POLYVALENT IRON OXIDE MAGNETIC NANOPOWDERS SYNTHESIZED BY ELECTROEROSION DISPERSION FOR MICROWAVE ABSORBING COATINGS

T. Prikhna[1,a], M. Monastyrov[1,2,b], A. G. Mamalis[3,c], B. Halbedel[4,d], S. S. Ponomaryov[5,e], V. Moshchil[1,f], O. Prysiazhna[1,g]

[1]*Bakul Institute for Superhard Materials of the National Academy of Sciences of Ukraine (NASU), 2, Avtozavodskaya Str., Kiev 07074, Ukraine.*

[2] *Institute of Ecology and Alternative Energetic of the Open International University of Human Development "Ukraine", 23 Lvivs'ka Str., 04071 Kiev, Ukraine*

[3]*Project Center for Nanotechnology and Advanced Engineering, NCSR "Demokritos", Greece*

[4] *Department of Inorganic-Nonmetallic Materials, Institute for Material Engineering, Technische Universität Ilmenau, POB 10 05 65, D-98684 Ilmenau, Germany*

[5]*Institute of Semiconductor Physics of the National Academy of Sciences of Ukraine (NASU), 41, Nauky Ave., Kyiv 03028, Ukraine*

[a]prikhna@ukr.net.ua, [b]mmonastyrov@gmail.com, [c]mamalis@central.demokritos.gr , [d]bernd.halbedel@tu-ilmenau.de
[e]s.s.ponomaryov@gmail.com, [f]vik_ism@ukr.net, [g]orgenic.pris@gmail.com

Abstract. The method for simple preparation of polyvalent magnetic iron oxide nanopowders by electroerosion dispersion (EED) of carbon steel in water will be presented. The developed low cost masking coatings based on corrosion resistant polyurethane and acrylic-urethane priming, varnishes and paints of Ukrainian manufacture (InterGasSinthez) with the addition of EED nanopowders of polyvalent iron oxides, carbon, omega spheres (based on silica and alumina), basalt fibers demonstrated high absorption abilities (90-99%) of microwaves in the wide range of frequencies (10-70 GHz, wavelength 0,03-0,0043 m) and close to zero reflection of the microwaves (-10 Db - - 23 Db or 10% -0.5%).

1. Introduction

Magnetic nanoparticles (MNP) have attracted considerable interest in many fields of research and applied science due to their impressive properties. In the past, especially biomedical problems have promoted the development of MNPs. For technical applications e.g. wastewater treatment and absorption of electromagnetic waves, the existing synthesis approaches are too expensive and/or the producible quantities are too low. Modern applications with high-frequency electromagnetic fields (satellite-TV, mobile funk, WLAN technologies, radar for traffic and aerial supervision, microwave heating, drying, sintering, up to automotive and medical applications) require such low-cost absorbing materials in order to reduce the electromagnetic radiation exposure on biological systems or assure the safe operation of instruments and equipment as well as for their security (prevention of wireless signal leakages) or facilitate modern communication applications. We describe the synthesis method, the laboratory installation and discuss the structural, chemical and electromagnetic properties of the synthetized EED powders as well as their applicability for microwave absorption compared to other available ferrite powders. The electromagnetic properties of the EED powder allow microwave absorption values like that of hexaferrite powders and values considerably larger than that of the commercially available iron oxide powder Magsilica®. However, the production of the EED powder is much simpler [1].

2. Experimental procedure and sample preparation

The method of electroerosive dispersion (EED) is a physical process of instanta-neous evaporation-condensation of a metal in a liquid medium. The stoichiometry of the obtained powders depends on the quality of the raw materials (chips, cuttings, granules, etc.) and the working liquid medium, as well as the stoichiometry of the electrode material. Varying the above factors and controlling the parameters of electrical discharges (voltage, frequency of discharges, and shape of pulses) determine the powder quality: composition, size of grains (from several nanometers up to several microns), their shape (spherical or with a highly developed surface), phase state (amorphous, glassy, and crystalline). Changing the type and/ or the composition of the working liquid medium (water, spirit, kerosene) with suitable additions provides the possibility to synthesize pure metals, oxides, carbides or nitrides. In the present study, the iron chips and electrodes from structural grade carbon steels, e.g. St3 (composition see in data sheets DSTU 2651-94/ GOST 380-94, A568M/ ASTM or in 1.0116/ DIN EN 10025) were used for preparation of polyvalent ron oxides. The shape of the electrodes practically does not affect the EED process. The shape of the electrodes is determined by the shape of the reactor and can be cylindrical, trapezoidal, rectangular parallelepipeds, segments of the discs etc. The quality of water is determined by the requirement for cleanliness of the obtained powders. In this study tap water was used.

To prepare the coatings we used polyurethane and acrylic-urethane priming, varnishes and paints of Ukrainian manufacture (InterGasSinthez). We mixed the polymer media with the EED nanopowders of polyvalent iron oxides, carbon, omega spheres (based on silica and alumina), basalt fibers in different proportions and then painted surfaces of the objects several times (using mixtures with different concentrations of the ingredients).

Results and conclusions

As a result the new cheap corrosion resistant coatings based on polyurethane and acrylic-urethane with nanopowders of polyvalent iron oxides (contained FeO, Fe_3O_4 and some Fe), carbon, omega spheres, basalt fibers have been developed. The thick coatings demonstrated high absorption abilities (90-99%) of microwaves in the wide range of frequencies (10-70 GHz, wavelength 0,03-0,0043 m) and close to zero their reflection (-10 Db - - 23 Db or 10% -0.5%). Polymeric bases of the developed coatings are used to protect against corrosion of metal structures in all macroclimatic areas, in sea and fresh water, in saline solutions, in oil and oil products, resistant to ultraviolet radiation, aggressive media. They demonstrate high mechanical performance (adhesion, strength, elasticity) and long service life. The coatings can be used for painting of ships, deck structures, containers, building constructions and buildings, auto and railway transports, parts and mechanisms, etc. The results of structural study using SEM with microprobe analysis of the coatings of different thicknesses and their absorbtion characteristics (estimated transparency and reflectivity in the special anechoic chambers) will be presented and discussed. The iron oxide powder density 5.175 g/cm^3, the average particle size is 20-50 nm. With the help of cerimetry or cerimetric titration it was found that the Fe^{2+} content in the powder was 53.83 ± 1.23% by weight. Prime cost of the powder is about 20 USD/kg (in fact the price of the used electricity), productivity of one EED installation which can be located on the area of 7 m^2 is 1 ton per month. The selling price of analogue is 400-500 USD/kg and the delivery is no more than 50 kg per month. Specific gravity of the developed coating is 1 g/cm^3, the weight of 1 m^2 of the coating with the maximal absorbtion ability in 10-70 GHz range is 9 kg and its prime cost is about 50-70 USD.

Reference

[1] Halbedel B., Prikhna T., Quiroz P., Schawohl J., Kups T., Monastyrov M. Iron oxide nanopowder synthesized by electroerosion dispersion (EED) – Properties and potential for microwave applications; *Current Applied Physics*, 2018, **18**, 1410-1414