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CONTRIBUTIONS TO ACHIEVE A COMPOSITE MATERIAL FOR ADVANCED ELECTROMAGNETIC SHIELDING OF LIVING AND WORKSPACES

First part- Shielding material

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Abstract: *The paper refers to a new material for electromagnetic shielding of living and workspaces in order to reduce the electro smog. The material and manufacturing technology described comes in support of the activities carried on by electromagnetic compatibility of high frequency radiation emitted by mobile antennas, radar, cell phones, microwaves, computers, wireless networking, on the environment. The shielding material described by the authors is of composite type and it is in the form of nets with fine meshes made of thin steel wires on which a high-purity copper shirt, coated in its turn by a polymer shirt, is deposited, the latter one's aim is to protect against oxidation of copper coating. Nets, supplied in rolls, can be integrated under the plaster of working and living spaces performing an advanced electromagnetic shielding throughout the duration of building those spaces belong to.*

Key words: *electromagnetic compatibility with the environment, electromagnetic shielding nets.*

1. Introduction

Electromagnetic radiations are mixed waves containing electric and magnetic alternative fields. Electric field is generated by potential differences and magnetic field is generated by current flow. Those radiations are present everywhere in the environment, they forms there the electricity is produced, consumed and distributed.

Wavelengths λ covers the field of 10^{-11} m (gamma radiation) up to 10^{3} m (radio waves) and their frequency cover a total of 14 orders of magnitude from 1 Hz to 10 000 THz. Electromagnetic radiation need not matter to propagate. In vacuum the speed of propagation is those of the light and a propagation speed in given environment is limited due to its refractive index. The interference extent of electromagnetic radiation with matter, including the living matter, depends on frequency and wavelength thereof [1],[2]. Electromagnetic radiation is divided into two main areas after wavelength: ionizing and non-ionizing radiation. The wavelength of Ionizing radiation is between 0.01 nm to 100 nm and is represented by gamma radiation, X-ray radiation (X-rays) and ultraviolet radiation. The wavelengths of non-ionizing radiation is between 1 mm and 1000m and are represented by infrared radiation, microwaves, radio waves and low-frequency waves of power supply networks. Between the two types of radiation it is the visible range (neutral white light) of electromagnetic radiation, domain considered to be a buffer zone between ionizing radiation and non-ionizing radiation. When the visible spectrum is split by an optical system in different wavelength, it is perceived colorful and named visible color spectrum, Figure 1, [3].

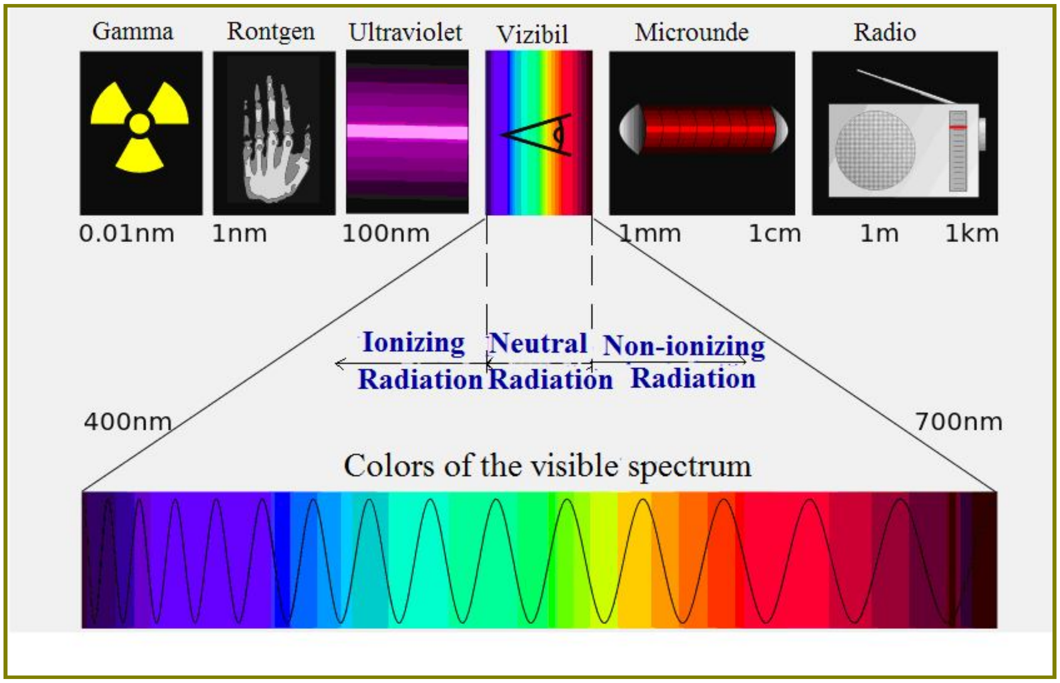

Fig.1.Wavelength range covered by electromagnetic radiation. Recovering files [3]

Due to the very small wavelength and extremely high frequency effect of ionizing radiation on matter is pronounced causing its ionization. The effect of ionizing radiation on living organisms is destructive leading to rapid death in the case of their relatively short exposures to gamma radiation and tumor diseases more likely in the case of a longer exposure to X-ray and UV radiation. [4],[5],[6].

Higher wavelength and lower frequency of nonionizing radiation makes their effect on living organisms to be not so pronounced as that of ionizing radiation, but far from being neglected. The fact that the low intensity of this radiation effect on living organisms is not as strong as those ionizing radiation and that the harmful effects of this radiation occurs after long periods of the order of years or even decades, has led and lead today many people to a tolerant viewpoint, often even the negation of the effect of this radiation. The latest scientific research clearly shows that non-ionizing radiation acting on living organisms long time, leading to cell damage and advanced affecting of nervous system [7],[8].

As a protection against non-ionizing electromagnetic radiation in the electromagnetic compatibility dealing with the extent to which electrical devices influence each other by electromagnetic fields unwanted was defined a subdomain called electromagnetic compatibility with environment [9],[10],[11] that defines compatibility emission of electromagnetic fields with the environment, especially with the man and sets limit values to ensure his safety and to prevent his disease due to these radiations. Measuring instruments of electromagnetic radiation development, characterization, testing and production of special materials [12],[13] for shielding the high and low frequency fields and measuring their intensity are also under the environment protection measures and [14],[15],[16]. In the electromagnetic compatibility of environmental the general term of electro-smog is used to express the pollution which refers both at forms of appearance and manifestation of electric fields, magnetic and electromagnetic fields and their undesirable effect on living matter. Viewed through the concept of electrosmog non-ionizing electromagnetic radiation can be divided into low-frequency radiation (0 - 300 Hz) and high frequency radiation (300 Hz - 300 GHz). Low frequency radiation are produced by power lines, electric trains, electric generators, transformers, electrical household appliances and high-frequency radiation from radio broadcasting antennas, telephone, television and mobile, radar and microwaves, TVs, computers, etc.

2. Shielding material used to shield living and workingspaces against electromagnetic radiation of low and high frequency

Corresponding frequency domain of non-ionizing electromagnetic radiation shielding means are divided into means of shielding for low frequency and high frequency. This paper deals with a shielding material both for low frequency of electromagnetic radiation and those of high frequency. The low-frequency electromagnetic radiation shielding is performed by means of Faraday cage, a mesh of metal wires binding connected to the ground. [1], [2]. The materials used for the Faraday cage consumes the electric component of the electromagnetic field by two mechanisms. A mechanism consists of earth leakage part of the electricity and the other mechanism is to use a part of the electric current through the resistive effect. The later effect makes for achieving Faraday cage to be used and metallic material having a lower electrical conductivity than copper, such as for example, the steel. High-frequency electromagnetic radiation shielding is achieved by eddy currents which final effect is local heat generation. The most important condition to be fulfilled in this case by the shielding materials is their high electrical conductivity. For shielding high - frequency electromagnetic radiation are used two solutions. First solution consists in the shielding with copper sheet of all areas of a space [16]. On the one hand this type of shielding is provided a shielding factor of more than 100 dB and, on the other hand is a very expensive solution, gives real problems of integration the copper plate under the plaster of living or working space. Besides these disadvantages the oxidation phenomena of copper sheet surface determine a sensitive lowering of electrical conductivity of surface layer and its negative manifestation of the effect Skin [17], [18] in order to reduce the shielding capacity. Currently, this solution is mainly used for shielding of high generating frequency devices and less for shielding workspaces (apart from some military applications) or those for living.

A second solution refers to the development of some schielding nets with small meshes, with a matrix made of natural or synthetic wires. In this matrix are integrated by various methods electrically conductive materials such as carbon nanofibers, copper and silver[19], [20], [21], 22]. When using shielding nets besides high conductivity of the material must be respected and electrical resonance condition. The size of the mesh side should be less than half of the wavelength (λ/2) of the electromagnetic wave that is desired to be schielded. Compared to massive copper shielding, iron nets presents the advantage of lower cost price, high mechanical flexibility, as well as that of perfect compatibility with various coatings can be easily integrated together in finishing of walls structures or in fibrous wood boards used for making furniture, paneling etc. The disadvantage of this type of shielding mesh is that of a lower electrical conductivity than that of copper sheet. This technology is mainly due to the use of metallic and non-metallic powders (carbon nanofibers), usually in the form of inserts in a polymer matrix from which is then pulling the wires in order of nets achieving. Even if copper or silver carbon nanoparticles touch each other, in the wires constituting the mesh shielding, the contact is only in one point that leading to a local electrical resistance increased and finally to a weaker closing of eddy currents in the mesh shielding. This is why the shielding efficiency of such mesh shielding is at the maximum values of about 30 dB. In order to obtain the best values of shielding efficiency the percentage of silver and copper particulates in mesh wires is greatly increased that leads to values of 30-70 dB of shielding, at the same time, however, the price of each m^2 of schield mesh is over an order of magnitude, and values over 70 dB of shielding lead to an increased price by more than two orders of magnitude.

2.1. Shielding mechanism

In order to achieve the new type of shielding material proposed [23] and studied by the authors it is use primary metallic nets of thin steel wire mesh, small squares with the mesh side of millimeter order. In the first phase, the net wires are coated uniformly, by electrochemical or chemical way, with a thin layer of high conductivity of pure copper, and in the second phase, which follows immediately after the first stage, with a layer of monomer that is converted by ultraviolet irradiation in a thin polymer coat.

The final product is a composite material in a net form which is based on steel wire coated with a thin layer of electrolytic copper which in turn is coated with a polymeric structure that protects it against oxidation. The novelty character of this advanced shielding material results from the fact that the structure of steel wire core wrapped in a pure copper shirt so it shields both electromagnetic radiation of low frequency and high frequency. Shielding at low frequency occurs by earth leakage of the electric field captured by the copper coating and by the resistive power consumption achieved by the steel core of low-frequency current. As already mentioned, high-frequency electromagnetic radiation shielding is achieved by eddy currents whose final effect is local heat generation. Given the fact that at high frequency currents of contact, including eddy currents inductive generated, moving to the area and not in the depth of conductors, metallic material thickness that provides the shielding may decrease more, in terms of ensuring an advanced shielding with increasing of frequency (Skin effect). Based on this consideration, electrolytic copper coatings thicknesses of several μm, made around some thin steel wires, are an excellent electrical conductor, and these threads woven in small meshes constitute an advanced electromagnetic shielding means. At these advantages is added a price of low cost compared to other shielding materials and a durability provided by the polymer coating of metallic wires that delivers an advanced protection against oxidation of copper from the shielding nets throughout the duration of building structure which includes the space shielded.

3. Technology and flow realization of composite material for shielding electromagnetic radiation of low and high frequency

In order to achieve the new electromagnetic shielding material authors have developed three ways of achieving nets of composite material. The first method is based on electrochemical deposition, galvanically, a pure copper coating on some nets of thin wire steel, Figure 1. A second way of achieving shielding meshes is chemically reducing a thin layer of pure copper on meshes made of thin steel wire, Figure 2., and the third way consists in electrochemical deposition without an external power of thin pure copper layer on steel wire of nets, the same Figure 2.

3.1. Flow and continuous line production of metallic nets for electromagnetic shielding obtained by galvanic deposition of high-purity copper on wire steel meshes

The manufacturing flow consists in, Figure 1, a power supply unit which comprises a drum 1 rolling a primary net 2 with meshes of thin steel wire, a pickling bath 3 for steel wire primary net 2, a bath 4 for rinsing the net 2, a bath 5a galvanic thermostated for electrochemical deposition of copper containing an galvanic electrolyte 6 based on copper cyanide for the electrolytic deposition of a thin coating of pure copper on steel wire of primary mesh 2, a power source 7 for supplying electric current of soluble electrolytic copper anode 8 and metallic drum 9 that powering primary steel mesh 2 that form the cathode of galvanic bath 5, Figure 2, another rinsing bath 11 for intermediate metal mesh 12 of steel wire wrapped in a shirt of pure copper, a tunnel 13 for drying intermediate metallic net 12, a impregnating bath 14 for wire of intermediate metallic net 12 with a monomer in order to provide advanced protection from oxidation of copper deposited electrolytically, a line 15 in UV for polymerization of monomer deposited on intermediate metal wire mesh 12, a start drum 16, and a drum winder 17 of the final shielding net 18 having a composite structure of the type: thin steel wire - electrolytic copper shirt - polymeric shirt.

Production line includes some drums Tg with guiding- stretch role and some drums Tt with traction- return role.

Operator mode to obtain electromagnetic shielding nets by galvanic deposition of copper is as follows: the drum 1 is installed for rolling the primary net 2 of thin steel wire meshes, the end of the primary net 2 is attached by means of a cross-clamps belonging to a net of polymeric material. The latter net has the same width with the net of steel wire, its role only for traction it up when metallic net passes through all stages of process. The net of polymeric material is driven by the opening drum 16 that is under winding drum 17. After connecting the two nets it commands the starting of continuous manufacturing operation of final shielding nets 18 respecting the forward speed prescribed for their high quality.

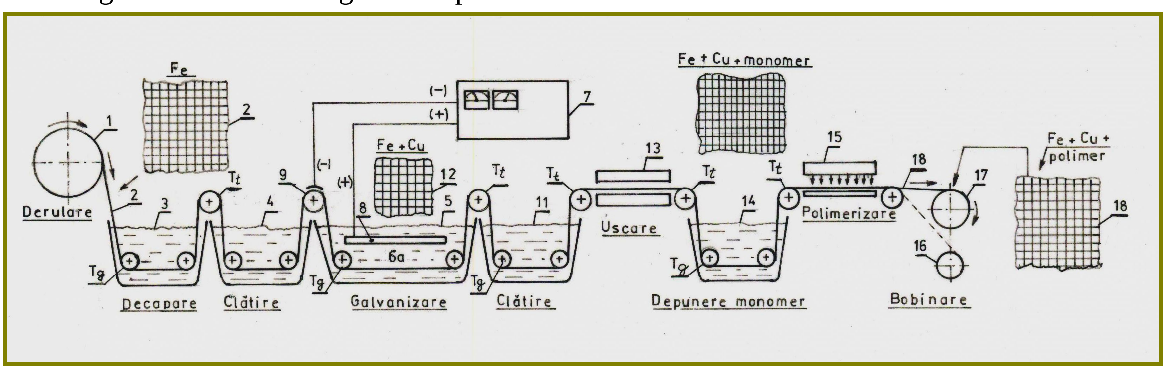

Fig.1. Flow and continuous line of manufacturing metallic electromagnetic shielding nets obtained by galvanic deposition of high-purity copper on nets of wire steel. 1-rolling drum, 2-primary net with steel wire, 3- pickling bath, 4- rinsing bath, 5a- galvanic bath thermostated, 6- galvanic electrolyte, 7- continuous current power supply, 8- electrolytic copper soluble anode, 9- metallic drum for powered on, 10- thermostat, 11- rinsing bath, 12- intermediate net with steel wire wrapped in a shirt of pure copper, 13- drying tunnel, 14- impregnating bath with monomer, 15- line of monomer polymerization with ultraviolet radiation, 16- opening drum of rolling, 17- winder drum, 18- final net shielding with a composite structure type: thin steel wire- electrolytic copper shirt - polymeric shirt, T_g- drums of guiding - stretch role, T_t- drums of traction-return role.

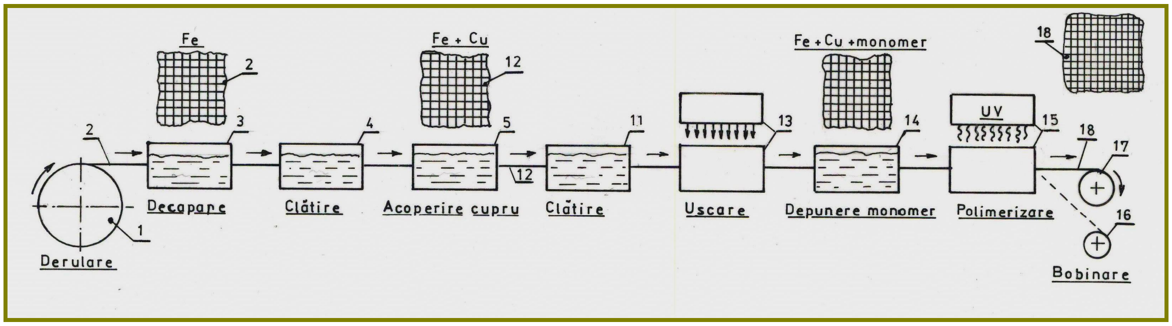

Fig.2. Flow and continuous production line of metallic nets for electromagnetic shielding obtained by electrochemical deposition of high-purity copper on nets of wire steel, without using external power sources or deposition of copper by chemical reduction.1- rolling drum, 2-primary net of steel wire, 3- pickling bath, 4- rinsing bath, 5b-galvanic bath thermostated, 11- rinsing bath, 12- intermediate net with steel wire wrapped in a shirt of pure copper, 13- drying tunnel, 14- impregnating bath with monomer, 15- line of monomer polymerization with ultraviolet radiation, 16- opening drum of rolling, 17- winder drum, 18- final net shielding with a composite structure type: thin steel wire- electrolytic copper shirt – polymeric shir

When the end of final net shielding 18 reaches the winding drum 17 clip cross coupling of two nets automatically unfolds and the end of the final net shielding 18 is routed to the winding drum 17, operation taking place until the primary net 2 is entirely consumed from the rolling drum 1. In Figure 2 is shown a flow of continuous production of the metallic net shielding based on the achievement of high-purity copper deposit through electrochemical process without external power and chemical reduction of copper in a copper sulfate bath, on thin steel wire, forming the primary meshes that is presented in turn, as well as that of the first embodiment, as a winding drum. The manufacturing flow based on chemical reduction of copper consists in a power supply unit which comprises a rolling drum 1 of a primary net 2 with meshes from thin steel wire, a pickling bath 3 for steel wire of primary mesh 2, a rinsing bath 4 of primary net 2, a thermostatic bath 5b for depositing copper by chemical reduction of copper from a sulfate electrolyte 6c on the basis of copper sulftate, another rinsing bath 11 of the metallic intermediate net with the coated steel wire in a shirt of pure copper, a tunnel 13 for drying the intermediate metallic net, a bath 14 for Impregnation of metallic intermediate net wire with a monomer in order to provide superior protection to oxidation of copper electrolytically deposited, a line 15 for polymerization in UV radiation of the monomer deposited on the metal wire of intermediate net, drum 16 to open roling and a winding drum 17 of final shielding net 18, the latter having, like in the first embodiment, a composite structure of the same type: thin steel wire- electrolytic copper shirt- polymeric shirt. The operating mode of this example is identical to that of the first embodiment.

4. Conclusion

The composite material for shielding of living and workspaces to electromagnetic radiation of low and high frequency presented in the paper is an achievement of authors team concerned to ensure an acceptable electromagnetic compatibility with the environment using for this purpose modern and efficient solutions.The solution described combine into a single material in the form of nets, a high shielding capacity both against low-frequency radiation and high frequency radiation. By shielding performance and low cost price, shielding nets described are recommended for advanced shielding of all six sides of living or workspace. Material forming shielding meshes of nets consists in thin steel wires coated with high-purity copper and outer polymeric coating for protection against copper oxidation. The nets can be invisible placed under the plaster of a certain space making its advanced electromagnetic shielding throughout the duration of the building to which it belongs. Full description of the manufacturing process flow of shielding nets enables immediate addressing of their production.

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