

# EMC tests and properties vs. microstructure for auxetic materials

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**Abstract-** A new class of auxetic materials, a hexachiral honeycomb structure with good mechanical properties, is investigated through computer simulation and measurement. The electromagnetic properties for shielding applications are taken into account. This new material shows some interesting EMC properties (e.g. -40dB transmittance @ 2.4GHz) and promises better performance using different insertion techniques.

## I. Introduction

In the past years, an increasing amount of effort has been invested in the development of new materials, with good mechanical properties, low weight and low cost. In particular auxetic materials benefit from their negative Poisson's ratio and are investigated closely in the last decade [1], [2], [3]. In the same time, we witness an increase in the electromagnetic pollution of the spectrum especially in the free (e.g. 2.4GHz) bands. Coding techniques have been developed to ensure the “peaceful” coexistence of multiple emitter/receiver pairs in the same frequency band. In some cases, these techniques are not sufficient, especially when good shielding for an enclosure is imperative (aeronautics [4], medicine etc.). A natural step forward is to investigate the electromagnetic properties of these materials, in order to provide good electromagnetic shielding.

## II. Computer simulation

### A. Test details

The structure used in tests was a fiber reinforced polymer [5] prototype, developed in the framework of the CHISMACOMB FP6 EU project by the Italcompany (figure 1). The structure is a hexachiral honeycomb, each of the equally spaced cylinders being connected with strings to 6 of his neighbors.

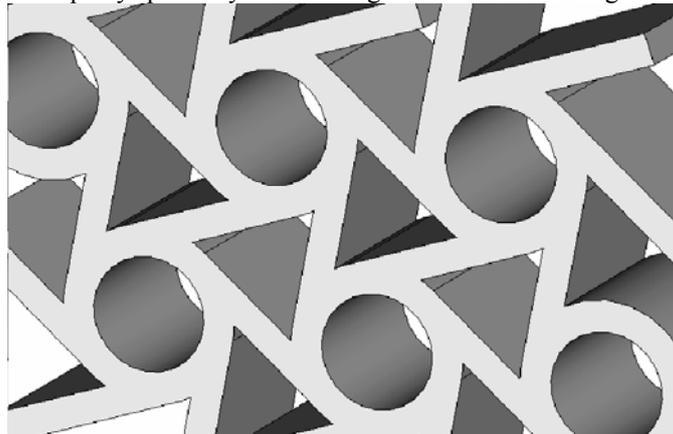
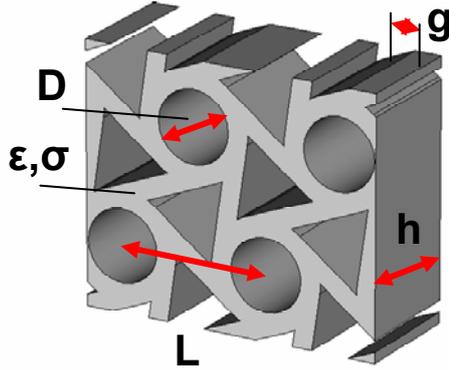


Figure 1. Hexachiral honeycomb

In order to limit the dimensions of the model, the periodicity of the structure has been investigated, the rectangular unit cell is showed in figure 2, the length and width being equal to  $2 \cdot L$  (x direction) and  $L \cdot \sqrt{3}$  (y direction) respectively (where L is the cylinder separation). The typical dimensions used in tests were those of the prototype mentioned above, also shown in figure 2.



Parameter	Value
D	18.58 mm
H	19.75 mm
L	24.72 mm
g	3.3 mm
$\epsilon$	2.5 (4)
$\text{tg } \delta$	0 (0.1-0.5)

Figure 2. Rectangular unit cell and typical dimensions

We investigate the interaction between a plane wave and an infinitely large sheet of auxetic material, at normal incidence. The boundary conditions are set to electric wall (both walls on x directions) and magnetic wall (y direction walls). A input wave port is placed at some space from the structure, the second (exit) wave port is added only when losses inside the structure are taken into account.

The results of the simulation show the S parameters for the structure. The typical shielding parameters reflectance, transmittance and absorption are connected to the S parameters like in equations 1-3.

$$R = |S_{11}|^2 \quad (1)$$

$$T = |S_{21}|^2 \quad (2)$$

$$A = 1 - R - T = 1 - |S_{11}|^2 - |S_{21}|^2 \quad (3)$$

## B. Accuracy of the results

The software product used for the electromagnetic simulation was CST Microwave Studio, which is capable to perform both frequency and FDTD simulations. In order to verify the boundary conditions setup a three layer Jaumann microwave absorber was investigated in the same test setup. The result were found to be identical to those mentioned in the literature [6].

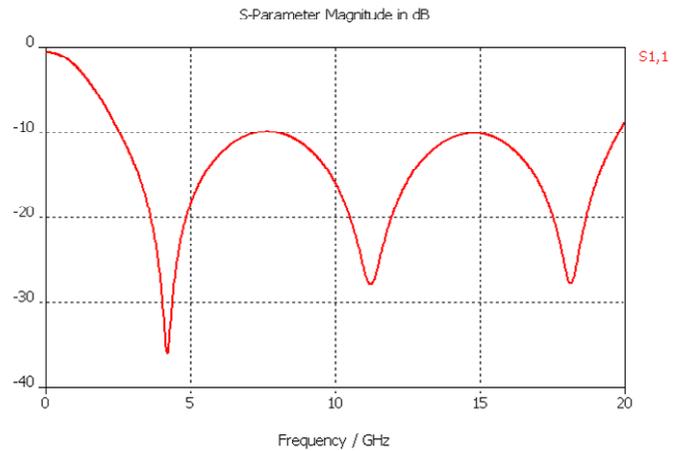
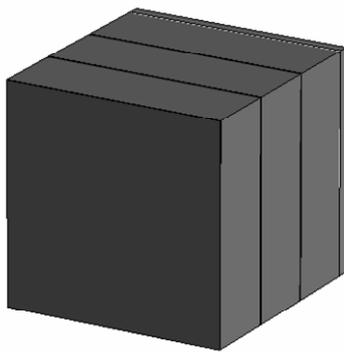


Figure 3. Three layers Jaumann microwave absorber and results

For the hexachiral structure under test, the auxetic layer is illuminated with a plane wave, coming from the z direction, with normal incidence to the material. The polarization of the plane wave is imposed by the electric/magnetic wall boundary conditions, and for correct calculations we expect the electromagnetic fields inside the structure to follow the characteristics of the incident wave. As in figure 4, we find that inside the hexachiral honeycomb, the electric field will have only x direction component  $E_x$ , whereas the magnetic field shows only y direction component  $H_y$ .

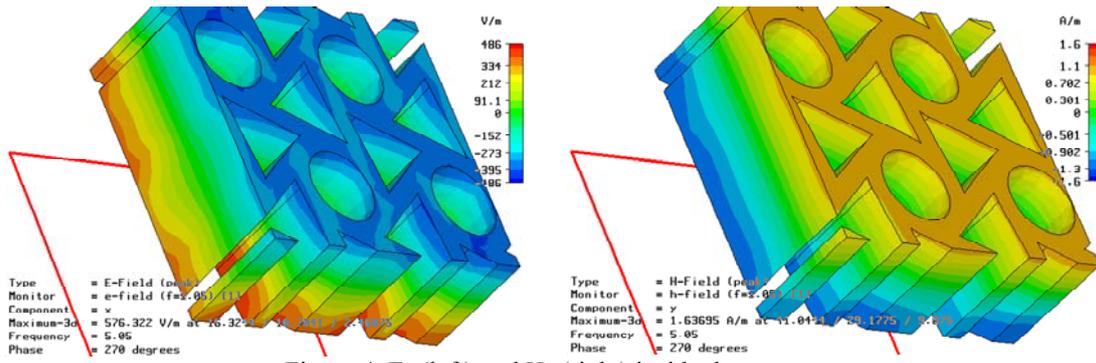


Figure 4.  $E_x$  (left) and  $H_y$  (right) inside the structure

The final test was the comparison between the FDTD and frequency analysis results for the same structure. The two computation methods are not related, even the mesh is different (tetrahedral with PBA – Perfect Boundary Approximation [3] for FDTD and hexahedral for the frequency domain solver). The results are found to be essentially the same (figure 5).

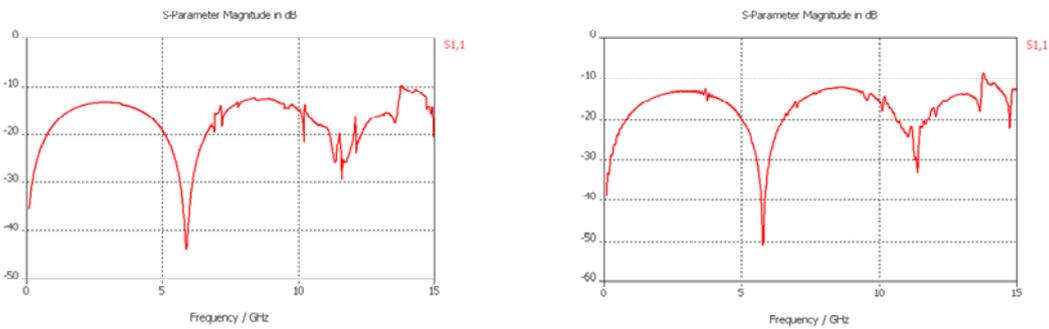


Figure 5.  $S_{11}$  for the lossless structure by frequency (left) and FDTD (right) computation

### C. Parametric analysis

Analysis shows that the chiral structure has almost identical properties (figures 5, 6, 7) with a homogenous layer from the same material, so the mechanical and thermal advantages provided by the structure do not affect the electromagnetic properties in the bandwidth considered (0.1-10 GHz).

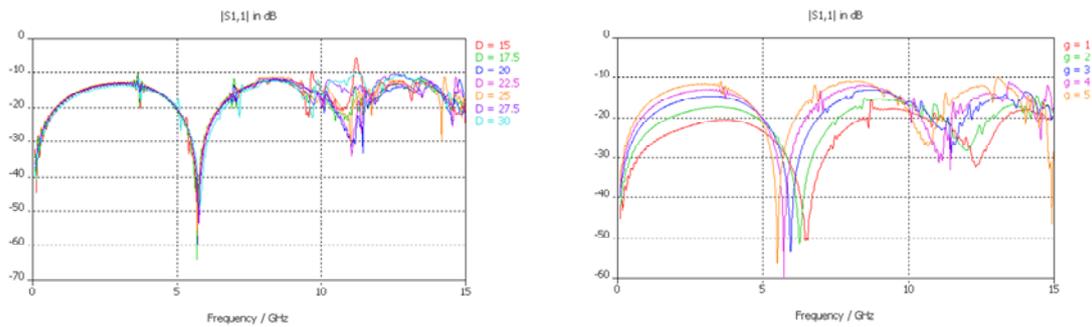


Figure 6. Internal cylinder diameter (D - left) and string width (g - right) influence over  $S_{11}$

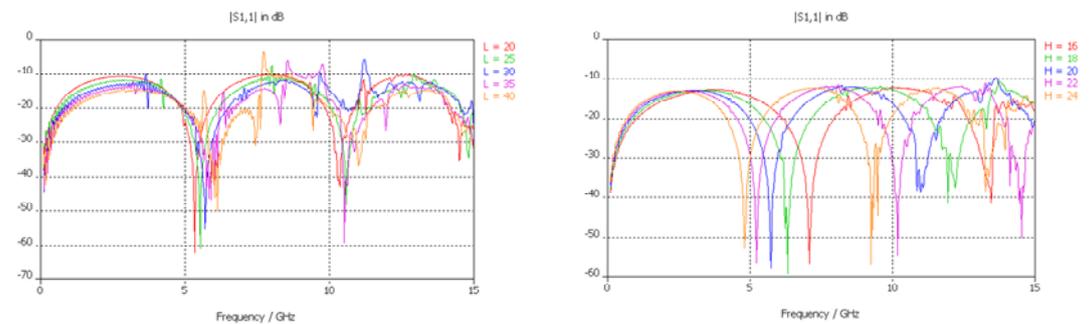


Figure 7. Cylinder separation (L - left) and layers' height (h - right) influence over  $S_{11}$

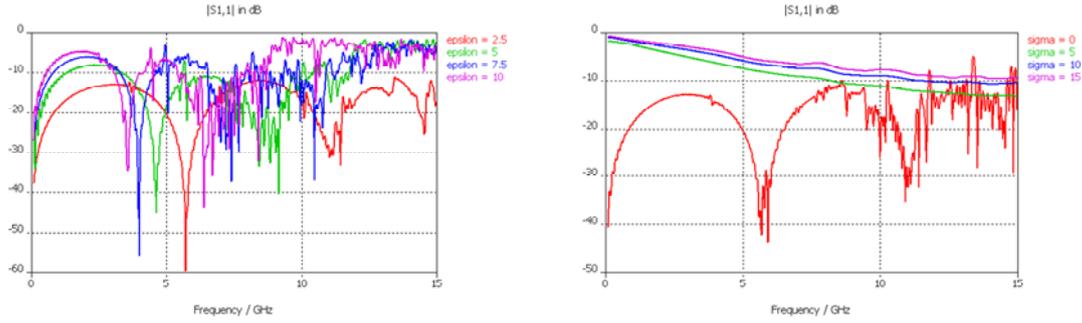


Figure 8. Electrical permittivity ( $\epsilon$  - left) and electric conductivity ( $\sigma$  - right) influence over  $S_{11}$

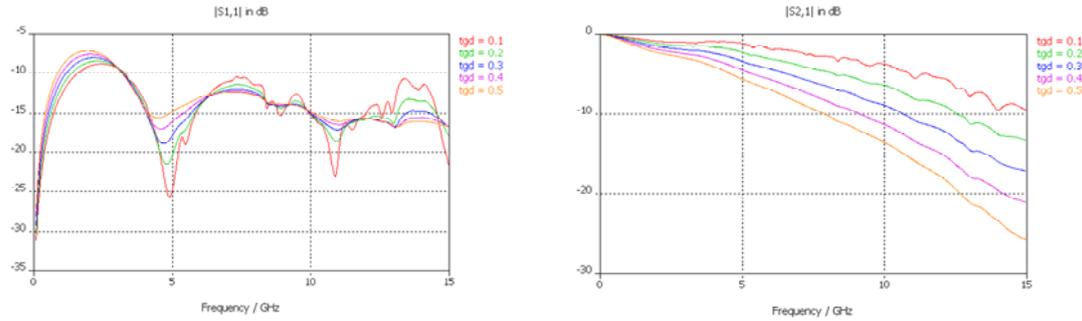


Figure 9. Loss tangent ( $\text{tg } \delta$ ) influence over  $S_{11}$  ( $\epsilon$  - left) and electric conductivity ( $\sigma$  - right)  $S_{11}$

Parametric studies investigated the effect of the dimensions ( $L$ ,  $D$ ,  $h$ ,  $g$ ) and material properties ( $\epsilon$ ,  $\sigma$ ,  $\text{tg } \delta$ ). Figures 6-7 show the influence of  $D$ ,  $g$ ,  $L$ ,  $h$  (in this order) for the lossless dielectric over the reflection coefficient ( $S_{11}$ ), and figures 8-9 show the influence of  $\epsilon$ ,  $\sigma$ ,  $\text{tg } \delta$  over reflection coefficient ( $S_{11}$ ) or over the transmission coefficient ( $S_{21}$ ) when losses are taken into account. An interesting conclusion is the almost undetectable influence of the cylinder diameter ( $D$ ) and cylinder separation ( $L$ ) over the shielding properties, meaning that those parameters can be chosen strictly from mechanical and thermal considerations. Others parameters offers the expected results, e.g. lower transmission with greater losses ( $\text{tg } \delta$ ), increased string width ( $g$ ) and zero frequencies variation with layers' height ( $h$ ).

### III. Measurements

#### A. Measurements detail

Measurements were performed using an E7405A EMC spectrum analyzer, E8257 PSG Analog Signal Generator, a horn antenna and a GTEM Cell. In this case an  $\sim 0.5$ mm thick aluminum foil (typical case in shielding applications) was applied on one side of the layer, and the bandwidth investigated was around the free 2.4 GHz band (e.g. 1.5-3 GHz). Multiple measurements were performed with different power levels at the generator (0 dBm, -10 dBm, -20 dBm) and were repeated seven times [7].

#### B. Measurements results

The measured transmitted power (figure 10) and the computed transmittance (figure 11) are plotted.

The measured values show good repetitive values. The transmittance at 2.4GHz (the free bandwidth of interest) has an interesting value of -40dB transmission (figure 11) which denotes that the structure under test can clearly be used as a microwave absorber, this values being typical for a good microwave absorber.

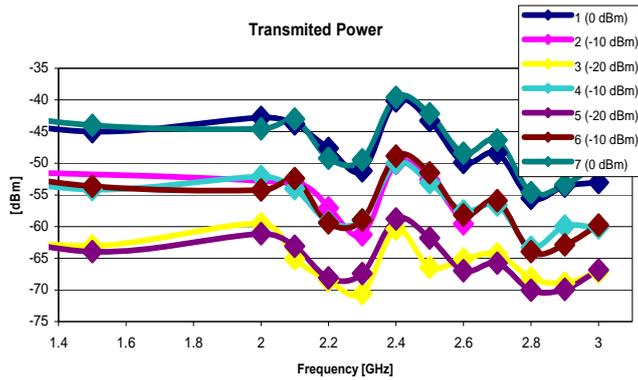


Figure 10. Transmitted power, measured out of the receiving antenna

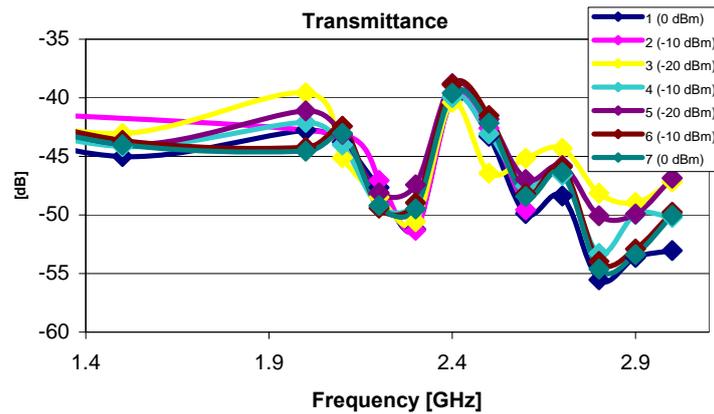


Figure 11. Hexachiral structure transmittance

#### IV. Conclusions

The evaluation of the intrinsic electromagnetic properties of an auxetic material was made. The results show that the performance of the hexachiral structure is equivalent to a homogenous dielectric layer, some of the properties being influenced by the specific geometry of the structure. The same structure which offers good mechanical and thermal behavior gives access to some improvement techniques. This work will be followed by the investigation of the possibility to improve those properties through the use of insertions, metallization etc.

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