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MEASUREMENT AND SIMULATION RESULTS OF Ti COATED MICROWAVE ABSORBER

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Abstract

Microwave absorbers are coated with resistive thin films. S parameters are measured before and after coating. The measured data are used to check the simulation results of software HFSS which are in good agreement with the measurement results.

1 INTRODUCTION

At Fermi lab anti-proton cooling system, ferrite materials are to be put on walls of beam lines to absorb unwanted microwave signals. A layer of resistive coating can change the distribution of electromagnetic fields and affect attenuation of the signals. In order to study such effect, microwave absorbers (Ni-Zn ferrite) were coated with titanium thin film and put into a waveguide (see Figure 1.) S parameters were measured before and after coating.

The combination of thin layers of ferrite material with large variation of magnetic loss tangent and resistive surface boundary composes a challenge to the simulation software used for designing microwave system. Therefor measurement results have been used to check the simulation results from commercial software HFSS (High Frequency Structure Simulator.) These results can also be used to confirm the correctness of permittivity and permeability parameters measured by us.

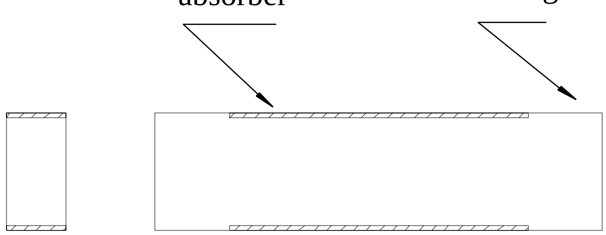

Figure 1. Configuration of absorbers and a waveguide

2 SAMPLE DESCRIPTION

Nickel-Zinc ferrite samples (TT2-111 from Trans-Tech Inc.) were cut into rectangular shape (0.795 in x 1.98 in). Sixteen pieces were grounded to 0.065 inch thick and eight pieces were grounded to 0.125 inch thick. Samples were divided into 6 groups. Half of these samples (group 4 - 6) were sputtered with Ti at Fermilab, and half of them (group 1 - 3) were sputtered with Ti at Thin Film Technology Inc., California. Samples in each group (4 pieces with same thickness) were coated together. The goal of the coating was to achieve surface resistance of 210 - 270 Ω/square. The thickness of Ti thin film coated at Fermilab (Group 4 - 6) is 137A°-141A°. The corresponding surface resistance is 210 -260 Ω/square. The thickness of Ti thin film coated at Thin Film Technology Inc. (Group 1 - 3) is ~216A°. The corresponding surface resistance is 216 -252 Ω/square. These parameters are listed in Table 1.

Table 1: Surface resistance of coated absorbers

Group #	Thickness of Absorber	Thickness of Ti film	Surface Resistance Ω/square
1	0.065”	216 A°	230-240
2	0.065”	216 A°	216-252
3	0.125”	216 A°	230-240
4	0.065”	137 A°	240-260
5	0.065”	141 A°	210-230
6	0.125”	141 A°	210-230

Since the coating is very thin, the resistivity of these films is sensitive to the parameters of sputtering process such as purity and mixture of gas, sputtering rate and kinetic energy of the sputtered target particles. This can be seen in samples made by both Fermilab and Thin Film Technology Inc. This fact can also contribute to the thickness difference of Ti films made at Fermilab and Thin Film Technology Inc. However, thickness difference of ~80 A° does not matter since the surface resistance is the only factor to be considered.

In order to see the stability of these thin films, surface resistance was measured immediately after coating and re-measured 7-10 days later. There was no significant change.

Permittivity, permeability and loss tangent of TT2-111 material and other ferrite materials were measured at Fermilab. To measure these parameters, a ferrite material was machined into a rectagular slab (1.59” x 0.795”) to fit into a section of WR-159 waveguide (area of the cross secion is 1.59” x 0.795”.) Cables and coax-waveguide

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adaptors were calibrated using TRL (Thru-Reflect-Line) method. The S parameters were measured using a network analyzer (HP 8510.) The real and imaginary part of permittivity and permeabily were deduced from measured S_{11} and S_{21} parameters with a computer program [1][2]. These perameters are listed in Table 2 and used in simulation discussed later.

Table 2: Permittivity/permeability of absorber

Freq. (GHz)	ε_r	Loss tangent (E)	μ_r	Loss Tangent (M)
5.0	12.83	0.025	0.0155	137.2
5.2	12.83	0.027	0.0322	63.25
5.4	12.83	0.027	0.0547	35.66
5.6	12.87	0.027	0.0797	23.24
5.8	12.89	0.027	0.0906	19.59
6.0	12.92	0.029	0.1058	15.95
6.2	12.95	0.031	0.1187	13.47
6.4	12.92	0.033	0.1281	11.96
6.6	12.92	0.030	0.1288	11.29
6.8	12.93	0.031	0.1328	10.54
7.0	12.92	0.031	0.1361	10.05

3 MEASUREMENT RESULTS

S parameters were measured before and after resistive coating using a 6” long waveguide (WR159) and a network analyzer (HP8510.) Four pieces of absorbers (a group) were measured each time. Absorbers were put inside of the waveguide (against inner surfaces of two narrow sides of the waveguide, two pieces of samples on each side, see Figure 1.) The measured S parameters of un-coated absorbers with same thickness of 0.065” are very close to each other: deviation of S_{21} from mean value of group 1,2,4 and 5 (listed in Table 1) is less than 3%. After coating with Ti thin film, each group of absorbers was measured again. The measured S parameters of coated absorbers with same thickness are still close to each other, though the deviation of S_{21} from mean value of the 4 groups increased to less than 5% which was due to the variation of surface resistance.

Since the results are close to each other, only two groups’ results are presented here. Shown in Figure 2 and 3 are the measured S_{21} and S_{11} parameters for group 1 (samples with thickness of 0.065 inch.) Shown in Figure 4 and 5 are the measured S_{21} and S_{11} parameters for group 3 (samples with thickness of 0.125 inch.) All results show that attenuation of microwave signals was decreased after resistive coating. The decreases of attenuation depended on the thickness of samples: the thicker samples’ attenuation decreased more since thicker samples occupied more space were the electric field was stronger.

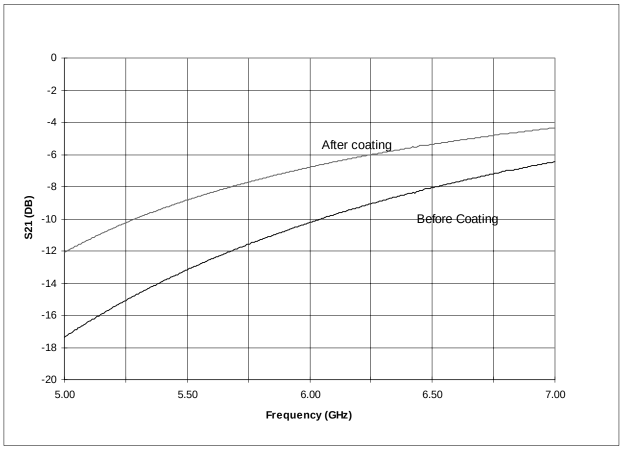

Figure 2. S_{21} of group 1 (sample thickness: 0.065”)

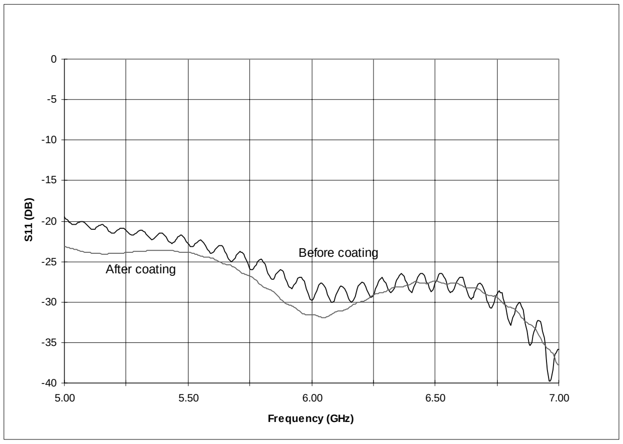

Figure 3. S_{11} of group 1 (sample thickness: 0.065”)

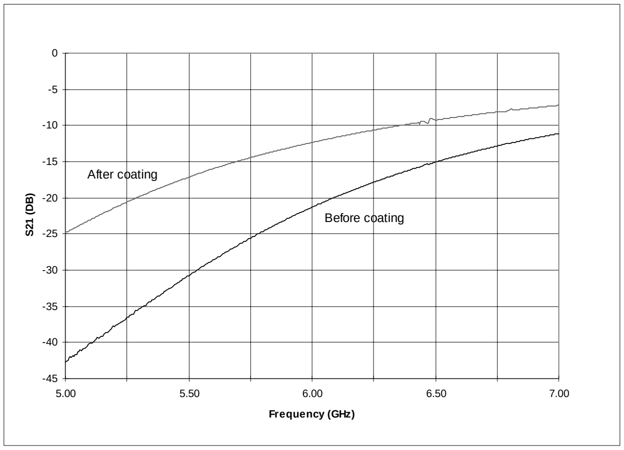

Figure 4. S_{21} of group 6 (sample thickness: 0.125”)

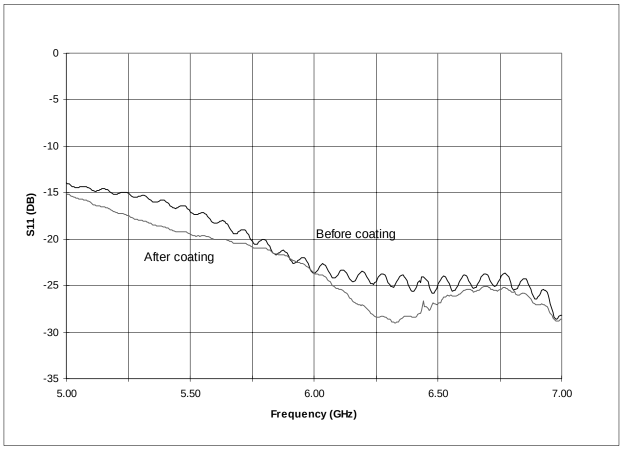

Figure 5. S_{11} of group 6 (sample thickness: 0.125”)

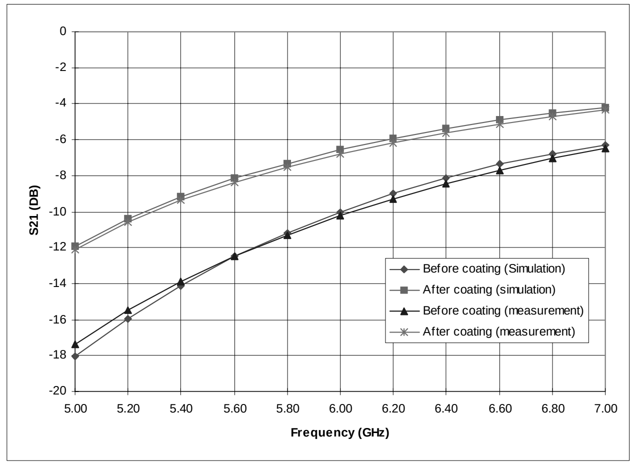

Figure 6. S_{21} of Group 1 (simulation and measurement)

4 SIMULATION RESULTS

Commercial software HFSS is extensively used for designing microwave components at Fermi lab. In order to check the capability of this software dealing with complex permittivity and permeability, large loss tangent, resistive surface boundary conditions and relatively large geometry ratio between different materials (area of the cross section of WR159 waveguide is 1.59”x0.795” while the thickness of the absorbers is 0.065”), simulations were performed using software HFSS from Ansoft corporation (v.6 beta.) In simulations, thickness of absorbers was 0.065 inch and surface resistance was 235 ohm/square. Therefor the simulation results should be compared with the measured results of group 1. Since HFSS does not have the capability to change permittivity and permeability with frequencies during a simulation, simulations were performed at 11 single frequencies. At each frequency, permittivity, permeability and loss tangent were set to the measured value listed in Table 2. In this way the software is more accurately evaluated since the meshes are refined at the same frequency and the permittivity/permeability parameters are the true value at that frequency. The convergence criterion of simulation was set to 0.001 for delta S. Shown in Figure 6 and 7 are simulation results. As a comparison, the measured data are also plotted (S_{11} data of “Before coating” has been smoothed out at each frequency by averaging adjacent 20 points.) These figures show that the simulation results are in excellent agreement with the measured data.

This result also indirectly prove that the measured complex permittivity and permeability parameters (used in simulation) are reliable. (Since the real part of permeability of such ferrite can be close to zero, extra care has to be taken during the measurements and data extraction of these E-M parameters. Therefor an extra prove of those data is always a good practice.)

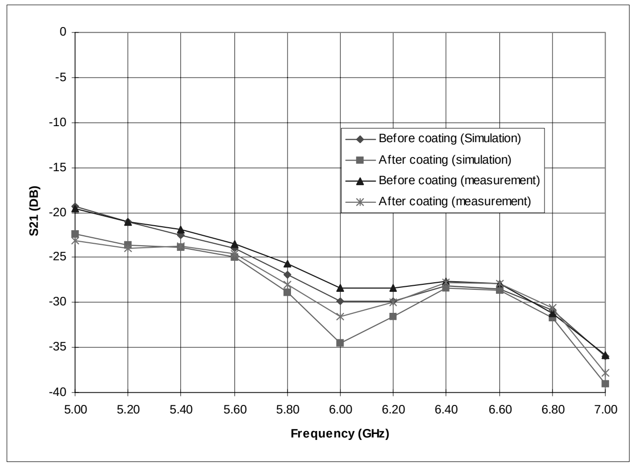

Figure 7. S_{11} of Group 1 (simulation and measurement)

5 ACKNOWLEDGEMENT

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6 REFERENCES

[1]David McGinnis, Fermilab PBAR NOTE No. 594
[2]Ding Sun, Fermilab PBAR NOTE No. 599