FINAL TECHNICAL REPORT

Structural Composites with Tuned EM Chirality

AFOSR Grant # FA9550-08-1-0399

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Technical detail: An array of metallic coils lacks a plane of symmetry, unless a combination of right- and left-handed coils is used, e.g., Figure 1 (left). Hence a medium containing similar coils will exhibit chirality due to the coupling between the electric and magnetic field vectors. An incident oscillating electric filed creates a solenoidal current in the coil which in turn creates an in-phase (with the electric field) magnetic field; See Figure 1. The resulting superposition gives rise to the coupled overall constitutive relation.

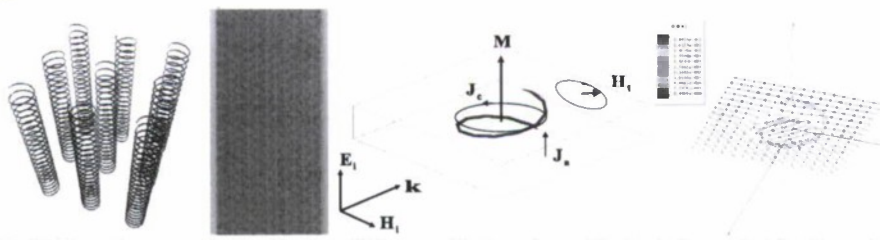

Figure 1: (Left) Alternating array of coils. (Center left) A woven fabric made up of braids in the vertical direction and unwoven fiber bundles in the horizontal direction, to be resin-impregnated. (Center right) The axial electric field E_i creates a charge density in the coil and unit cell with two components: axial J_a and circumferential J_c. The axial component causes the plasmonic behavior and modifies the dielectric constant. The circumferential current density induces a magnetic dipole M which is out of phase with the incoming H_i. The total magnetic field H_t is not linearly polarized, but rather elliptically polarized. (Right) Magnetic ield patterns calculated for a unit cell of a coiled medium using Ansoft-HFSS. The wave is propagating along the *x*-axis and the fields on the two *yz*-faces have 50° phase difference (the wavelength is 360/50 times the length of the cell in the *x*-direction). The electric field vector of the incoming wave on the far *yz*-face is at this time polarized parallel to the axis of the coil.

We have developed and implemented methods to predict the overall EM properties tensors including the coupling tensors based on the geometry and microstructure of an array of scattering elements, and fabricated and measured both the EM and mechanical properties of some simple typical samples under the present seedling funding. Figure 2 shows our measured stress-strain relations for a typical braid under both dry (left) and resin-impregnated conditions (center), in preparation for developing braided structural composites with controlled EM chirality. In Figure 2 (right) we show a typical (measured) EM data for a woven composite with embedded alternating left- and right-handed copper coils. We are preparing an experimental setup to measure the chirality parameters as well as the dielectric constant for fully left- or right-handed structures.

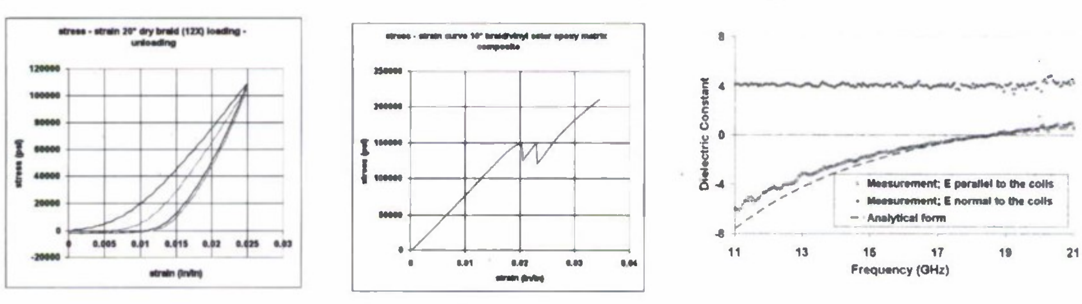

Figure 2: The overall material properties of braided composites. (Left) Dry braid stress-strain curve. (Center) Stress-strain relation changes substantially after addition of resin. (Right) The dielectric constant of a woven composite with alternating left- and right-handed copper coils, measured using focused-beam EM characterization setup.

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14. ABSTRACT

We have developed and implemented methods to predict the overall EM properties tensors including the coupling tensors based on the geometry and microstructure of an array of scattering elements, and fabricated and measured both the EM and mechanical properties of some simple typical samples under the present seedling funding. Figure 2 in the report, shows our measured stress-strain relations for a typical braid under both dry (left) and resin-impregnated conditions (center), in preparation for developing braided structural composites with controlled EM chirality. In Figure 2 (right) we show a typical (measured) EM data for a woven composite with embedded alternating left- and right-handed copper coils. We are preparing an experimental setup to measure the chirality parameters as well as the dielectric constant for fully left- or right-handed structures.

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Structural Composites with Tuned EM Chirality

Technical Objectives:

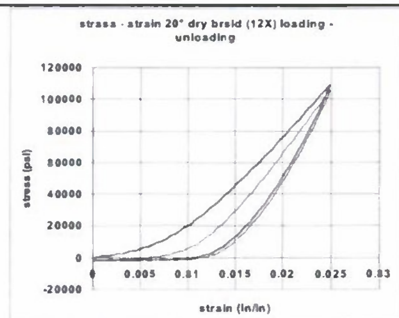
- Design, fabrication and experimental measurement of the EM and mechanical properties of metallic coil – polymer braid composites
- Extraction of the coupled material tensors from numerical simulations
- Elimination, enhancement, and control of chirality coefficients and mechanical properties by design

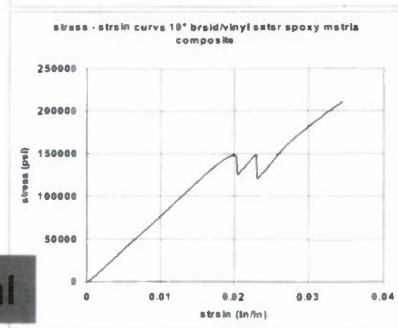
Accomplishments/Payoffs

- We are now capable of producing chiral composites within a range of microwave frequencies and mechanical attributes
- We have developed analytical and numerical methods to predict the chiral material constants
- We have made preliminary measurements of both mechanical and EM properties of chiral composites; see below

Approaches:

- Numerical and analytical modeling of various chiral microstructure and prediction of the overall response
- Novel composite fabrication methods such as double-coiling
- Direct experimental measurement of the overall response

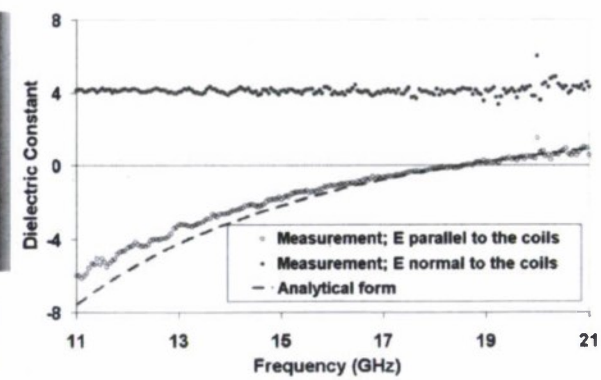




mechanical

Results:

EM



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