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INNOVATIVE ASPECTS REGARDING UHF WAVES USED IN TEXTILE FUNCTIONALIZATION

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Abstract: *This paper we present several innovative aspects regarding the UHF (ultra high frequency) microwaves used in textile functionalization for obtain a dielectric surface. The UHF microwaves (MW) are in the range 300 MHz÷3 GHz. In general, the microwaves are in the range between 300 MHz and 300 GHz, but for our experiment was used the microwaves at the 2.45 GHz frequency. The microwaves are generated by a magnetron device and used for textile functionalization in order to accelerate the polymerization reaction.This work is a survey regarding the microwave applications for textile functionalization for setting the textile functionalization process by microwaves. The innovative technologies, such as plasma or microwave, have been used frequently in physics area research and in electronics. Both plasma and microwave devices operating in the field of radio waves, LF, UHF [1] and in general, the radio waves are used for TV signals transmission, for satellite communications and mobile telephony. The microwave radiation is is produced by magnetron microwave generator in microwave cavity (vacuum tube). However, for our experiment was used the microwaves at 2.45 GHz. Microwaves (MM) system are based on the absorption of a relatively strong radiation of this frequency in materials (plastics, textiles). The microwaves propagation on the textile materials depends on the dieletric material property.*

Key words: *microwave, functionalization, textile finishing, electromagnetic, hydrophobic, oleophobic.*

1. INTRODUCTION

The MM waves are used, for example in astronomy, while THz waves represent a radiation with a wavelength (0.1-1 mm) shorter than microwaves and is investigated and used in several practical application such as security THz spectroscopy, 3D imaging, THz tomography, submilimeter astronomy and security. The infrared radiation (light) is very helpful in the physico-chemical analyzes by spectroscopy. Also it is also used for the transmission of wireless data but at small distances, as is the case at almost all remotes for TVs and other household appliances. The ultraviolet radiation (light) is responsible for the tanning of the skin. X-rays (or an x-ray sequence) are used for a long time in medicine for viewing the internal organs. Finally, the gamma rays occur often in nuclear reactions

Even if the microwaves are in the range between 300 MHz and 300 GHz (figure 1), for experiments in the textile domain are used the microwaves at the 2.45 GHz frequency.

The microwave used in textile finishing may lead to obtain the highly hydrophobic and oleophobic textile surfaces. In this way, are significant results in using the microwave for grafting the fluorosilane in maximum 1 minute [2]. The MW radiation has been used in processes such as desizing scouring, bleaching, dyeing [3, 4], drying processes, durable press finishing, flame retardant [5, 6] and Also, the silver nanoparticles silver nanoparticles were synthesized on the pretreated silk fabric under microwave irradiation [7] and ZnO-coated textile fabric was synthesized by microwave method [8, 9].

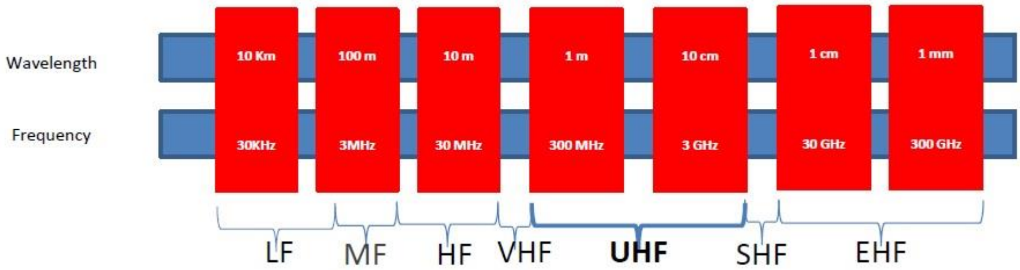

Fig. 1. *Wavelenght vs. frequency*

2. EXPERIMENTAL PART AND DISCUSSIONS

The microwaves were generated by a magnetron device and used for textile functionalization in order to accelerate the polymerization reaction. Conducting polymer coated textiles have potential can be used in absorbtion/shielding of the electromagnetic radiation.

The MW systems used in textile surface functionalization consist of three main units: magnetron, waveguide and applicator.

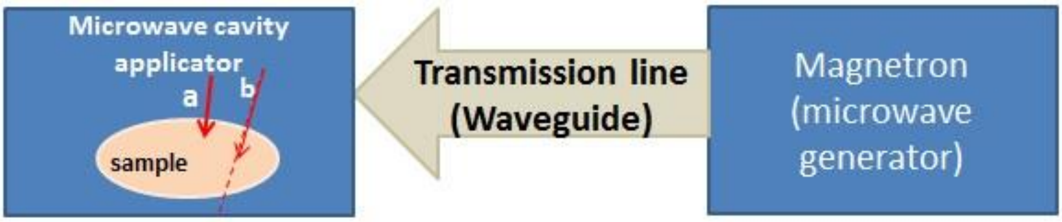

Fig. 2. *Microwave system*

Microwaves generated are spreading in the cavity of the appliance and hitting the walls and after are reflected or are absorbed in whole or in part in the fabric, generating warming up the whole material.

If the textile material is exposed to the microwave radiation, the microwaves:

-are reflected if the surface is a conductive material;

-penetrate the material without being absorbed in the case of textile materials with good insulating dielectric properties (glass fiber fabrics treated with ceramic or particle –fig1-b)

-are absorbed if the fabric has low dielectric properties. When microwave energy is absorbed by the fabric and is converted into heat.

The advantage of the MW technique is the uniformity of the treatment (heating, drying) that can improve the textile surface functionalization by acceleration of the polymerization.

A dieletric materials are electrical insulators that can be polarized by apply an electric field [11-14]. For use of textile in electronic devices, named as textronics or smart garment it is very important to have information about relative dieletric permittivity (1) ÷(4) of the material [12-13].

$$\varepsilon = \frac{E_0}{E} \qquad \textbf{(1)}$$

Where:
ε is the relative dieletric permittivity;
E_0 is the electrical field inside the dieletric material;
E_p is the field generated by the material polarization P.

$$E=E_0+E_p \quad \textbf{(2)}$$

$$E_p = \frac{-P}{\varepsilon_0} \quad \textbf{(3)}$$

$$\varepsilon = \frac{\varepsilon_0}{\varepsilon_r} = \varepsilon_0(\varepsilon_r' - j\varepsilon_r'') \quad \textbf{(4)}$$

The average microwave power absorbed by a dielectric material is stated in the math expression (5) [15]. The increasing of the frequency f = (3...300GHz) means the decreasing of the wavelengths and penetration will be superficial, in broad terms the radiation will not integral absorbed in the material. The degree of the radiation absorbtion it is depending on the dieletric material property [16] and is inverse proportional with the frequency and direct proportional with the wavelength.

$$P = \omega\varepsilon_0\varepsilon_2 E_{eff}^2 V \quad \textbf{(5)}$$

Where:
V is the volume of the dielectric material;
E_{eff} is the square of the average electric field in the volume unit (V)
ε_2 is the imaginary part of the dielectric constant ($\varepsilon = \varepsilon_1 + i\varepsilon_2$)

The moisture content can influence the dieletric property of the textile. For develop an insulator material is important to involve the intense drying of the material that can be obtained by microwave treatments. From polymers used for textiles, polyethilene and polypropilene has the lower relative dieletric permittivity.

4. CONCLUSIONS

The microwaves uses for textile functionalization *have the advantages*:
-generate less heat;
-reduced time for cleaning/activation of the textile surface;
-reduce the time allocate for polymerization (1 minute)
-the processes are in a cavity EM protected;
-do not generate water consumption;
-do not generate waste;
-generate the curing of the sample.
The *disadvantages are*:
-the energy consumption is high.
-involve sophisticated manufacturing technologies;
-involve higher costs for mentenance;
-generate a high-energy consumption;

REFERENCES

[1] Technical standard for radio spectrum, ITU.
Available: https://www.itu.int/en/Pages/default.aspx

[2] R. A. Hayn, J. R. Owens, S. A. Boyer, R. S. McDonald, H. J. Lee, "*Preparation of highly hydrophobic and oleophobic textile surfaces using microwave-promoted silane coupling"*, J Mater Sci, Springer, 2010

[3] D. Katovic, S. B. Vukusic, S. Hrabar and J. Bartolic, "*Microwaves in Chemical Finishing of Textiles*," 2005 18th International Conference on Applied Electromagnetics and Communications, Dubrovnik, pp. 1-4, 2005.

[4] Bunshiro Kawaguchi - US Patent 4425718A Apparatus for development and fixation of dyes with a printed textile sheet by application of microwave emanation, 1981

[5] D. Katović, S. Bischof, S. F.Grgac, "*Aplication of microwaves in textile finishing processes*". Tekstil. 54. 313-318, 2005.

[6] B. Y. Buyukakinci, *"Usage of Microwave Energy in Turkish Textile Production Sector",* Energia Procedia volume 14, pp.424-431, Elsevier, 2012

[7] L.H. Peng, R.H. Guo, J. W. Lan, S. X. Jiang, X. Wang, S.J. Lin, C. Li, *"Silver nanoparticles coating on silk fabric with pretreatment of 3-aminopropyltrimethoxysilane in supercritical carbon dioxide"*, Jounral of Industrial Textiles, Volume 47, Issue 5, pp. 883-896, 2018

[8] V. H. T. Thi, K. L. Byeong, *"Development of multifunctional self-cleaning and UV blocking cotton fabric with modification of photoactive ZnO coating via microwave method"* Journal of Photochemistry and Photobiology A: Chemistry volume 338, pp.13-22, 2017.

[9] H. Ebneth, H. G. Fitzky, *"Metallized sheet form textile microwave screening material, and the method of use"*, US4439768A, 1984

[10] J. L. Zhuang, D. Ar, X. J. Yu, J. X. Liu, A. Terfort, "*Patterned deposition of metal-organic frameworks onto plastic, paper, and textile substrates by inkjet printing of a precursor solution*", Adv Mater., volume 25, issue 33, pp. 4631-5, 2013

[11] https://en.wikipedia.org/wiki/Dielectric

[12] J.LEŚNIKOWSKI, Dielectric permittivity measurement methods of textile substrate of textile transmission lines, PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), ISSN 0033-2097, R. 88 NR 3a, 2012

[13] O. S. Nelson and A. W. Kraszewski, DIELECTRIC PROPERTIES OF MATERIALS AND MEASUREMENT TECHNIQUES, Drying Technology Journal, pp. 1123-1142, 2017

[14] R. Salvado, C. Loss, R. Gonçalves and P. Pinho, Textile Materials for the Design of Wearable Antennas: A Survey, Sensors, Vol 11, 2012

[15] M. Vollmer, Physics of the microwave oven, PHYSICS EDUCATION,volume 39, issue 1, IOP publishing, 2004

[16] National Research Council. Microwave processing of materials. Vol. 473. National Academies Press, 1994.