FABRICS WITH ELECTROMAGNETIC SHIELDING PROPERTIES ACHIEVED BY MAGNETRON SPUTTERING DEPOSITION

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REZUMAT. Ecranarea electromagnetică obținută prin utilizarea materialelor flexibile a dobândit o semnificație crescută mediul actual poluat de radiații electromagnetice [1]. Pentru a obține materiale textile pentru ecranarea electromagnetică, trebuie asigurată o bună conductivitate electrică a suprafaței, obtinuta de obicei prin depunerea unor filme metalice [2]. Tehnica de depunere - sputtering magnetron este una dintre abordarile moderne de acoperire a țesăturilor cu straturi metalice, pentru a le asigura conductivitatea electrică și eficacitatea ecranării [3]. Această tehnică are câteva avantaje: imbunatatirea ecranarii prin reflexie daca straturile metalice sunt depuse pe ambele părți ale țesăturii, precum și masa redusa și o flexibilitate bună datorită grosimii straturilor la nivel nano. În lucrarea prezentă, țesături din bumbac și poliester avand parametri structurali diferiți, cum ar fi finețea firelor, densitatea, grosimea și masa specifică, precum și probe de țesături cu fire conductive inserate din argint și oțel inoxidabil au fost utilizate ca probe pentru a fi acoperite cu straturi metalice. Tehnica de sputtering Magnetron a fost utilizată pentru depunerea straturilor de Cu de diferite grosimi, fie pe o parte, fie pe ambele părți ale țesăturilor. Grosimea, masa specifică și cantitatea de Cu prezenta în materialele textile acoperite au fost determinate. Pentru evaluarea influentei straturilor de Cu depuse in plasma asupra proprietatilor de suprafata ale tesaturilor obtinutte au fost utilizate microscopia electronica de scanare (SEM) și determinarea rezistivitatii electrice. Pentru probele acoperite cu Cu au fost efectuate teste de evaluarea a atenuarii electromagnetice utilizand o celulă TEM, conform standardului ASTM ES07. Țesăturile cu fire conductive introduse acoperite cu straturi de cupru sputter magnetron au o eficiență de ecranare cu valori cuprinse între 20-34 dB.

Cuvinte cheie: depunere PVD, magnetron, straturi Cu, ecranare eletromagnetica, materiale

ABSTRACT. Electromagnetic shielding achieved by flexible materials has gained an increased significance in today's radiation polluted environment [1]. In order to obtain electromagnetic shielding textiles, a good surface electrical conductivity has to be ensured, usually offered by the deposition of metallic films [2]. Magnetron sputtering technique is one of the modern approaches to coating fabrics with metallic layers in order to render them electrical conductivity and shielding effectiveness [3]. This technique has some advantages: improved reflections of the fabric once metallic coatings are deposited on both sides of the fabric, as well as lightweight and good flexibility due to nanoscale thickness of layers. In the present work, cotton and polyester fabrics with different structural parameters, such as yarn fineness, fabric density, thickness, and specific mass, as well as fabric samples with inserted conductive yarns of silver and stainless steel, were used as samples to be coated. Magnetron sputtering technique was utilized for the deposition of Cu layers with various thicknesses either on one side or on both sides of the fabrics. Thickness, specific mass, and the amount of Cu present in the coated textile materials were determined. Scanning electron microscopy (SEM) and resistivity were used in order to evaluate the influence of plasma-deposited Cu layers on surface properties of the achieved fabrics. Electromagnetic shielding tests were performed on the copper-coated samples using a TEM cell, according to the ASTM ES07 standard. The fabrics with inserted conductive yarns coated with magnetron sputtering copper layers had shielding effectiveness with values between 20-34 dB.

Keywords: PVD, magnetron sputtering, Cu layers, electromagnetic shielding, fabrics

1. INTRODUCTION

Due to the agressive development of the technologies based on electromagnetic waves, such as the radiation of mobile GSM communication or internet WiFi networks [1], it is necessary to develop materials to reduce the harmful effect of the electromagnetic field to human life. The functioning of electronic devices may interfere with electromagnetic waves from various sources (such as power transmission lines, telecommunication, broadcasting), causing electromagnetic interference (EMI) [2]. In general, the electromagnetic waves cause heating of cellular tissues with adverse long-term effects [3].

The adequate solutions are to shielding the electromagnetic waves, using specific techniques from Electromagnetic Compatibility (EMC) discipline. EMC's main aim is to ensure proper functioning of electronic devices and integration with other electronic components [4, 5]. To avoid interference with other electronic devices functioning at various frequencies, a rigorous set of measures has to be followed within design of electronic devices. Shielding materials are based on good electrical conductivity, being conventionally made out of metallic plates and also out of fabrics with metallic insertion or coatings [2]. When compared to metallic plates, electrically conductive fabrics present some advantages, such as flexibility, lightweight, mechanical resistance, and shape-ability, well described in scientific literature [4]. Magnetron plasma is a novel technology for coating fabrics with metallic layers on nanometre scale [6-9] while inserting conductive yarns into a fabric structure is already a conventional technology. The main aim of this paper is a study on manufacturing methods for electromagnetic shields out of fabrics [9, 10], based on magnetron plasma coating and using textile woven structured based on non-conductive yarns and with conductive yarns inserted on weft and warp directions. The paper focuses mainly on both manufacturing methods and the evaluation result based on shielding effectiveness of the fabrics.

2. EXPERIMENTAL PART

For our experiments were designed six woven textile structures, presented in Table 1, using yarns 100% CO Nm20/1; Nm 10:1 and the yarns 100% polyester filament 167 dtex /48x2 and condutive yarns based stainless steel Bekinox BK Nm50/2, and yarns with silver content STATEX 117 dtex. In order to design the structures, have been calculated the parameters of the structures for diagonal 3/1 and 2/1 and the canvas. Also were investigated the physico-mechanical properties of the untreated woven structures. In tabel 2, respective tabel three are presented the degree of coverage, respective the degree of compactness for the woven structures designed. The investigation of the characteristics of the physico-chemical properties of the textiles treated in the plasma and covered with a layer of copper has been carried out in accredited laboratories within the INCDTP.

Table 1. **Yarn specifications – weft and warp**

Fabric variants	**Yarn composition**		**Yarn finesse Tex (Nm)**		**Yarn diameter (mm)**	
	The weft	**The weft**	**The weft**	**The weft**	**The weft du**	**The weft db**
P1	100% co		50 (20/1)		0,204	
P2	100% co		100 (10:1)		0,289	
P 3	100% PES		16,7x2(29,94)		0.180	
P4	100% PES		16,7x2 (29,94)		0.180	
P5	U1:100% co U2: 80/20 % co/stainless steel	B1: 100% co B2: 80/20 % co/stainless steel	U1:20x2(50/2) U2:20x2(50/2)	B1:20x2(50/2) B2:20x2(50/2)	U1: 0,183 U2: 0.167	B1: 0,183 B2: 0.167
P6	U100% co	B1: 100% co B2: yarnPA gold-plated Ag	U:11,76 x2 (85/2)	B1: 11.7(85/1) B2: 11.7 (85,47)	0,140	B1: 0,099 B2: $0.114

Table 2. **Degree of coverage**

The variant	**The diameter of the yarn (mm)**		**Thickness of technology (Wires/10 cm)**		**Degree of coverage**		
	Du	**Db**	**Pu**	**Pb**	**I**	**Eb**	**Et**
P1	0,204	0,204	300	150	0,612	0,306	0,7307
P2	0,289	0,289	260	160	0,7514	0,4624	0,8663
P3	0.180	0.180	350	210	0.63	0,378	0,7698
P4	0.180	0.180	360	340	0,648	0,612	0,8634
P5	0,183	0,183	180	170	0,3294	0,3111	0,5380
P6	0,140	0,099	650	340	0.91	0,3366	0,9402

Table 3. **Degree of of compactness**

The variant of the fabric	Yarns density (yarns/10cm)		Yarn diameter, mm		The report connection	Number of passes	Cosα	Cosβ	Ku (%)	Kb (%)	Kt (%)
	Pu	Pb	Du	Db							
P1	300	150	0,204	0,204	4	2	795	0.73	75,27	44,37	59,82
P2	260	160	0,289	0,289	2	2	0.90	0.75	112,71	83,23	97,97
P3	350	210	0.180	0.180	3	2	0.93	0.78	86,52	59,47	72,99
P4	360	340	0.180	0.180	8	2	0.86	0.86	76,46	72,21	74,33
P5	180	170	0,183	0,183	2	2	0.86	0.86	56,65	53.50	55,07
P6	650	340	0,140	0,099	2	2	795	0.72	111,80	77,19	94,49

3. RESULTS AND DISCUSSIONS

By analysind data from tables, 1 and 2, we ca conclude that:

- The best value of the degree of coverage has been achieved for variant made from P6 (94,49%), made of 100% Co and silver thread, Statex 117 dtex;
- The best value the degree of compactness (97,97%) was obtained for variant made of 100% Co wire Nm 10:1, followed by the variant P6 (94,49%), made of 100% Co and silver thread, Statex 117 dtex.

The diameters of the yarns used in the design of the fabrics carried out within the framework of the project have been measured using the equipment in the equipment of the laboratories INCDTP PROJECTINA. The equipment is fitted with specialized software for measuring the diameter of the yarn.

The retrieved images using the microscope Projectina on samples of textile materials with deposits of layers of copper are shown in figure 3.1, respective 3.2. In figure 3.3 are presented the image of the cotton fibers untreated with Cu, and in figure 3.4 are presented cotton fibers covered with Cu, using an optical microscope.

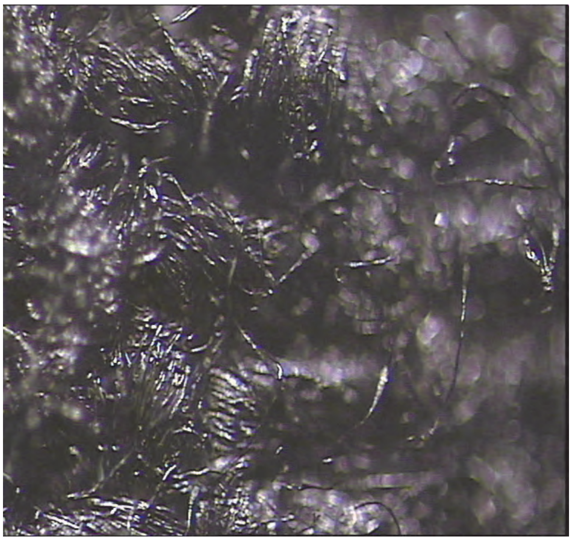

Fig. 3.1. Fabric, 100% cotton, covered with a layer of copper

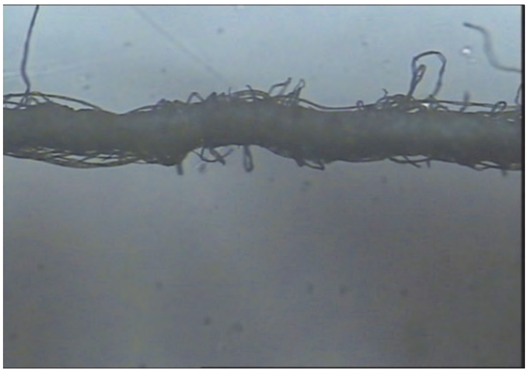

Fig. 3.2. Cotton yarn covered with a layer of copper (the yarn was extracted from the fabric)

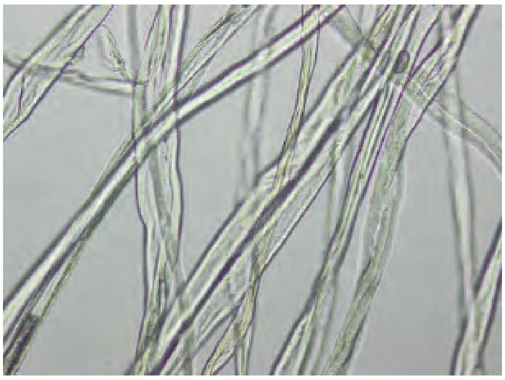

Fig. 3.3. Cotton fibers untreated with Cu

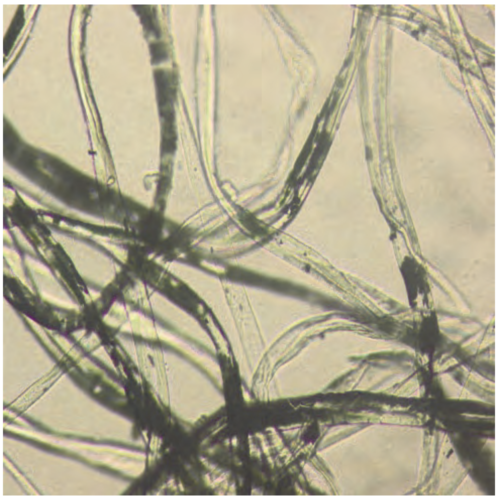

Fig. 3.4. Cotton fibers covered with a layer of copper (fiber extracted from the yarn)

In figure 3.3 may be observed in the layers of copper deposited in the plasma magnetron sputtering on textile materials. The layers of copper, of different thicknesses, namely: 200 nm and 400 nm and 800 nm and 1200 nm, have been submitted on the textile media for improving the alleviation of em and the nature of the fire.

4. CONCLUSIONS

The results of the electromagnetic attenuation obtained on the TEM cell tests, are between 20 - 33 dB in case of the woven structure with conductive yarns inserted, such as silver (STATEX) and stainless steel (Bekinox), and treated in plasma with particles of copper. Also, it has identified a relatively better correlation between conductivity and EM attenuation. For fabrics treated with Cu on a single-sided value of the EM, attenuation was at a low er level of 3-8.5 dB.

The optimal value of the degree of coverage has been achieved for variant made from P6 (94,49%), made of 100% Co and silver yarns Statex 117 dtex.

The variant P6 also presents a good value of the degree of compactness (97,97%).

It ca be concluded that it is adirect relationship between the degree of campactness and coverage and the attenuation of the electromagnetic waves on diferent frequencies.

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Acknowledgement: This work was support by Manunet project, Contract C28/2018 TexEMFiRe, and Program 1 - Development of the national RD system, Subprogram 1.2 - Institutional Performance - RDI excellence funding projects, Contract no. 6PFE/2018.

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