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Using Plasma Metallisation for Manufacture of Textile Screens Against Electromagnetic Fields

Abstract
In this study, a method of the metallisation of polypropylene (PP) nonwovens is presented. The influence of power dissipated in the target on the efficiency of screening a flat electromagnetic wave is discussed. Fabric metallisation was carried out using the standard magnetron sputtering process of Zn-Bi metal targets in argon ambient. A pulse current source with a changing group frequency was used for powering the target. The metallic layers obtained were characterised by good adhesion to PP, with a screening efficiency approaching 45 dB.

Keywords: *magnetron sputtering, screens against electromagnetic fields, Zn.*

Introduction

One of the research fields regarding the application of technical textiles is the manufacture of screens protection against electromagnetic fields (EMF). Light and low-priced textile materials may be a way of protecting humans and sensitive electronic devices against the harmful effects of EMF. With the huge increase in EMF sources (radio broadcasting television, radio-communication, cellular radio), it is necessary to protect different rooms and facilities like banks, data bases, and hospitals against the interferences of external fields, or access to prohibited information. The application of this type of material depends on the level of attenuation. It can be realised by application of metallic or composite screens (fabrics covered with a metallic layer or conductive oxide layers [2]). Thus this study on the development of new metallisation methods of fabrics seem to be justified.

Some fabrics made of polymeric fibers, like polypropylene (PP) or polytetrafluoroethylene (PTFE [1]) are very difficult to metallise due to the properties of their surfaces. Classical methods of metallic layer deposition (vacuum evaporation, electron beam evaporation or chemical deposition of metaloorganic compounds) do not give desired results in this case. Deposited layer has very poor adhesion and is subject to wear . The only possibility is plasma activation of the surface followed by the deposition of a metal layer by vacuum evaporation. It is, however, a two-stage process.

The magnetron sputtering method itself also consists of two stages [2, 5]. It is, however, a rapid and environmentally friendly process. By this method it is possible to deposit metallic, semiconductor, and dielectric layers. The deposition rates of the layers are much higher than in cathode sputtering; for metals the rates are of several μm/min, and for oxides they from 40 nm/min to 600 nm/min . An additional advantage of this method is good adhesion of the deposited layers to the substrates.

Plasma method of polypropylene nonwoven metallisation

Nonwovens, especially polypropylene nonwovens are frequently used in technical applications mainly due to their low cost.

The metallization process of PP fabrics (nonwovens) was carried out by sputtering metallic targets with the compositions 0.9Zn-0.1Bi and 0.96Zn-0.04Bi, fitted on a magnetron gun of the WMK-10 type. The targets were powered by a DPS unit with a power of 12 kW which is fitted for supplying the plasma gun with an AC-M current of f = 80 kHz ***(Figure 1a)*** or an unidirectional DC-M current of f = 160 kHz ***(Figure 1b)***. In both cases the current is group modulated with rectangular pulses with the frequency ranging from 100 Hz to 5kHz. The highest voltage of the current was 1.2 kV.

In standard systems, the power dissipated in the target is controlled by the level of the current supplying the magnetron. In our case the magnetron was pulse supplied, and the power was adjusted by the pulse width in the range of 10-0.2 ms. In such conditions the stability of the reactive processes was assured. The stability is achieved by the elimination of uncon-

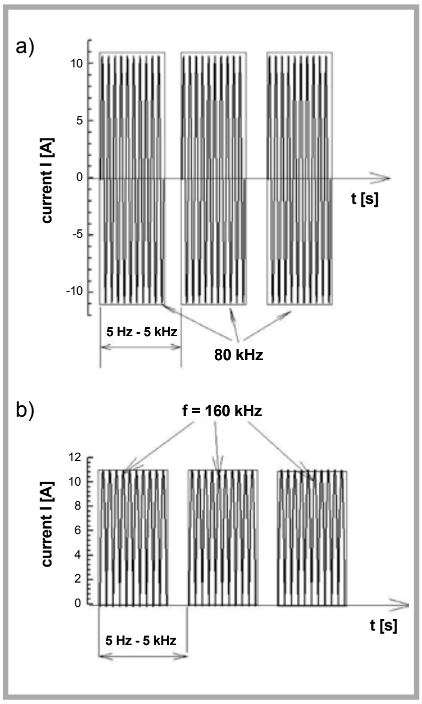

Figure 1. *Kinds of pulse modulation, a – AC-M current, b – unidirectional DC-M current.*

trolled arch discharges. Since in a single pulse there is always a peak value of the sputtering rate, such pulse modulation allowed us to increase the ratio of the sputtered material to impurities.

To evaluate the power supplied by the feeder, we can use two electric values: real power – P, and circulating power – P_c. The first one directly defines the efficiency of layer deposition, whereas the second one characterises the supply system. It reflects changes in plasma characteristics (change in impedance) con-

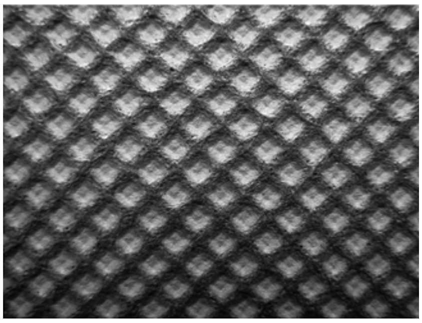

Figure 2. *PP fabrics with deposited Zn-Bi layer.*

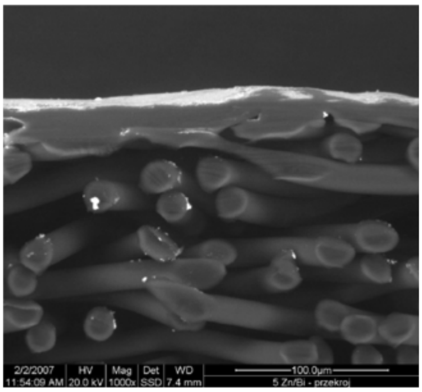

Figure 3. *SEM image (SEM 1000x) of cross-sections of polypropylene fabric deposited by the DC-M method (a) for P = 180 W, (b) for P = 400 W.*

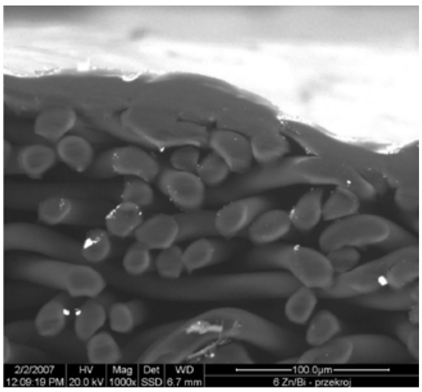

Figure 4. *SEM image (SEM 5000x) of PP fiber surface obtained by the AC-M method at a low power level, P = 180 W, of the target supply.*

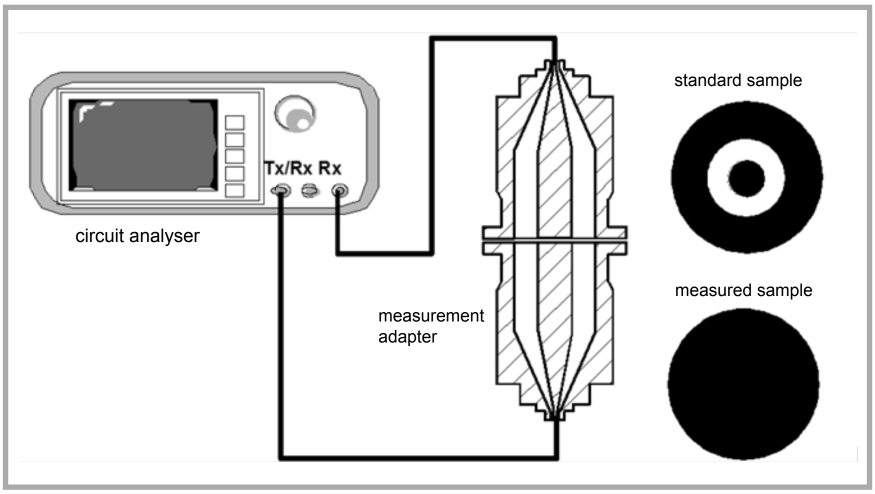

Figure 5. *Scheme of the method's measurement system according to ASTM D4935-99.*

nected with the change in concentration, and the kind of charged particles. It is particularly noticeable during sputtering in oxygen ambient.

The sputtering processes were performed under argon pressure (5N) in the range of 10^{-2} Pa to 10^{-1} Pa. The power dissipated in the target was changed from 100 W to 1 kW. The frequency of group modulation was 5 kHz. The distance target – substrate was 10 cm. For power below 1 kW all the deposited layers were characterised by good adhesion to PP fabrics, as well as a uniform thickness and metallic colour ***(Figure 2)***. For power exceeding 1 kW, the colour of the layer became darker, which could be the result of heating the PP with zinc and bismuth ions and is also connected with the effect of gas desorption on the surface.

Examinations of the surface morphology were made with a Quanta 200 scanning electron microscope using the low vacuum mode (without coating the sample surface with a gold layer, i.e. in a natural state). A 15.0 kV acceleration voltage was applied to the electron beam and SSD detector . In order to evaluate the structure of the deposited metal layer, the surface and its cross-section were examined at amgnifications of 300x, 1000x, and 5000x. The studies showed that the deposited layers were not uniform. which could be connected with metal penetration into interspaces between fibers. With increased power dissipated in the target, which is illustrated in SEM images – ***Figure 3***, the average thickness of the layer grew markedly. The number of fractures and delamination in deposited layer was very low, and its adhesion was very good.

At low power levels the layer is not continuous. In such samples metal grains are recognisable on single fibers ***(Figure 4)***.

Results of testing PP; Zn composite attenuation

Measurements of screening attenuation were made according to the ASTM D4935-99 method [6], on a stand developed at the Institute of Telecommunication Teleinformatics and Acoustics of Wrocław University of Technology [7]. The measurement system is shown in ***Figure 5***. It consists of a circuit analyser of the HP 8711A type by Hewlett-Packard (with range of measurement frequencies from 300 kHz to 1300 MHz) and a measurement adapter in form of a section of a coaxial air line with a characteristic impedance of 50 Ω and diameter ratio of 76/33 mm.

The adapter is equipped with a flange of 133 mm diameter. In a correctly set up measurement system, the inaccuracy does not exceed ±2 dB in a frequency range of 30 MHz to 1.5 GHz. The dynamics of the measuring system exceed 100 dB. The photograph ***(Figure 6)*** shows a material

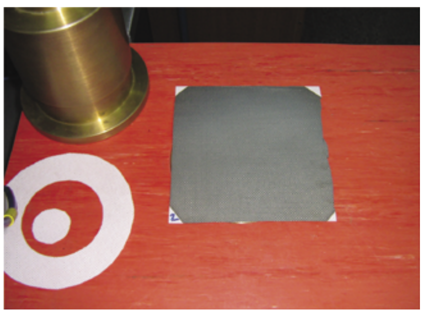

Figure 6. *Material sample prepared for measurement.*

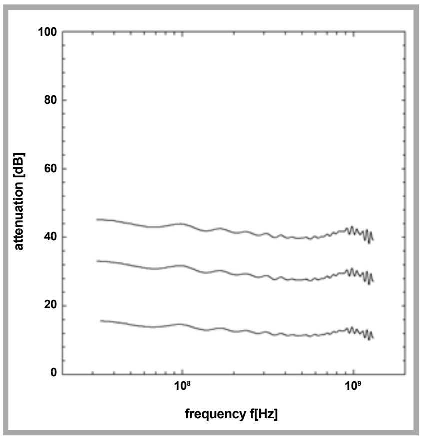

Figure 7. Effect of power dissipated in the target on the value of the EM field attenuation of PP fabric coated with a 0.9Zn-0.1Bi metallic layer. Sputtering in the DC-M mode at the group frequency f = 5 kHz.

sample prepared for testing the screening efficiency. The measurement procedure consists of two stages.

Firstly, a reference sample of sputterred material is put into the adapter in order to compensate for the feedback capacity. This sample consists of a disk of 33 mm diameter and a ring of 133/76 mm. At the second stage a proper sample is tested. The efficiency of screening is determined as the difference between the transmittance or attenuation level of the reference and tested samples. The difference is established using the calibration process. The correction determined in the calibration process is automatically included in the measurement.

Effect of power dissipated in the target on the attenuation level

Figure 7 shows the effect of power dissipated in the target on the value of the attenuation factor. The target was powered in the DC-M mode. It can be seen that with the increase in the level of dissipated power, the value of the attenuation factor also rises. It is connected with the increase in the thickness of the metallic layer . When the AC-M mode is applied, the final thickness of the deposited layers is lower. Also the attenuation factor is two-times lower than that obtained for a similar range of applied power ***(Figure 8)***.

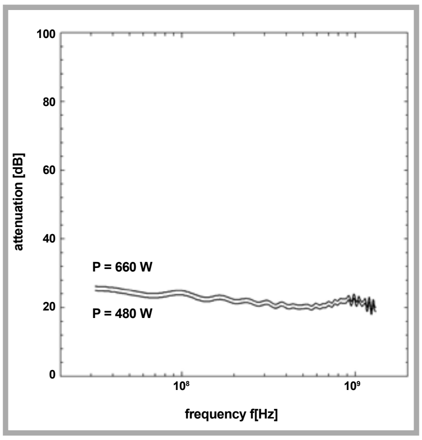

Figure 8. Effect of power dissipated in the target on the value of the EM field attenuation of PP fabric coated with a 0.96Zn-0.04Bi metallic layer. Sputtering in the AC-M mode at the group frequency f = 5 kHz.

The resistance of the sputtered samples, evaluated according to Standard EN 1149-1, showed a similar level of the order of 10^3 Ω. Once again it was confirmed that the value of the resistance measured is a necessary but not conclusive factor in obtaining a good attenuation effect. The second necessary condition is the formation of a conductive net on the surface of the carrier, with good contacts at the connection points. In the studies performed such a net was obtained ***(Figure 9)***.

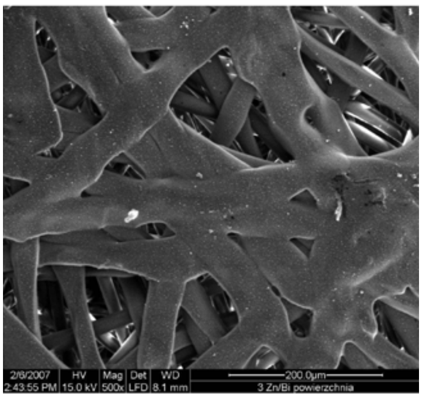

Figure 9. Microscopic image (SEM 1000x) of the surface of a sputtered Zn-Bi sample.

Conclusions

The metallisation of PP fabric by pulse magnetron sputtering gives the possibility to obtain metallic layers with very good adhesion, which is impossible to get by other methods. The martindale method was used to assess the resistance to dry rubbing of such metallic layers. The layer formed is very fine, which is measured in nanometers – a decimal order of magnitude. No visible defects (in SEM) appear when the bending of samples occurs. The bending strength can be tested according to the proper standard only after acquisition of bigger samples.

It was stated that for similar levels of power dissipated in the target, the DC-M mode assures higher efficiency. It is connected with increased deposition rates of the metallic layer.

It was confirmed that the value of resistance tested is a necessary but not conclusive factor in obtaining good attenuation. The second condition necessary to fulfill is the formation of a conductive net on the carrier surface with good contact at the connection points.

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