STUDY OF EFFECTIVENESS OF UV ELECTROMAGNETIC WAVES SHIELDING BY TEXTILE MATERIALS

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Abstract: *The article is devoted to a study of effectiveness of ultraviolet (UV) electromagnetic radiation shielding by textile materials. Degree of protection from UV radiation and their ability to be used as a protective material was determined. Polyethylene terephthalate (PET) fabric having a high degree of absorption was investigated. Its modification by Cu increased protective properties and degree of absorption from UV radiation. Positive effect of Cu on the bleached calico was determined and indicated that it energy illumination significantly decreases. New kind of "sandwich" material, which consists of different materials: 2 layers of PET fabric, 2 layers "Sharnet" and 3.0% silicon dioxide, was developed. Developed material was characterized by high level of protection from electromagnetic radiation.*

Keywords: *textile materials, electromagnetic radiation, textile composite materials, electromagnetic field, shielding.*

1 INTRODUCTION

Today, a large number of textile materials is used in everyday people life. The clothing that was made from textile materials provide various functions. A protective function is most important. The clinical, physiological and epidemiological studies have shown that UV electromagnetic radiation (UVEMR) has a negative influence on the human body. Genetic changes, lower immunity and a fatigue are very dangerous for human [1].

The problem of protecting a human body from UVEMR has become a very important through an extremely high level of development of electronic equipment (computers, mobile phones, home appliances, health diagnostics and physiotherapy, etc.). That is why development of a modern effective methods and means of individual protection of the human body from artificial UVEMR is one of the most urgent tasks for scientists [2]. Protective textile materials and their products must play a special role in this task. A long-term durable and stable fabric for all-weather outdoor application was conducted in the study [3]. In this work, a facile dip coating design has been adopted to fabricate PEG/PEDOT: PSS treated fabric. The enhancement in electrical conductivity was found. The exclusive "void-filler" inclusion in the whole fabric has been evaluated in order to correlate their microstructure (both 2D and 3D) along with the desirable conducting features. But, this work is limited by X-band electromagnetic spectrum.

Conductive filler loading in the polymer matrix is a common practice to transform insulative polymers to conducting composites [4]. In case of the textiles, a highly promising approach has been coined by virtue of fabricating with conductive adhesive homogeneous coating. Fabrication approach has been developed by two-stage of wet mixing technique including synthesis of silver nanoparticles, decorated by graphene sheets (rGO/Ag). In this work the novelty lies in the choice of conductive material and coating to make lightweight and flexible smart electronic fabric. However, the electromagnetic interference (EMI) shielding effectiveness of the prepared coated textile measured only in the long range X-band (8.2-12.4 GHz). The verification of conducted research, in terms of the reliability and effectiveness of textile materials, is necessary.

A high mechanical strength of a cotton fabric with EMI shielding properties has been developed [5]. The coated fabric was tested under rigorous environmental and practical factors, which provide information regarding the sustainability of the fabric for outdoor applications. For extensive functionality an EMI shielding of the coated fabric was experimented under some simulated practical forces. But, there is no application technology of silver nanoparticles deposition in the fabric surface.

In the work [6], conductive natural high-performance fabric was prepared by plasma assisted coating of cotton fabrics with different conductive polymers in presence or absence of silver nanoparticles. By changing the type of conductive polymer and the incorporation of silver nanoparticles, high-performance fabrics with altered or improved multifunctional properties were obtained. Such materials receive antibacterial, electrical conductivity, thermochromism, acid sensitivity and responsiveness to metal ions for a variety of potential purposes, such as biomedical, geo-textile and antistatic applications. However, the conducted studies do not cover a protective property from UVEMR. An intelligent cotton fabric was fabricated [7] using a non-ionic surfactant based on the macro structured carbonaceous coating through the 'knife-over-roll' technique. Developed fabric shows an outstanding EMI shielding efficiency over the X-band frequency range (8.2-12.4 GHz). But, proposed technology doesn't use lover frequency which can lead to a decrease of all the proposed characteristics.

There is a need to create a new concept of textile composite materials (TCM) that screen EMR across a wide range of electromagnetic waves lengths [8-10]. Development of the textile "sandwich" structures, which are obtained by stratification of two or more layers of textile fabrics of a certain raw material composition, is actual task. The maximum number of layers is determined by several factors, main of them – required degree of protection and thickness of the textile composite.

It is possible to modify each of the surfaces of textile layers and an interlayer space (nano- and polydispersed fillers, nano-layers of metal or pigments). Thus, layered textile structures can be extremely effective in absorbing electromagnetic field (EMF), especially for electronic shielding of means [11]. EMR in all wavelengths affects on the human health and has long-lasting effects, according to ecologist's and doctors-hygienists [12]. Electric fields of industrial frequency are surrounding a man every day through radiation from wiring, lighting, household appliances, power lines, etc. It is proved, that effect of these EMFs on humans is more dangerous than radiation [13].

Statistics showed: increasing magnetic field from 0.1 to 4 μT increases in several times the risk of developing leukemia in children. In general, oncological diseases occur in a twice where the magnetic field value is 0.3 μT or higher. The Swedes introduced a hygienic standard of a low-frequency magnetic field of 0.2 μT value basis of these data. Similar results were obtained in the USA, Canada, France, Denmark and Finland, but today in many countries of the world it is considered safe level of a low-frequency magnetic field 0.2 μT [14].

Ukraine has developed standards and norms that are toughest in the world [15]. The standards (health standards) determine the values of EMF parameters, which don't cause disease or abnormal health in population (Table 1).

Table 1 Exceeding limits of EMR standards

EMR source	Radiation indicators [μT]	Excess [times]
Wire from the lamp	0.7	3.5
Refrigerator	1	5
Coffee maker	10	50
Electric shaver and hair dryer	15-17	75-85
Mobile phone	40	200
Computer	1-100	5-500
Microwave oven	8-100	40-500
Tram, trolley bus	150	750
Metro	300	1500

Electromagnetic pollution has become so serious that the World Health Organization has considered this problem as one of the most relevant for humanity. Experts consider EMR one of the most powerful factors with is a possible catastrophic effect on the human gene pool. Nowadays it is necessary to have fundamentally new methods of diagnostics and an appropriate metrological base in comparison with the existing.

The mechanism of EMF effect on human body has not been thoroughly studied. The threshold intensity of thermal action of electromagnetic waves is normalized depending on frequency range, in particular on electrical and magnetic component of EMF [16-18].

The analysis of scientific, technical and patent literature shows that a specially designed multi-layered textile structures as protection means from UV electromagnetic waves have not been sufficiently investigated. That is why this study is an actual.

The motivation of this study is to protect a human from UV electromagnetic waves. The main goals are: study of effectiveness of UV electromagnetic waves shielding by textile materials; developed a special textile sandwich material for protect peoples from UV electromagnetic waves.

2 EXPERIMENTAL

The different tools and measures are applied to protect a person from the action of EMF: distance, shielding radiation sources, reduction of radiation directly at the source of radiation, establishment of sanitary boundaries around the EMF source, screening of workplaces, allocation of radiation zones, remote control in a screened room, medical examination, shortening of a working days, using personal protective equipment and other.

Comparative studies with conductive filaments (carbon or steel) were conducted first of all.

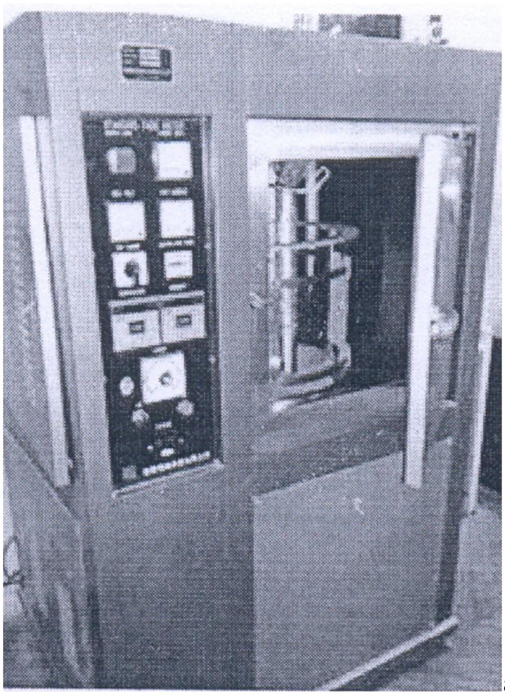
The layered textile composite materials (TCM), which screen UVEMR over a wide range of electromagnetic wavelengths, were investigated.

Each textile layer in "sandwich" structure can be further modified by metal nanoparticles.

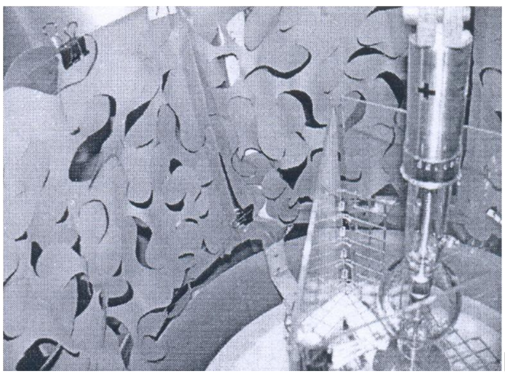
The interlayer space in the TCM can also be modified by the selected fillers. Such structure of TCM will provide additional multiple reflection, dispersion, refraction and partial absorption of UVEMR. The maximum number of layers is determined by several factors, main of them – required degree of protection and thickness of textile composite.

2.1 Equipment

When using the mixture of highly dispersed fillers, which have different dispersion and chemical nature (metal, organic, ceramic, carbon, etc.), their particles will be "selectively" absorbed, reflect, disperse and refract the UVEMR with different wavelengths. Polydispersity of fillers of different chemical nature and possible additional modification of surface of mineral fillers metal nanolayer will increase the level of reflection. As a result is reducing the permeability of UVEMR through textile composite material as a whole.



a)



b)

Figure 1 Experimental equipment, Fadometer LE-1 model KT7035: a) external view; b) internal view

The relative absorption of UVR in the studies of degree of UVEMR screening was conducted. The basis of this method is the measurement of energy illumination (*E*) in front and behind of the sample under the action of UVR. The samples were irradiated on Fadometer LE-1 model KT7035 (Figure 1).

The UVR source is xenon arc lamp with air-cooled thermal and light filters of Osram Xenon Short Arc Display/optic lamp, XBO^R Xtreme Lite with a wavelength range of 200-400 nm.

The irradiation intensity and the irradiation dose were measured on a Tensor-71 UV radiometer. The scheme of Fadometer is given in Figure 2.

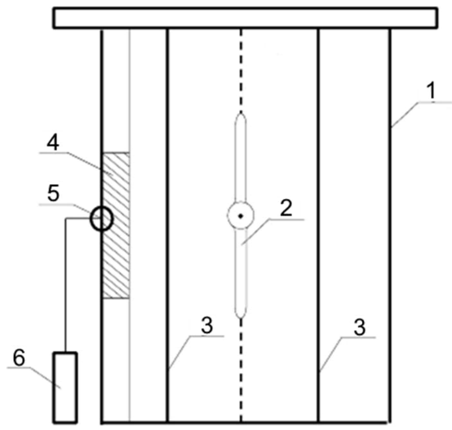


Figure 2 Scheme of Fadometer: 1) frame for placement of textile samples; 2) xenon lamp of arc type; 3) triangular prism filter; 4) textile material sample; 5) UV radiometer Tenzor-71; 6) electronic unit with UV radiometer screen

There is an opportunity to determine a degree of protection from UVR and ability for use as a protective material for different textile materials, using Fadometer LE-1.

2.2 Materials

Textile materials used in the experimental studies were polyethylene terephthalate (PET) fabric, bleached calico and developed "sandwich" material. New kind of "sandwich" material that characterized of a high degree of protection was proposed. Its characteristics are described below.

PET fabric - art. AS 703 with conductive thread (99% PET and 1% carbon thread); fabric structure - simple weave; thickness 1 mm; surface density 114 g/m^2;

Bleached calico - 100% cotton; fabric structure - simple weave; thickness 1 mm; surface density 140 g/m^2;

Adhesive material – "Sharnet" 3116 is fusible polymer mesh (copolymer of ethylene and vinyl acetate) with melting point of the material 90°C; thickness 1 mm and surface density complex.

"Sandwich" material - two-layers textile composite (2 layers of PET fabric, 2 layers "Sharnet" 3116, 3.0% silicon dioxide).

Samples of multi-layered textile materials with 1 mm thickness where obtained by the adhesive bonding method. Special press EB-K2 was used for this purpose and for a textile materials duplication. The press is equipped with means for regulating of the pressing force with a heating temperature of pillows up to 200°C.

3 RESULTS AND DISCUSSION

Experimental study, that was conducted, allowed to explore different textile materials, determined their degree of protection from UVR and their ability to be used as a protective material. The degree of absorption of UVR by textile material is calculated as differences ratio between radiation intensity of xenon lamp and energy illumination by sample when dividing by radiation intensity of xenon lamp.

The research allowed to determine a nature of protection of different fabrics from UVR. Investigated, that PET fabric artic AS 703 have a high degree of absorption in the range A and in the range B. Modification of such material by Cu greatly increases its protective properties from 4.2 W/m^2 to 0.2 W/m^2 after sample.

The energy illumination decreases significantly for range A (on 4 W/m^2) and for range B not significantly 0.2 W/m^2. Also increases degree of absorption from UVR: range A on 7.8% and range B on 2.3%. In general, it has a positive effect on overall level of human protection from electromagnetic radiation and shielding effectiveness.

The positive effect of Cu on bleached cotton fabric was determined. Energy illumination significantly decreases for range A (on 4.1 W/m^2) and for range B 4.4 W/m^2. Defined increasing degree of absorption from UVR: range A on 8% and range B on 49.4%. For bleached cotton fabric in comparison with PET fabric artic AS 703 observed a significant improvement of characteristics. General level of increasing is in average of 28.7%. It has a positive effect on overall level of man protection from electromagnetic radiation and shielding effectiveness.

Such positive effect is produced by Cu, which penetrates into the fibers of fabric, providing guaranteed saturation and protection from action of ionizing radiation. Also, saturation of fabric fibers with particles of Cu has an antibacterial effect.

“Sandwich” material has a high degree of protection in the range A (98.6%) and average degree of protection in the range B (72%). A special structure of material improves characteristics and performs a multifunctional value. That indicates increasing protective properties of PET fabric and will help to protect peoples from a harmful effect.

During the proposed "sandwich" method, the thickness of the textile material was controlled by special equipment. The movement of EM waves can be detected through the two layer "sandwich" model.

A wave that reached to the first layer passes through it on a certain principle. It is partially reflected, absorbed by the textile layer, passes into an interlayer space and “meets” with the second textile layer. These processes are repeated on a second layer, especially if the textile composite is multi-layered.

A wave that meets with another textile layer is behaves similarly. But, the degree of its passing is a greatly reduced. This principle of passing through different layers is typical for fabrics. Thus, their ability to reflect UV electromagnetic waves will depend on the number of layers of materials and their characteristics.

The numbers of absorption were measured by according to experimental purposes and mathematical methods of statistics. The mean values and 95% confidence intervals of means where used in a researches. The statistical error of the studies did not exceed 5%, which is in the acceptable limits. The minimum number of experiments was determined by the methods of mathematical statistics. It was 32 experiments in our investigations. Average values of the characteristics were calculated after the experiments. The results are presented on Figures 3-5.

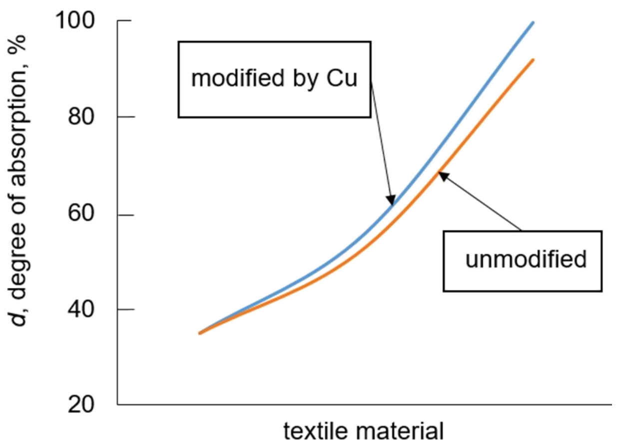


Figure 3 Graphical dependence of the change of absorption degree *d* for PET fabric art. AS 703

PET fabric art. AS 703 after modifying by Cu is characterized by growing of a degree of absorption (Figure 3). Modification of such material by Cu increases its protective properties from 4.2 W/m^2 to 0.2 W/m^2. An energy illumination decreases for range A (on 4 W/m^2) and not significantly for range B 0.2 W/m^2. A degree of absorption from UV radiation it is also increases for range A on 7.8% and for range B on 2.3%.

After modifying by Cu a bleached calico increases on 8% in comparison with unmodified sample (Figure 4). There is a positive effect of Cu on a bleached calico. Energy illumination decreases significantly for range A on 4.1 W/m^2 and for range B on 4.4 W/m^2. Defined degree of absorption from UVR range A is 8%

and for range B 49.4%. It has a positive effect on overall level of man protection from electromagnetic radiation and shielding effectiveness.

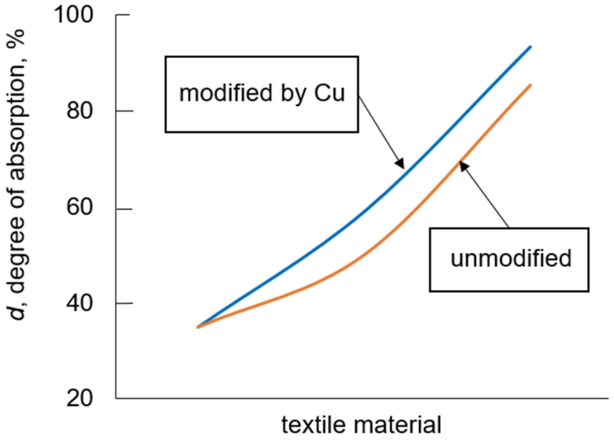


Figure 4 Graphical dependence of the change of absorption degree *d* for bleached calico

Developed "sandwich" material is characterized by a high degree of protection from UV radiation (Figure 5) in range A 98.6% and in range B 72%. Developed material is characterized by improved protection from electromagnetic radiation.

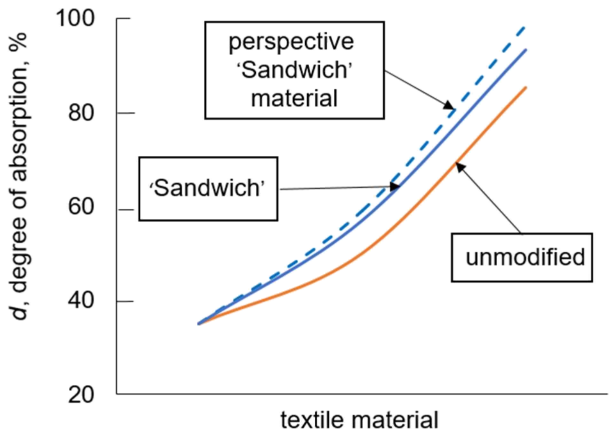


Figure 5 Graphical dependence of the change of absorption degree *d* for developed "sandwich" material

Therefore, a new method for modifying metal nanoparticles has been proposed and investigated. It is based on the method of impregnation in a solution of salt followed by the recovery of metal ions, in the structure and on the surface of textile material (for example, copper sulphate solution). This technique can be used to obtain metal nanoparticles from soluble metal salts of the first group; some salts of the second group of metals (chlorides, bromides, iodides, nitrates) and some others. The proposed method is simple, available and effective (cheap and available reagents, treatment is possible on the painting equipment); can be used for porous substrates of any chemical nature.

There are some drawbacks of research. A much larger number of different materials should be tested to increase variability and quality of experiments. Proposed two-layer textile composite "sandwich" material in range B has insufficient characteristics for quality human protection (Table 2). The series of experimental studies should be carried out in order to improve this parameter. It will provide the opportunity to eliminate the disadvantages and enhancing the characteristics of the proposed material. These disadvantages do not impair conducted researches, but indicate a prospective ways of further research.

4 CONCLUSIONS

The studies of effectiveness of electromagnetic radiation shielding by a textile materials were conducted and explored different textile materials. The experimental results of this work can be summarized as follows:

- The degree of protection from UV radiation for different materials and their ability to be used as a protective material was determined;
- A nature of protection of different fabrics from UVR was determined;
- PET fabric art. AS 703 have a high degree of absorption. Its modification by Cu increases a protective properties and degree of absorption from UV radiation. Energy illumination decreases for range A on 4 W/m^2 and for range B on 0.2 W/m^2. A degree of absorption from UV radiation it is also increases, for range A on 7.8% and for range B on 2.3%.

Table 2 Research results of determining UV absorption efficiency of radiation by textile materials

№	Sample characteristics	Energy illumination [W/m^2] (range A*)		Degree of absorption in range A d_A [%]	Energy illumination [W/m^2] (range B**)		Degree of absorption in range B d_B [%]
		in front of the sample	behind of the sample		in front of the sample	behind of the sample	
PET fabric, art. AS 703							
1	unmodified	51.1	4.2	91.8	8.9	0.5	94.4
2	modified by Cu		0.2	99.6		0.3	96.7
Cotton fabric							
1	unmodified	51.1	7.5	85.3	8.9	5.1	42.7
2	modified by Cu		3.4	93.3		0.7	92.1
'Sandwich' material, two layer textile composite (2 layers of PET fabric art. AS 703, 2 layers "Shamet" 3116, 3.0% silicon dioxide)							
1	1AS+2Sh+SiO_2+1AS	48.2	0.7	98.6	9.6	2.7	72

Note: *range A – 315-400 nm; ** range B – 315-280 nm

- There is a positive effect of Cu on a bleached calico. Energy illumination decreases for range A on 4.1 W/m^2 and for range B on 4.4 W/m^2. There was defined an increasing degree of absorption from UVR, for range A 8% and for range B 49.4%. It has a positive effect on overall level of man protection from electromagnetic radiation and shielding effectiveness.
- A new kind of "sandwich" material was developed (2 layers of PET fabric art. AS 703, 2 layers "Sharnet", 3.0% silicon dioxide). It is characterized by a high degree of protection from UV radiation (range A 98.6%; range B 72%). Developed material is characterized by a high level of protection from electromagnetic radiation.

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