Epsilon-near-zero (ENZ) Materials as Insulators for Nanocircuit Elements

M. G. Silveirinha[1,2] and N. Engheta[1]

[1]University of Pennsylvania, USA
[2]Universidade de Coimbra, Portugal

There has been a growing interest in research on metamaterials with negative parameters, i.e., double-negative (DNG) or single-negative media [1, 2]. However, metamaterials with other unconventional material parameters have also attracted a great deal of attention. One class of such materials is the media in which the relative permittivity and or permeability is near zero. These materials, which can be referred to as epsilon-near-zero (ENZ) or mu-near-zero (MNZ), have been the subject of study recently [3, 4]. We have shown theoretically that electromagnetic or optical waves may be able to tunnel through very narrow channels or waveguide bends filled with ENZ materials, and that this property can play an interesting role in reducing the reflectivity at certain waveguide bends. It has also been shown that zero-index materials can be used to narrow the far-field pattern of an antenna embedded in the medium and to transform curved wavefronts into planar ones.

In the present work, we explore another interesting feature of ENZ materials, namely, their role as insulators for nano-scale circuit elements at the infrared (IR) and visible frequencies. The concept of circuit elements in the optical domains, i.e., nanoinductors, nanocapacitors, and nanoresistors has been introduced recently [5], in which it was suggested that plasmonic and non-plasmonic nanoparticles can behave as circuit elements, i.e., inductor and capacitor, at optical frequencies. One of the interesting questions in this context is the following: "Can we have an equivalent of "insulators" or "shields" for such nanocircuit elements at the optical frequencies that minimizes the coupling between the circuit elements?". One possible answer to this question is the use of ENZ layers as insulating shields around optical nanoelements. Our theoretical analysis has shown that such layers can, under certain circumstances, indeed act as insulators supporting zero displacement current, resulting in the confinement of the displacement current inside the nanoparticles. Therefore, ENZ-shielded nanocircuit elements can be regarded as elements with lesser leakage coupling among neighboring nanoelements.

In this talk, we will present some of our theoretical results, and we will forecast some future ideas and potential applications for this concept.

REFERENCES

1. Ziolkowski, R. W. and N. Engheta (Guest editors), Special issue of *IEEE Transactions on Antennas and Propagation on metamaterials*, Vol. 51, No. 10, October 2003.
2. Itoh, T. and A. A. Oliner (Guest Editors), Special issue of *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, No. 4, April 2005.
3. Engheta, N., M. Silveirinha, A. Alù, and A. Salandrino, "Scattering and reflection properties of low-epsilon metamaterial shells and bends," *2005 International Conference in Electromagnetics in Advanced Applications*, Turino, Italy, September 12–16, 2005.
4. Ziolkowski, R. W., "Propagation in and scattering from a matched metamaterial having a zero index of refraction," *Physical Review E*, Vol. 70, 046608, 2004.
5. Engheta, N., A. Salandrino, and A. Alù, *Physical Review Letters*, Vol. 95, 095504, August 2005.