

Application peculiarities of magnetic materials for protection from magnetic fields

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Abstract. In different materials for magnetic shields, the maximum permeability is achieved for different values of the magnetic field. This determines the choice of material. So for protection from magnetic fields strength of 10 – 150 A/m it is advisable to apply the amorphous ribbon 84KXCP. For stronger fields (more than 400 A/m) it is recommended to use MFS based on Ni₂₀Fe₈₀. Use of these materials allows creating an effective shield working in a wide range of magnetic field strengths.

1. Introduction

In modern physics experiments and installations detectors (detection units) scientific equipment is used that is susceptible to constant magnetic fields. For example, accelerators (ATLAS CERN) widely use photomultiplier tubes (PMTs) that are very sensitive to magnetic fields, which are adjacent to the superconducting magnet generating a magnetic field with a strength of several Tesla (10^4 Gauss). The same situation is observed in the equipment installed on the spacecraft. For example, the "Pamela" experiment, which is a magnetic spectrometer, uses a magnetic system based on the strengths of the constant magnets and the PMT. In the equipment used in nuclear medicine the situation is the same.

The most difficult case of protection from exposure to external fields is the shielding from static magnetic fields [1, 2]. Usually, the magnetostatic shielding is based on the principle of shunting the magnetic field by ferromagnetic material [3, 4], the main essence of which is enclosing the force lines inside the material with a low resistance to magnetic flux.

One of the main and most effective ways to protect against EMR is shielding. Therefore, the work on creation of highly effective shield against alternating electromagnetic radiation, as well as against the constant magnetic fields on the basis of new materials and technologies is very important.

To provide a high shielding effectiveness in a wide range of frequencies it is desirable to apply the multilayer metallic shields, consisting of layers with high permeability and layers with high electrical conductivity. The shielding effectiveness in such materials increases due to the fact that there is a multiple reflections of the EMI between the layers in multilayer shields consisting of metals with different characteristic impedance. The reflection effect is observed at interfaces with different wave resistances.



2. Method and experiment

Magnetic shield is formed by electrodeposition method of soft magnetic alloys $\text{Fe}_{20}\text{Ni}_{80}$ [5]. Quantitative evaluation of the shielding effectiveness E conducted by ratio of the voltage measurements or magnetic field induction in the protected area of space in the absence of the shield H (or B) and in the presence of his H_1 (or B_1) [6]:

$$E = B/B_1 = H/H_1$$

The figure 1 shows the dependences of the shielding effectiveness of magnetostatic field for the shields based in electrodeposited alloy $\text{Ni}_{80}\text{Fe}_{20}$ and amorphous ribbon 84KXCP. For magnetic fields from 15 to 135 A/m the effectiveness of the shield of ribbon 84KXCP is higher than the one of the shield of the alloy $\text{Ni}_{80}\text{Fe}_{20}$. In the interval from 135 to 2700 A/m shields based on alloy $\text{Ni}_{80}\text{Fe}_{20}$ are more preferred, although in the sense of μ_a values they are inferior to shields based on amorphous ribbon 84KXCP. From this experiment it follows that the shielding effectivenesses for different materials are substantially different. For the amorphous alloys 84KXCP with high μ_a values and low values of coercivity $H_c = 0.7$ A/m the position of maximum of the magnetic permeability curve ($\mu = f(H)$) should be in the range of magnetic fields lower than 1 A/m. Lower values of $H\mu_a$ of shields based on amorphous ribbon 84KXCP compared to shields based on alloy $\text{Ni}_{80}\text{Fe}_{20}$ (figure 1) determine their high effectiveness in magnetic field range from 15 to 135 A/m (figure 1). For values of $H \geq 100$ A/m all 84KXCP material goes into magnetic saturation and the efficiency of the shield decreases sharply. Based on the above results, we can conclude the following: for optimum protection from static magnetic fields it is necessary to have clearly defined parameters of these fields; the selection of the shielding materials should be taken into account as long as the main magnetic characteristics - initial and maximum magnetic permeability, saturation magnetization, residual magnetization and the maximum field strength of the magnetic permeability. Parameter $H\mu_a$ is a very important characteristic to evaluate and predict the effectiveness of magnetic shields.

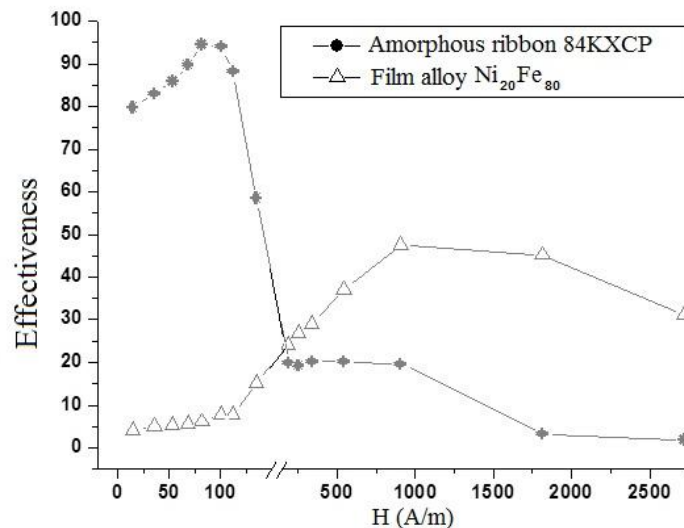


Figure 1. Dependence of the effectiveness of shields. Experimental errors located within the points. (Lines connecting points are guided to the eyes only).

It should also be noted that the maximum efficiency of the final cylindrical shields is achieved for external magnetic fields greater than the value of H corresponding to the maximum μ . For example, for the amorphous ribbon 84KXCP and alloy $\text{Ni}_{80}\text{Fe}_{20}$ the values H at which μ has a maximum, are equal to 1 A/m and 80 A/m, respectively. Maximum shielding effectiveness of the amorphous ribbon 84KXCP is achieved for the magnetic field of 80 A/m and for the alloy $\text{Ni}_{80}\text{Fe}_{20}$ – 900 A/m. This is

due to the different topologies of the magnetic flux in the sample during the measurement of parameters μ and E . In the first case we have a uniform, closed magnetic flux in a ring-shaped sample. In the second – two magnetic fluxes directed toward each other in a sample of cylindrical shape. Some inconsistencies in the results of measurement of the alloys $\text{Ni}_{80}\text{Fe}_{20}$ shielding effectiveness are caused by significant differences in the size and shape of the testing shields.

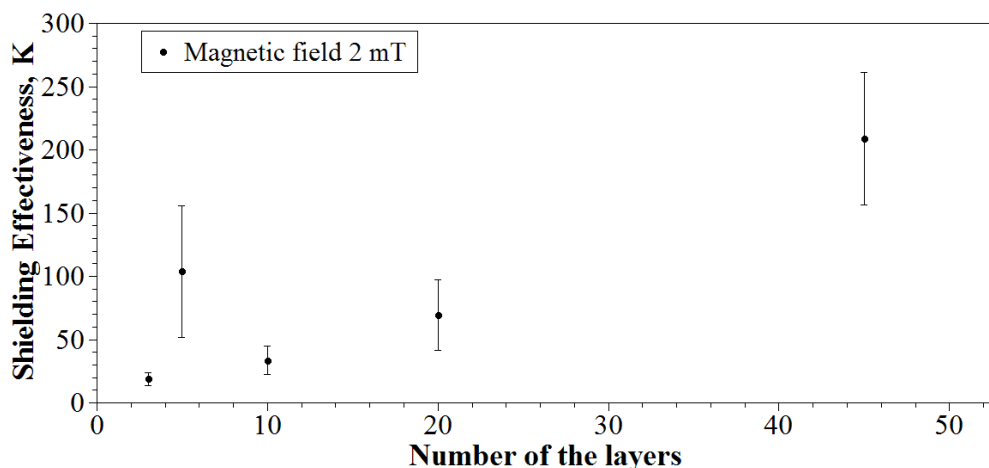


Figure 2. Dependence of the shielding effectiveness against a constant magnetic field induction on the number of layers (at a constant total thickness of the soft magnetic material).

The shielding effectiveness increases with the number of layers in the shielding screen (at a constant total thickness of the soft magnetic material). The figure 2 shows the shielding effectiveness versus number of layers dependence for the magnetic field of 2 mT. The result obtained for the shield with five layers, possibly due to an error in the deposition of the magnetic layers of this shield.

3. Conclusion

Thus, this paper is devoted to the comparison of the magnetic shields based on the amorphous ribbon 84KXCP and alloy $\text{Ni}_{80}\text{Fe}_{20}$. Experimental results on the shielding effectiveness made of the $\text{Ni}_{80}\text{Fe}_{20}$ alloy and the industrial material 84KXCP show that for magnetic fields in the range from 100 to 2700 A/m shields based on alloy $\text{Ni}_{80}\text{Fe}_{20}$ are preferred over shields based on amorphous ribbon 84KXC.

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