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

S. Bellucci (Resp. INFN), I. Aguzzi (bors.), R. Baldini (Tecn.), S.Bistarelli (Dott.), A. Cataldo (assegnista.), F. Micciulla (assegnista), I. Tabacchioni (bors.)

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. NAmiceMC 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 current state of the art in the development of terahertz and microwave electromagnetic (EM) materials is determined, in many respects, by the success in the design, fabrication and tailoring of artificial composite materials. Such materials can often exhibit pronouncedly properties (chirality, anisotropy, nonlinearity) unattainable on such a high level in natural media. Conductive polymer composites find large-scale applications as antistatic materials, in printed electronics, super capacitors, organic solar cells, biosensors, flexible transparent displays, etc. In spite of the practical limitations of use because of their confined processability and manufacturing cost, dc and ac conductive composites are rapidly gaining attention in new applications such as packaging for electronics and chemical industry, metal replacement, heating elements and fuel cells, and for electromagnetic shielding and absorption in GHz frequency ranges, where traditional radar materials, if not completely inapplicable, lose their attractiveness due to rising consumer wants.
Among various fillers, different forms of carbon, such as carbon black, carbon fibers, carbon nanotubes (CNTs) and their mixtures, exfoliated graphite (EG), graphene-related materials, onion-like carbon, turned out to be especially attractive for the design of EM materials giving the benefit of both lightweight and chemical inertness. This is because carbon is indeed a model material, whose morphology and properties strongly depend on the structure at the atomic level. Carbon fillers can thus be totally isotropic (as in the case of some carbon blacks and coals, whose porosity can be tailored by activation) or highly anisotropic (carbon nanotubes and graphite flakes, the latter being available with different aspect ratios, from thick graphene to oblate ellipsoids).

Project achievements in 2016:

In 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.
There are a number of ways to produce new advanced EMC materials on the carbon basis. The first one is already mentioned idea to achieve the synergy of well-known properties of host polymers, e.g. epoxy resin, with new potentialities originating from the fillers and providing the multifunctionality of the coatings and tailoring their properties. For example, CNTs, with their extraordinary mechanical

properties and unique electronic structure, being incorporated into the polymer matrix demonstrate impressive shielding. Due to the high aspect ratio of carbon nanotubes, a low percolation threshold is expected to be observed, which is an important issue for producing effective electromagnetic coatings with extremely low content of nanocarbon inclusions, providing the maximal values of EM reflection/absorption. In our papers we have reported a low percolation threshold of CNT-based polymer composites.
The exfoliated graphite flakes also imparts excellent electrical properties to the polymer composites. Due to the skin effect (i.e., the phenomenon that high frequency electromagnetic radiation only interacts with some surface region of a conductor), a high surface area of the conductor is desirable.
Based on the results reported in our data, the remarkable properties of high-surface area carbons (like exfoliated graphite or activated carbon), compatible in that with carbon nanotubes (CNT), provide a tremendous opportunity for fabrication, even at very low filler concentrations, of composites with outstanding electrical and electromagnetic properties far above those of base polymers.
We made progress to fully exploit, because of their multi-functional properties, carbon/polymer composites as lightweight and thin effective electric components, optical devices, thermal interface and structural materials, as well as electromagnetic shielding and absorbing coatings and conformal materials for structurally integrated RF antennas.

A special session on annual conference "Nanoscience & Nanotechnology 2016" Frascati, Rome, Italy, September 26 - September 29, 2016, devoted to NAMICEMC project was organized.

Publications by LNF Authors in the Year 2016

1. The cluster architecture of carbon in polymer nanocomposites observed by impulse acoustic microscopy
V Levin, Y Petronyuk, E Morokov, L Chernozatonskii, P Kuzhir, V Fierro, ...
physica status solidi (b) 253 (10), 1952-1959 (2016)

2. Bulk microstructure and local elastic properties of carbon nanocomposites studied by impulse acoustic microscopy technique
V Levin, Y Petronyuk, E Morokov, L Chernozatonskii, P Kuzhir, V Fierro, ...
AIP Conference Proceedings 1736 (1), 020056 (2016)

List of Conference Talks by LNF Authors in the Year 2016

S.Bellucci, Electromagnetic properties of nanocomposite materials, Univ. Cassino Departmental Seminar, May 13, 2016