NAmiceMC: Nano-thin and micro-sized carbons: Toward electromagnetic compatibility application

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External collaborating Institutions:
- University of Lorraine, France,
- Laboratory of Electrodynamics of Inhomogeneous Media at the Institute of Nuclear Problems of Belarusian State University,

We participate as a partner (the INFN unit) to the PEOPLE MARIE CURIE ACTIONS International Research Staff Exchange Scheme Call: FP7-PEOPLE-2013-IRSES. FAEMCAR has a duration of 48 months and started its activities in the fall 2013, PIRSES-GA-2013-610875. The consortium binds together two Universities and one Research Organization.

Project objectives:

The main aim of the project is to provide comparative study of EM shielding effectiveness of carbon foams, carbon ultra-thin films and epoxy/carbon composites with low filler concentration in microwave frequency range and to support the experimental data with an adequate theoretical model of materials' electromagnetics. On the basis of our theoretical simulations and experimental database collected within the project implementation, we intend to contribute to solving one of the most challenging problem in material science: developing EM coating through design-oriented-approach. In the GHz range, due to increasing utilization in EM materials of novel nanostructures, the classical electromagnetic compatibility (EMC) faces new problems, while traditional electromagnetic methods gain new life in their application to new objects. The first aim of the project is to reach a high enough mitigation of the microwave radiation with as small as possible concentration of carbon additives in order not to destroy well-known properties, mechanical and thermal, of polymer used for composites fabrication. Our philosophy is to provide, through a joint synergetic work of participants experienced in condensed-matter physics, chemistry, micro- and nano-carbon synthesis, electromagnetic theory / modeling and functional characterization, not only a detailed experimental analysis for many different densities, and different thicknesses of the samples, but also to provide a consistent theory which will model electromagnetics of these highly non-regular structures, where the typical sizes could be compatible with the wavelength in the material.

Project achievements in 2015:

The remarkable properties of high-surface area carbons, compatible in that with carbon nanotubes, provide a tremendous opportunity for fabrication, even at very low filler concentrations, of composites with outstanding electrical and electromagnetic properties. Due to their multifunctional properties, carbon/polymer composites can be widely used as relatively low weight and ultra-thin effective electric and optical components, as well as electromagnetic (EM) shielding and absorbing coatings. At the same time, ultra-lightweight carbon foams, being highly conductive, are expected to have very high EM shielding ability due to their cellular structure. Moreover, carbon foams have extremely low cost, and demonstrate outstanding thermal insulation / fire resistant and good mechanical properties. Along

with polymer/carbon composites and highly conducting porous carbon monoliths, one more very attractive object for investigation its electromagnetic properties is ultrathin carbonaceous film - pyrolytic carbon or a few layer graphene. We expect that they could absorb up to 50% of the incident microwave power despite the fact that their thickness is only a small fraction of the skin depth. The idea of the project is to provide comparative study of EM shielding effectiveness of carbon foams, carbon ultra-thin films and epoxy/carbon composites with low filler concentration in microwave frequency range and to support the experimental data with an adequate theoretical model of materials' electromagnetics. On the basis of our theoretical simulations and experimental database collected within the project implementation, we intent to contribute into solution of one of the most challenging problem in material science: to develop EM coating through design-oriented-approach.
The electromagnetic response of a heterostructure based on a monolayer of hollow glassy carbon spheres packed in 2D was experimentally surveyed with respect to its response to microwaves, namely, the Ka-band (26–37GHz) frequency range. Such an ordered monolayer of spheres mimics the well-known "moth-eye"-like coating structures, which are widely used for designing anti-reflective surfaces, and was modelled with the long-wave approximation. Based on the experimental and modelling results, we demonstrate that carbon hollow spheres may be used for building an extremely lightweight, almost perfectly absorbing, coating for Ka-band applications.
This result published in Appl Phys Lett in the beginning of 2016 got a wide scientific community interest, being advertised in Science daily "Antireflective Coating: Sugar-based carbon hollow spheres that mimic moth eyes" and many other sorces, see e.g.

http://www.sciencedaily.com/releases/2016/01/160105223546.htm

http://myinforms.com/en/a/21483349-antireflective-coating-sugar-based-carbon-hollow-spheres-that-mimic-moth-eyes/

http://uk.anygator.com/article/sugar-based-carbon-hollow-spheres-that-mimic-moth-eyes__4500078
http://gizmodo.com/these-sugar-based-anti-reflective-fake-moth-eyeballs-ar-1751205484

Special sessions on Fundamental and Applied Nanoelectromagntics NATO Advanced workshop, FANEM, Minsk, Belarus, 25-27 May 2015 devoted to NAMICEMC project was organized. Three tutorials were delivered by Project coordinator and two partners PIs.
A. Celzard, "Carbon, a unique model material for condensed matter physics and engineering science"
S. Bellucci, "Electrical conductivity of graphene: a time-dependent density functional theory study"
P. Kuzhir, "Carbon periodic cellular architectures at high frequencies: metamaterial and photonic crystal"

A special session on annual conference "Nanoscience & Nanotechnology 2015" Frascati, Rome, Italy, 2-5 October 2015 devoted to NAMICEMC project was organized.

Publications by LNF Authors in the Year 2015

1. Kranauskaite, J. Macutkevic, J. Banys, N. Volynets, A. Paddubskaya, P. Kuzhir, S. Maksimenko, V. Fierro, A. Celzard, S. Bistarelli, A. Cataldo, F. Micciulla, S. Bellucci, Broadband dielectric spectroscopy of composites filled with various carbon materials, IEEE Transactions on Microwave Theory and Techniques, Volume:63 , Issue: 6 2015 DOI:10.1109/TMTT.2015.2418758

2. V.M. Levin, Y.S. Petronyuk, E.S. Morokov, A. Celzard,S. Bellucci, P.P. Kuzhir
What does see the impulse acoustic microscopy inside nanocomposites?
Physics Procedia 70 (2015) 703–706

3. V.M. Levin, Yu.S. Petronyuk, L.A. Chernozatonskii, A. Celzard, V. Fierro, J. Macutkevic, P.P. Kuzhir, A.G. Paddubskaya, M.A. Pletnev, F. Micciulla and S. Bellucci, Microstructure, elastic and electromagnetic properties of epoxy-graphite composites, AIP Advances 5, 067137 (2015); http://dx.doi.org/10.1063/1.49228722014 International Conference on, Pages 1-4, IEEE Editor, 2014

List of Conference Talks by LNF Authors in the Year 2015

P. Kuzhir, S.A. Maksimenko, V. Fierro, A. Celzard, J. Macutkevic, S. Bellucci. Carbon porous structures for microwave applications. Nanoscience & Nanotechnology 2015, INFN-Laboratori Nazionali di Frascati (Italy) 28 September – 2 October 2015.

S. Bellucci, "Electrical conductivity of graphene: a time-dependent density functional theory study", Fundamental and Applied Nanoelectromagntics NATO Advanced workshop, FANEM, Minsk, Belarus, 25-27 May 2015