PBAR Note 598
Vacuum Properties of Some Microwave Absorbers
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This report is a summary of test results on vacuum properties of several microwave absorbers at rf power level of 50 watts (input power.) The tests were conducted in May and June, 1998. The goal of these tests is to check the materials which can absorb enough power and do not severely outgas after a reasonable time of conditioning.
Since vacuum behavior of a microwave absorber depends on several factors such as conditioning time, starting vacuum, and rf power levels (absorbed power), it would be more misleading than informative if I use plot of vacuum versus only one of these factors. Therefore I will mainly describe the vacuum behavior of tested materials by words instead of using plot. The summary of this description is listed in table 1 as well.

I. Tested Samples

The following are list of tested samples.

Flexible absorber (RFSW-N-090, R&F Products, Inc.)
MF124 (Iron powder and epoxy, Emerson&Cuming, Inc.)
SiC (CN-163, hot pressed, Norton, Inc.)
AlN-glassy C (AlN and glassy carbon, hot pressed, Ceradyne, Inc.)
AlN-40%SiC (AlN and SiC, hot pressed, Ceradyne, Inc.)
CMD10 (NiZn ferrite, ceramic-like, Ceramic Magnetics, Inc.)
TT2-111R (NiZn ferrite, ceramic-like, Trans-Tech, Inc.)
Ferrite50 (NiZn ferrite, ceramic-like, Trans-Tech, Inc.)

II. Configuration of Samples

Except for flexible absorber, all samples were cut into two pieces of triangle shape. The triangles are right angle triangles with base length of ~0.795 inch and height of ~2-3 inches. The thickness of the samples are 0.1-0.17 inches. The size of triangles varies because the size of available absorber materials are limited (some materials' sizes are smaller.) However the exact size is not important since we are mainly interested in the vacuum properties at certain absorbed power levels. These two pieces of triangles lay on an inner surface of a waveguide. The configuration of the samples are shown in figure 1 , 2 and 3. This configuration is to avoid possible overheating at center region of a waveguide. In figure 3 (AlN-SiC) one sample is above another one to increase the absorption.
Note: although the waveguide was cooled by water, the cooling of the absorber samples were not good since the samples just simply lay on the inner surface of the waveguide.

III. Procedure of Test

Samples were cleaned by alcohol (put into alcohol and wiped dry.) AlN-SiC was also cleaned by ultrasonic cleaner. This simple cleaning process definitely can not completely clean out the cutting fluids socked into the voids of porous samples such as hot pressed SiC (from Norton, Inc.). To reach vacuum of low E-8 torr range more quickly, more thoroughly cleaning and baking procedures will be needed or samples can be custom made to eliminate cutting process.

Basic procedures of conditioning (for TT2-111R , Ferrite50, AlN-SiC, and AlN-glassy C) are:

(1) pump down without rf power for 16-20 hous (AlN-glassy C was only pumped down for 1.5 hours)
(2) forward power was increased to 4W, 8W, 12W, 16W, 20W, 24W, 32W, 40W, 50W step by step. The dwelling time at each power level was determined by the vacuum: usually 5-30 minutes after vacuum passed the worst point.
(3) stay at 50W level to see the vacuum improvement.

Conditioning of samples other than TT2-111R, Ferrite50, AlN-SiC and AlN-glassy C were similar but did not follow the same power increase step.

IV. Summary of Vacuum Property

Vacuum behavior of tested materials are described below. The major facts in the description are also listed in table 1.

1. MF124 and Flexible Absorber

As reported before, flexible absorber and MF124 both were not good for high vacuum environment. Vacuum stayed at low or mid E-5 torr range even at low power levels of several watts. Both absorbers began to be overheated (burnt) at about 10 watts.

2. Hot pressed SiC

SiC was tested at 50-60 W for about 26 hours. Vacuum was 4E-5 torr at these power levels. At 60.5 W of input power, reflected power was 2.08 W and transmitted power was 27.5 W (-3.27 db attenuation.) So absorbed power was ~31 W. The attenuation was slightly deteriorated when power was increased (at 8W the attenuation was -3.53 db.) After system was opened, yellow and oily fluid was found. This fluid probably is the cutting fluid soaked into porous SiC and was “cooked” out. It was the cause of the poor vacuum. Cutting fluid shall not be a problem in the future since the absorber can be custom made into the required shape without cutting process. The SiC sample sent by Norton company is CN-163 which is quiet porous. This porosity bring up two potential problems: (a) prolong the time needed to reach low vacuum and (b) repeatability of E-M parameters (permittivity and permeability.) If we decide to use such a material, we should test other products from Norton company such as: CN-163L, CN-137, CN-237 and CN-983 which have higher density.

3. CMD10

CMD 10 was tested at 50-60 W for about 2 hours. The conditioning time before 50 W was 2.5 hours. The starting vacuum (at beginning of conditioning) was 3.5E-5 torr. After 2.5 hours of pre-conditioning, vacuum was 2~3E-6 torr. At 50-60 W level vacuum went down from 3E-6 torr to 2.6E-6 torr within 1.75 hours. This material was not tested for long time since it was not considered as a premier candidate at that time. At 60.0 W input power, the reflected power was 2.69 W and transmitted power was 36.3 W (-1.98 db attenuation.) So the absorbed power was ~21 W. The attenuation was deteriorated when power was increased (at 8 W level the attenuation was -3.55 db .)This material also has a hysteresis-like behavior. Since at 6GHz magnetic domain can not follow the microwave field, this should not be confused with hysteresis caused by magnetic domain movement.

4. AlN-glassy carbon

This material was tested at 50 W for total ~52 hours. The accumulative conditioning time before 50 W was 7.5 hours. The starting vacuum was 5.2E-6 torr. After 7.5 hours of conditioning and 20 hours pumping without power, vacuum was 1.1E-5 torr. At 50-60 W level the vacuum went down from 1.1E-5 torr to 5.5E-6 torr within 4.25 hours. The vacuum was 3.4E-7E-6 torr after 52 hours at 50 W and 1.7E-8 torr after another 120 hours' pumping without power. At 50 W of input power, the reflected power was 1.05 W and transmitted power was 4.67 W (-10.2 db attenuation.) Note: the samples were a little larger than other absorbers. So the absorbed power was ~44.28W. The attenuation was slightly deteriorated when power was increased (at 8W the attenuation was -11.4 db.)

5. TT2-111R

This material was tested at 50 W input power for total ~3.4 hours. The accumulative conditioning time before 50 W was 1.3 hours. The starting vacuum was 4.0E-7 torr. After 1.3 hours of conditioning the vacuum was 9.1E-7torr. At 50-60 W level the vacuum went down from 1.0E-6 torr to 4.9E-7 torr in 3.4 hours. This material was not tested very long due to its good vacuum behavior (vacuum did not change too much during conditioning.) At 50 W of input power, the reflected power was 2.97 W and transmitted power was 27.9 W (-2.27 db attenuation) So the absorbed power was ~19.13W. The attenuation was deteriorated when power was increased (at 8W the attenuation was -4.30db.)

6. Ferrite50

This material was tested at 50 W input power for total ~24 hours. The accumulative conditioning time before 50 W was 1.3 hours. The starting vacuum was 1.6E-7 torr. After 1.3 hours of conditioning the vacuum was 7.4E-7torr. At 50 W level the vacuum went down from 7.9E-7 torr to 2.2E-7 torr in 3.1 hours. After 24 hours at 50 W, the vacuum was 1.2 E-7 torr. At 50 W of input power, the reflected power was 2.90W and transmitted power was 27.5 W (-2.34 db attenuation) So the absorbed power was ~19.6 W. The attenuation was deteriorated when power was increased (at 8W the attenuation was -3.32 db.)

7. AlN-40%SiC

This material was tested at 50 W for total ~210 hours. The accumulative conditioning time before 50 W was 2.5 hours. The stating vacuum was 3.7E-7 torr. After 2.5 hours of conditioning the vacuum was 3.3E-6torr. At 50 W level the vacuum went down from 4.3E-6 torr to 2.2E-7 torr in 28.5 hours, 1.2E-7 torr in 46.5 hours (the vacuum without power was ~5E-8 torr) and 8.4E-8 in 216 hours. At 50 W of input power, the reflected power was 4.23 W and transmitted power was 5.55 W (-9.16 db attenuation.) So the absorbed power was ~40.22W. The attenuation was deteriorated when power was increased (at 8W the attenuation was -10.73 db.) Note: the configuration of the samples were different from other materials to increase attenuation.

V. Conclusion

1. Due to poor vacuum property, MF124, Flexible Absorber and other polymer included materials are not recommended to be used at power level of above 8-10 W in high vacuum environment.
2. Due to porosity related problem, CN-163 SiC is not good for our application too. However if needed, other type of SiC with much less porosity still can be considered.
3. Since AlN-glassy C is no longer available, it is not a candidate either.
4. Ferrite materials such as TT2-111R and Ferrite50 behave well under high vacuum. This is because they are ceramic-like: fine grain, several times of hot processing at high temperature to make ions exchange during fabrication. These features may help them to outperform the simply hot pressed material in high vacuum environment. However such process may affect the repeatability of their E-M parameters. We may need to order and measure more samples to make sure the E-M parameters are consistent.
5. AlN-40%SiC is also a good candidate though its vacuum is a little worse than the above two ferrite materials. If this is due to cutting fluid and lack of thoroughly cleaning, the problem can be avoided easily since samples can be custom made and no cutting process is needed.

Table1 Vacuum Property of Some Microwave Absorbers

	Vacuum (start/no power)	Time (hours to reach max. power)	Vacuum (worst at max. power)	Vacuum Hours at max. power	Vacuum Hours at max. power	Max. Power Forward Transmitted Reflected	Tempera-ture (wave-guide) at max. Power (F)
CMD10	3.5E-5	2.5	3.3E-6	2.6E-6 1.75	Not test for long time	60.0 36.3 2.69	98.2
AlN-glassy C	5.2E-6	7.5	1.8E-5	5.5E-6 3.25	3.4E-7 51.5 (1.7E-8 after another 120 hours' pumping without power, then apply power again)	50.0 4.65 1.00	123.8
TT2-111R	4.0E-7	1.33	1.0E-6	4.9E-7 3.4	Not test for long time	50.0 27.9 2.97	88.4
Ferrite50	1.6E-7	1.33	9.9E-7	2.2E-7 4.0	1.2E-7 24.0	50.0 27.5 2.90	89.8
AlN-SiC	3.7E-7	2.50	4.3E-6	7.0E-7 3.5	1.1E-7 48.0 8.4E-8 216	50.0 4.23 5.55	115.2

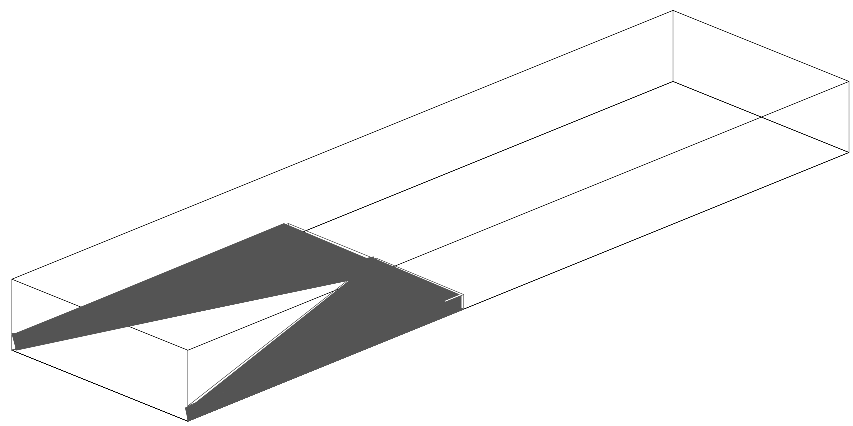

Figure 1. Configuration of TT2-111R, Ferrite50, CMD10 and SiC Samples

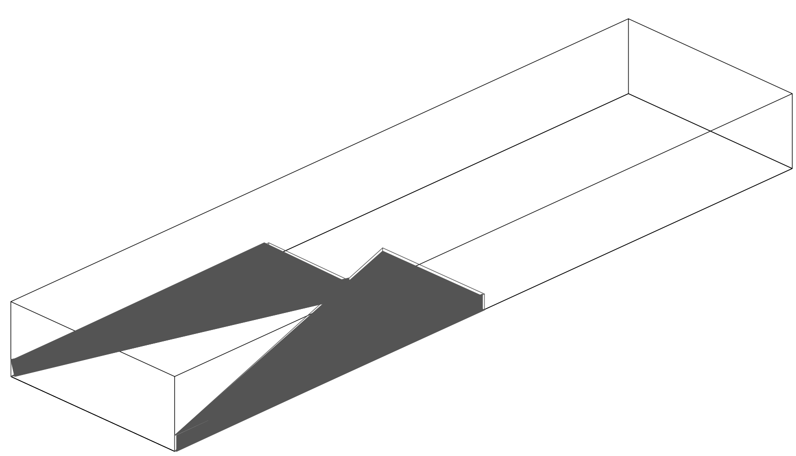

Figure 2. Configuration of AlN Glassy C Samples

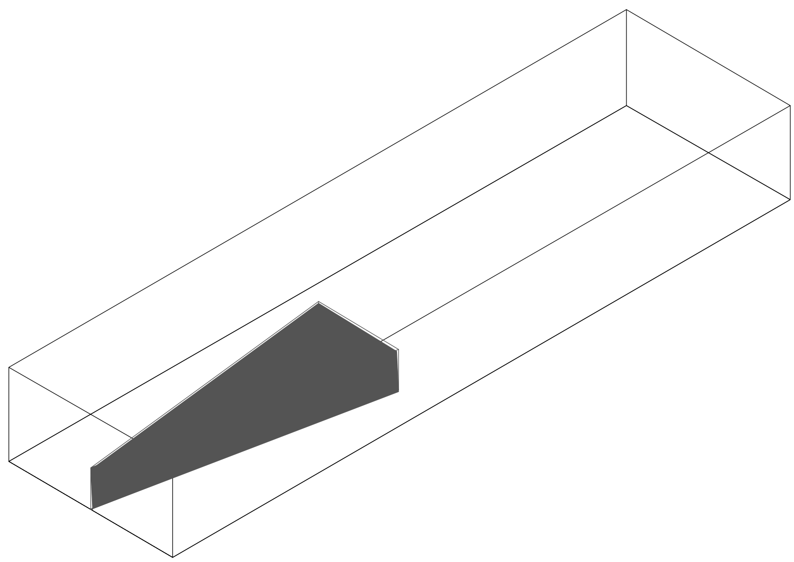

Figure 3. Configuration of AlN-40%SiC Samples