correlates with the number of treatments, and the increase in mass by 2 times when applying metals from two sides, indicates a uniform distribution of metals during processing. In addition, the mass of applied metals on the fabric did not lead to a noticeable weighting, the fabric remains flexible, soft and elastic. However, the application of metals to the experimental samples of fabrics led to a slight decrease in their hydrophilic properties, which were evaluated by the express method: applying a drop of distilled water to the material surface by estimating its absorption time. The research results are presented in table 2.

The research results showed that the absorption time of a distilled water drop depends on the type of applied metal.

Due to the fact that the main purpose of these researches was to develop a modification technology of polyester material to protect against electromagnetic radiation, after the metallization of fabric samples, the degree of electromagnetic radiation passing through the fabric from a cell phone was measured.

The measurements of the electromagnetic field levels of the radio frequency range were carried out without the use of fabric samples and when fabric samples were placing between the source of the electromagnetic field and the means of metrological control device. The measurements were carried out at a distance of 10 cm from the source of the electromagnetic field in terms of the RMS value of the electric field intensity. The source of electromagnetic fields served a cell phone. The test took place in two modes: when the cell phone is switched on in standby mode and when the phone is switched on in call mode. The measurement of electromagnetic radiation emanating from a cell phone was carried out through one layer of fabric and through a fabric folded into two, four and eight layers. The radiation around cell phone was: in standby mode - 7 µT, in call mode – 11 µT.

| №  | Name of samples                                      | Crucible weight, g | Sample weight, g | Weight of sample with crucible after firing, g | Ash weight, g |
|----|------------------------------------------------------|--------------------|------------------|------------------------------------------------|--------------|
| 1  | Polyester fabric "XV8555 JA" without coating         | 26.688             | 0.289            | 26.699                                          | 0.031        |
| №  | The sample before absorption | Sample after absorption | The absorption time |
|----|-----------------------------|-------------------------|--------------------|
| 1  | Aluminum coating on one side|                        | 26 sec             |
| 2  | Aluminum and titanium coating on one side | | 31 sec             |
| 3  | Aluminium and titanium coating on both sides | | 39 sec             |
| 4  | Polyester fabric "XV8555 JA" without coating | | 21 sec             |

The results of experiments on measuring the degree of electromagnetic radiation passing through the fabric when the cell phone is switched on in standby mode are shown in figure 1. The test results showed that the value of the electromagnetic field varies depending on the type of coating and the fabric layer numbers. The more layers of fabric, the less electromagnetic radiation it transmits. The best values showed the samples 1 and 2 with aluminum coating on one side and aluminum and titanium coating on one side, when the sample was folded into 8 layers. The research results of the measurement of the electromagnetic field around the cell phone when calling are shown in figure 2.
Figure 1. Effect of the coating type and the fabric layer numbers on the degree of electromagnetic radiation, passing from the cell phone in standby mode

Figure 2. Effect of the coating type and the fabric layer numbers on the degree of electromagnetic radiation, passing from the cell phone in call mode

As it can be seen from Figure 2, the electromagnetic radiation around the cell phone in call mode is much higher than when the cell phone is at rest. At the same time, fabric samples №1, №2, №3 show protective properties which depend on the type of applied metal and the fabric layer number. The best protective properties also show the fabric samples №1 and №2.

During the operation of the products, the protective metal layer is constantly exposed to physical influences that can affect the integrity of the material. Therefore, the researches have been conducted on the mechanical characteristics of fabrics. To establish the effect of the metal coating on the changes of the mechanical properties of the experienced fabric, tests were carried out to determine the abrasion resistance of the samples (State Standard 18976-73). After testing, the residual mass of the samples was determined as an indirect indicator of the coating resistance. The research results are presented in table 3.
Table 3. Weight of specimens have passed the test of resistance to abrasion

| Name of samples                                  | Sample weight before test, g | Sample weight after 250 rpm, g | Sample weight after 500 rpm, g |
|-------------------------------------------------|------------------------------|-------------------------------|-------------------------------|
| Polyester fabric "XV8555 JA" without coating     | 1.905                        | 1.587                         | 1.227                         |
| Aluminum coating on one side                     | 2.828                        | 2.799                         | 2.639                         |
| Aluminum and titanium coating on one side        | 3.048                        | 2.991                         | 2.747                         |
| Aluminium and titanium coating on both sides     | 4.110                        | 3.956                         | 3.816                         |

The experimental results revealed that the sample coated with aluminum and titanium on both sides is less susceptible to destruction than other samples. Consequently, the modification of polyester fabric by magnetron spraying also contributes to the increase of the exploitation properties.

4. Conclusion
After all the experiments, it can be concluded that the proposed modification method using the magnetron spraying of aluminum and titanium on the textile material surface is a universal solution for the protection of human health from electromagnetic radiation. It was established experimentally that it is enough to apply a layer of aluminum and titanium on the fabric to provide the necessary shielding properties.

The using research samples of metallized fabrics leads to a significant decrease in the levels of electromagnetic fields. This metallized fabric can be used as a means of the protection of a person from the adverse effects of electromagnetic fields emitted by a cell phone.

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