Epoxy Resin Based Multilayered Microwave Absorbing Coating System

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SUMMARY: A coating system based on different combinations of natural magnetite and carbon black filled epoxy resin has been developed. The influence of filler concentration and the ordering of the layers in the absorbing structure on the coefficients of attenuation and reflection of the electromagnetic waves in the frequency range 6.5-12.0 GHz have been investigated. The results show that the coating system (total thickness of about 2.5-3.0 mm) developed can be successfully used to reduce the overall signature and to prevent scattering from the sharp edges of complex shaped objects by attenuating surface currents.

Introduction

Electromagnetic waves or radar have contributed a lot to the fast growth and expansion of telecommunications, space exploration and navigation by air and at sea. In the same time reduction or suppression of microwave radiation is one of the main concerns of the microwave engineers in the industry and the army. Microwave absorbing materials are often used for solving such kind of problems using magnetic and dielectric loss mechanisms. A coating system of this category based on different combinations of natural magnetite and carbon black filled epoxy resin has been developed. The system is available in several grades (primer, midcoats, topcoat) with various filler loading to give a range of permittivities(ε_r) and permeabilities(μ_r). The final result of their application is a multilayered coating system with gradually increasing values of ε_r and μ_r in direction from the free space to the defended metal surface. Such kind of structure is shown in Fig.1.

In connection with their practical application the absorbing layers have to show low density and low thickness. Unfortunately it is very difficult to obtain layers having effective absorption and low reflection and in the same time low density and low thickness. Such kind of layers may be obtained only by coating system based on microwave paints, consisting of a filler (a substance with suitable magnetic and dielectric loss) and polymer dielectric matrix.

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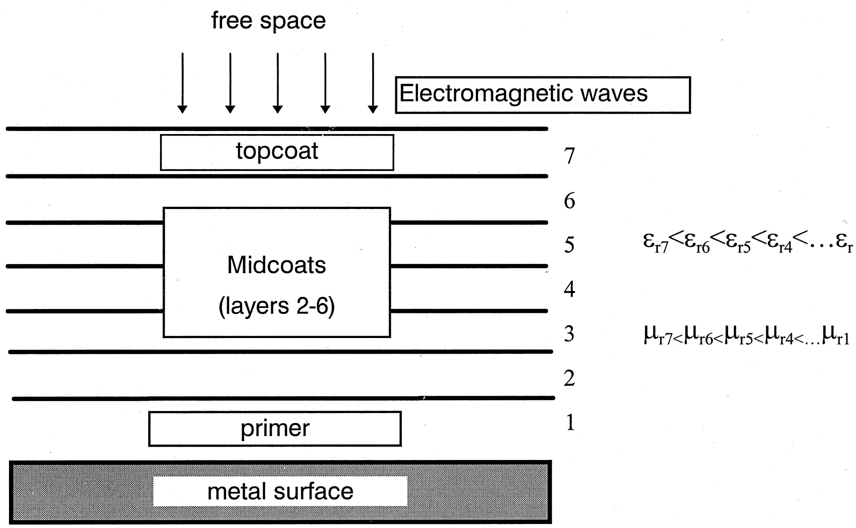


Fig.1: A multilayered coating structure.

Metal powders, SiC, graphite, carbon blacks and ferrites are often used as fillers, while epoxy and polyester resins and some synthetic elastomers are used as dielectric matrices[1-2]. The values of ε_r and μ_r strongly depend on filler/polymer ratio and usually increase with filler concentration increase.

The purpose of the paper is to present some recent results obtained about the influence of the natural magnetite and carbon black concentrations and the ordering of the layers in the absorbing coating structure developed on its microwave performance, especially on the coefficients of attenuation and reflection of electromagnetic waves in the frequency range 6.5-12.0 GHz.

Experimental

The compositions of the layers, included in the absorbing coating structure are shown in Table1. Natural magnetite with particle size 1-5 μm and furnace carbon black are used as fillers while an epoxy resin (Chs-Epoxy 1200, produced in Czech, density at 20 °C-1.12 g/cm^3) is a dielectric polymer matrix. Acetone in small amounts is used for regulation of the composition viscosity. In order to keep the optimum degree of the resin crosslinking the quantity of the hardener added to the epoxy resin was varied depending on filler concentration: 10 mass %, when the fillers concentration was below 30 g/100 g resin and 7.5 mass %, when the fillers concentration was over 30 g/100 g resin. The absorbing layers were obtained by consecutive casting of the compositions on the aluminum foils. After hardening of the layer the procedure was repeated with the next one, different in filler concentrations. A lot of variants different in fillers concentration and layers ordering were investigated. Data for some of them are shown in Table 2.

Table 1. Compositions of the layers in the coating system.

N	Natural magnetite, g	Carbon black, g	Epoxy resin, g	Type of the layer	Thickness, μm
1	40	20	100	primer	700
2	100	10	100	midcoat	100
3	50	-	100	midcoat	100
4	40	-	100	midcoat	100
5	30	-	100	midcoat	100
6	20	-	100	midcoat	100
7	10	-	100	topcoat	500

Table 2. Investigated multilayered structures.

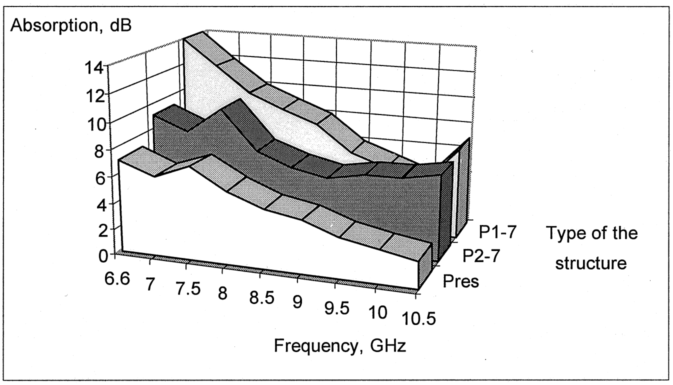
Structure	Ordering of the layers in direction from metal surface to the free space	Number of the layers	Thickness of the structure, mm	Weight, kg/m^2
P^*_{res}	0 - P_3 -P_4 -P_5 -P_6 -P_7	6	1.20	1.71
P_{2-7}	P_2 -P_3 - P_4 - P_5 -P_6 -P_7	6	1.00	1.85
P_{1-7}	P_1 - P_2 - P_3 - P_4 - P_5 - P_6 - P_7	7	1.70	2.50

* The layer named “0” does not contain fillers.

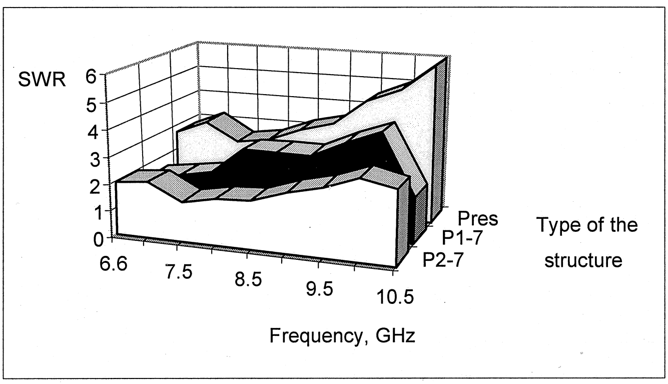
The microwave characteristics of the multilayered coating system were measured using the method of free space reflection because it is the closest method to the real absorbers application.

Results and Discussions

The dependencies between microwave absorption, standing -wave ratio (SWR) and frequency in 6.5-10.5 GHz range for the investigated multilayered structures are shown in Fig. 2. They show that in principal the microwave absorption decreases with the increasing of the frequency. The absorption is better when the layers contain bigger amounts of fillers(P_{1-7}, P_{2-7}). In the same time SWR value increases with the frequency which is better expressed for the composition $P_{res.}$ The SWR values for the compositions P_{1-7} and P_{2-7} vary from 2.5 to 4.0 in the investigated frequency range.



a)



b)

Fig.2: Frequency dependencies of absorption (a) and SWR (b) of multilayered epoxy resin based structures investigated.

Magnetite (Fe_3O_4) itself can be used as a microwave absorbing material. But the electrical conductivity of Fe_3O_4 is high and is responsible for the decrease of the absorption with the increase of the frequency. This was shown also by a comparison of the Fe_3O_4 containing rubber based microwave absorbers at the X and Ku bands[2)]. On the other hand the conductivity of the carbon black is lower than that of Fe_3O_4. Therefore carbon black included in the coating compositions is suitable for absorption at the wider band of microwave frequencies. Having in mind that in principal the microwave absorption increases and SWR decreases with the increase of the layer thickness, coatings with bigger total thickness (2.5-3.0 mm) and the composition of the layers shown in Table 1 were prepared. Their characteristics in 8-12 GHz range are shown in Fig.3.

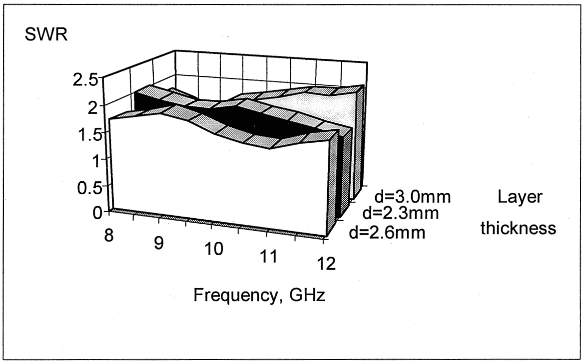


Fig.3: Frequency and layer thickness SWR dependencies.

From the figure one can see that in 8-12 GHz range the thicker layers reflect more weakly in the lower end of the investigated frequency range while the thinner ones - in the upper end. In all these cases the SWR value is less than 2.0.

The coating system developed can be brushed or sprayed up to the specific total thickness in multiple passes in steps of 100 μm using the specific cure times. The relatively long cure times are necessary to minimise the build up of tensions into the coating layers and so increase the resistance to breaking or cracking during process of ageing. If the metal surface has been treated with an anti-corrosion paint before the application of the absorptive coating it is necessary to take into account the electrical conductivity of the anticorrosion layer.

Conclusion

1. A multilayered microwave absorbing coating system on the basis of epoxy resin as polymer matrix containing magnetite and furnace carbon black as fillers has been developed.
2. The coating system obtained in a specific thickness has an improved microwave performance in 8-12 GHz range and can be successfully used in a lot of applications to reduce the overall signature and to prevent scattering from the sharp edges of complex shaped objects by attenuating surface currents.

References

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2. N. T. Dishovsky, K. G. Kostov, B.I.Vichev, XIII $^{-th}$ International Conference on Microwave Ferrites, Romania, *Proceedings,* 174(1996).