Study of the adhesion of metal coatings on synthetic textile materials

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Abstract. This paper is devoted to the study of the adhesion of metal coatings on synthetic textile materials based on polyester, polyamide and polypropylene. The metal coating was applied to the surface of textile materials by magnetron sputtering. To assess the adhesion of the metal coating to the substrate, the method of delamination testing using a tape with constant stickiness was used.

1. Introduction
Currently, due to the widespread use of electronic devices, the issue of human protection from electromagnetic radiation is becoming relevant. Highly sensitive measuring devices, as well as personnel of power plants and other enterprises where powerful sources of electromagnetic radiation are used, need mandatory protection from electromagnetic radiation. The most effective method of protection against electromagnetic radiation is shielding. Protective screens made of metal grilles and grids are widely used. However, the high metal consumption and bulkiness of the resulting structures limit the scope of their application [1].

Alternative materials for creating shielding products these are conductive textile materials obtained by applying a thin metal film to the surface of fibers. The following methods of applying metal films to the surface of materials are widely used in industry: film transfer, electroplating and vacuum spraying. The transfer method is characterized by unevenness of the resulting coatings and low adhesion of the coating to the substrate [2]. The method of electroplating metal coatings is the simplest to perform, but it can lead to the destruction of polymer materials, as well as to the destruction of other materials. It implies the use of chemically active reagents and is not environmentally friendly [3].

The most promising methods used for depositing thin films of various metals are vacuum evaporation-condensation methods, in particular magnetron sputtering. This method, in contrast to thermal evaporation, makes it possible to achieve the highest adhesion of the deposited metal to the substrate due to ionization. Compared to cathode, arc and ion-beam sputtering, the magnetron sputtering method is characterized by the most gentle effect, as well as the possibility of obtaining metal coatings of high uniformity without a drop phase [4].

This paper presents the results of the study adhesion of metal coatings deposited by magnetron sputtering on synthetic textile materials based on carbon-chain and heterochain polymers.

2. Materials, methods and equipment
As objects of research, textile belts were selected, the characteristics of which are presented in table 1.
Table 1. Characteristics of research objects.

| Fibercomposition       | Width, mm | Lineardensity, g/m |
|------------------------|-----------|-------------------|
| Polyester (PET) 100%   | 25        | 25                |
| Polyamide (PA) 100%    | 22        | 8.69              |
| Polypropylene (PP) 100%| 50        | 26.4              |

Metallization of synthetic textile belts was carried out on a magnetron sputtering unit WATT 1000-4M [5]. Magnetron sputtering was carried out for 10 minutes, at a pressure of 0.4 Pa, a direct current of 10 A, argon was used as the plasma–forming gas, and the target was an at0.5 alloy (aluminum/titanium 99.5/0.5%).

To evaluate the adhesion of the metal coating to the substrate, a 90° delamination test method using a 3M 610 Scotch® permanent adhesive tape was used [6]. A universal Autograph AGS-X testing machine (Shimadzu, Japan) was used for stratification testing. The scheme of the test sample for delamination is shown in figure 1.

![Figure 1](image-url)

**Figure 1.** Diagram of the test sample (side view): 1 – textile tape, 2 – tape with adhesive layer 3; F – applied load.

The adhesive tape surface was studied after being detached from the surface of metallized tapes using a confocal laser scanning microscopy (CLSM) on Olympus LEXT4100OLS.

3. Results

Results of confocal laser scanning microscopy (CLSM) the surfaces of textile belts before and after metallization are shown in figure 2.

Evaluation of surface images of metallized tapes (figure 2) indicates that the resulting metal coating is characterized by uniformity and no visible defects are observed, regardless of the fibrous composition of textile substrates.

Figure 3 shows CLSM images of the surface of adhesive tape with constant stickiness after its separation from the surface of the studied metallized textile materials.

According to the results of CLSM, it can be seen that when the adhesive tape with constant stickiness is torn off from the surface of metallized PET and PA tapes (figure 3, a, b), metal inclusions are present on its surface, the location and shape of which indicates that the separation of metal from the surface of textile tapes probably occurred in places of local surface contamination, which prevented the adhesion of the metal coating to the polymer substrate. When the adhesive tape with constant stickiness is torn off from the surface of the metallized PP tape (figure 3, c), complete detachment of the metal coatings layer from the surface of the textile material is observed, which indicates a low adhesive ability of PP fibers.
Figure 2. CLSM images of the surface of PET (a), PA (b) and PP (c) textile belts before (left) and after (right) metallization.
Figure 3. CLSM image of the adhesive tape surface after separation from metallized PET (a), PA (b), PP (c) tapes.

4. Conclusions
The conducted studies allow us to conclude that when metal coatings are applied by magnetron sputtering on fibrous materials based on polymers containing functional oxygen- and nitrogen-containing groups, the adhesion of the coating to the substrate is satisfactory. However, these fibrous materials require pre-cleaning of the surface before the metallization process to remove local contamination and accumulation of dressing compounds. During metallization of polypropylene fibers, the adhesion of the coating to the polymer substrate is weak, which is explained by the absence of a coating on the surface polyolefins of polar functional groups. This allows us to conclude that when using the magnetron sputtering method to produce metallized textile materials based on polyolefin fibers, it is necessary to pre-activate the textile substrate in order to graft polar functional groups on its surface [7] and increase the adhesion of the sprayed metal coating to the surface of the fibers.

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