SEMS: Spectroscopies, Electron correlations, Modeling-Simulations and low-dimensional systems

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Progress in 2016

We thoroughly investigated the possibility of Graphene Related Materials (GRM) to be used in a wide range of applications, focusing on electronics and energy fields. Beside these topics, we studied the possibility of using composites of epoxy resins and GNP (Graphene NanoPlatelets) for electromagnetic shielding applications, finding as a result attenuation of the electromagnetic signal at a level at least 10 dB in power for a film thickness of 1.1 mm (26–37 GHz), and in broadband range a significantly improve of the electromagnetic properties due to an annealing process, i.e. dc conductivity of epoxy filled with 4 wt% GNP 68 times higher. The so prepared samples were observed with a high-resolution ultrasonic technique allowed us to reveal the cluster architecture of the nanoparticle distribution and possible nonuniformity. In addition, modeling a graphene-based multilayer helped us to understand how a multilayer composite can absorb electromagnetic wave with a view to a shielding application.
In the electronics field, a GNP thin film was used for a tunable attenuator device. The GNP patch was deposited in two configurations (see Fig. 1), first in the gap of a microstrip line and secondly, as a novel enhanced design, two graphene patches located between the main microstrip line and two metal vias. The results show for the first configuration a wide band functionality from DC to 20 GHz, with a tunability of 7 dB and minimum insertion loss of 5 dB, and for the second an operation in a frequency band of DC to 5 GHz, with 14 dB tunability and minimum insertion loss of 0.3 dB.

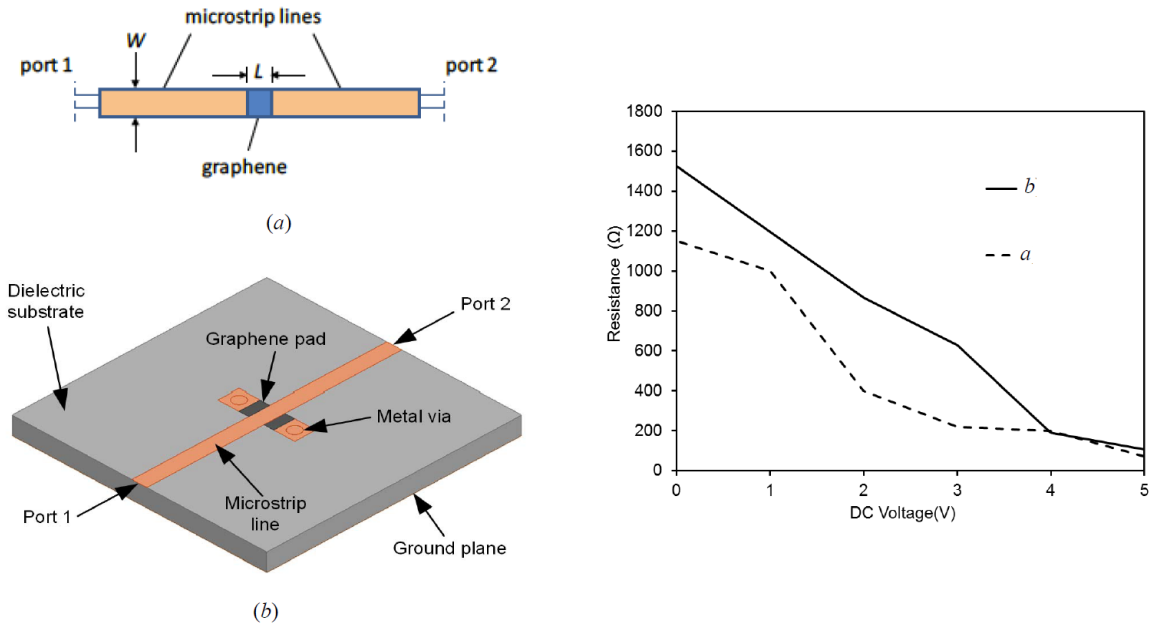

Figure 1 Geometry of the graphene-based tunable microstrip attenuator and Bias Voltage vs. Graphene resistance for two configurations. (a) Preliminary microstrip attenuator with the graphene pad located in a gap of the microstrip line. (b) Enhanced microstrip attenuator with symmetrical graphene pads, located between the microstrip line and grounded vias.

The same GNP thin film with a linear microstrip configuration (gap between copper strip 100 micron) was also used as a low-cost gas sensor using the variation of dc conductivity of the circuit to recognize the presence of the gas. Furthermore, the so fabricated microstrip showed the possibility of fabricating carbon based interconnects with large dimensions with thermally stable electrical resistance, with almost zero or even negative temperature coefficient of the resistance.

For energy applications, we produced a three phase composites. GNP were decorated with copper nanoparticles dispersed in poly(3,4-ethylenedioxythiophene): polystyrenesulfonic acid (PEDOT:PSS) as conducting polymer matrix. The obtained composite has good film forming properties and resistance (of about 380 W). The proposed low-temperature solution process opens a new approach to manufacturing of low-cost transparent (in the case of very thin films) and conductive electrodes. A second approach in this field is regarding the possible interaction between GNP and quantum dots. The interest to graphene-quantum dots composite is caused by the possibility to combine high absorption ability of quantum dots with high charge carrier mobility in graphene, what is of great importance for many electronic devices. We have studied two systems: (i) CdSe nanoplatelets with graphene nanoplatelets in poly-N-epoxypropylcarbazole and (ii) CdSe spherical nanoparticles with graphene nanoplatelets in MEH-PPV. Two maxima in the luminescence spectra of CdSe nanoplatelets were found, based on efficient absorption of photons between the neighbouring nanoplatelets. It was found that luminescence of the samples was weak both for polymer and nanoparticles indicating the luminescence quenching. Moreover, the luminescence of the active particles was found to be different in various places of the sample, being strongly dependent on the graphene type (stronger luminescence was observed in graphene with smaller number of defects). These results should be taken into account in the design of luminescent devices for energy applications.

Finally the charge scattering from spatially asymmetric antidots patterned on graphene has been investigated, in the ballistic scale. This work can be the basis for a systematic study of the Ratchet effect in the above kind of structure. A completely deterministic characterization of this effect was

proposed, based on the scattering of asymmetric defects under external electromagnetic excitation. The Ratchet effect could be usefully exploited to realize high frequency detectors, sensors, and harvesting devices.

Awards in the Year 2016

The paper: S. Bistarelli, Shuangxi Sun, J. Liu, L. Pierantoni, S. Bellucci and D. Mencarelli,
"Development of a numerical tool to characterize hybrid CNT-copper interconnects"
was awarded the First Prize at the IEEE Microwave Theory and Techniques Society (MTT-S) 2016 International Microwave Symposium (IMS2016) in San Francisco, California, (student design competition)
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7779296
with an App developed for Radio Frequency Nanotechnology.

The paper: M. Yasir, M. Bozzi, L. Perregrini, S. Bistarelli, A. Cataldo, and S. Bellucci,
"Innovative Tunable Microstrip Attenuators Based on Few-Layer Graphene Flakes,"
was awarded the Second Award in the Best Student Paper Competition at the
16th Mediterranean Microwave Symposium (MMS2016), Abu Dhabi, UAE, Nov. 14-16, 2016.

List of Conference Talks in the Year 2016

F. Micciulla, A. Cataldo, S. Bellucci, and A. Maffucci, A Low-Cost Gas Sensor based on a Self-Assembled Graphene Nanoplatelets Contact, 2nd Internal Forum on Research and Technologies for Society and Industry, Technologies for smarter societies, IEEE RTSI, Bologna, Italy, 7-9 Sept. 2016

S. Bellucci "Graphene materials for electronics: microwave-photonic devices (Lecture I and Lecture II", RIAPA-LDS2016 School Tabriz, May 24-25, 2016.

S. Bistarelli "Development of a numerical tool to characterize hybrid CNT-copper interconnects" IEEE Microwave Theory and Techniques Society (MTT-S) 2016 International Microwave Symposium (IMS2016) San Francisco, California May 22-27, 2016,

M. Yasir, M. Bozzi, L. Perregrini, S. Bistarelli, A. Cataldo, and S. Bellucci,
"Innovative Tunable Microstrip Attenuators Based on Few-Layer Graphene Flakes,"
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Publications by LNF Authors in the Year 2016

1. Ballistic Ratchet effect on patterned graphene, S Bellucci, L Pierantoni, D Mencarelli
Integrated Ferroelectrics 176 (1), 28-36 (2016)

2. Defect-induced blue luminescence of hexagonal boron nitride
B Berzina, V Korsaks, L Trinkler, A Sarakovskis, J Grube, S Bellucci
Diamond and Related Materials 68, 131-137 (2016)

3. Innovative tunable microstrip attenuators based on few-layer graphene flakes, M Yasir, M Bozzi, L Perregrini, S Bistarelli, A Cataldo, S Bellucci,
Microwave Symposium (MMS), 2016 16th Mediterranean, 1-4 (2016).

4. Ab initio modelling of dielectric screening and plasmon resonances in extrinsic silicene
CV Gomez, M Pisarra, M Gravina, S Bellucci, A Sindona
Research and Technologies for Society and Industry Leveraging a better r tomorrow (RTSI), 2016 IEEE 2nd International Forum on.

5. A low-cost gas sensor based on a self-assembled graphene nanoplatelets contact
F Micciulla, A Cataldo, S Bellucci, A Maffucci
Research and Technologies for Society and Industry Leveraging a better r tomorrow (RTSI), 2016 IEEE 2nd International Forum on.

6. Efficient and versatile graphene-based multilayers for EM field absorption
D Mencarelli, L Pierantoni, M Stocchi, S Bellucci
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A Maffucci, F Micciulla, A Cataldo, S Bellucci, G Miano
Signal and Power Integrity (SPI), 2016 IEEE 20th Workshop on, 1-4

8. Bottom-up realization and electrical characterization of a graphene-based device
A Maffucci, F Micciulla, A Cataldo, G Miano, S Bellucci
Nanotechnology 27 (9), 095204 (2016)

9. Plasmon Modes in Extrinsic Graphene: Ab initio Simulations vs Semi-classical Models
A Sindona, M Pisarra, D Mencarelli, L Pierantoni, S Bellucci
Fundamental and Applied Nano-Electromagnetics, 125-144 (2016).
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10. Volume reflection and channeling of ultrarelativistic protons in germanium bent single crystals
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11. On Extensions of the Optical Optimization
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M Ćosić, S Petrović, S Bellucci
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Universal Journal of Engineering Science 4(3): 45- 49, 2016

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14. 3rd International Symposium" Optics and its Applications" Yerevan, Armenia, October 1-5, 2015
David Blaschke, Gagik Buniatyan, Narine Gevorgyan, Angela M Guzman, Aram Papoyan, Katarina Svanberg, Irina Dolganova, Astghik Kuzanyan, Gernot Alber, Stefano Bellucci, Michael Berry, Aranya Bhattacherjee, Humberto Cabrera, Maria L Calvo, Vladimir Derbov, Aigars Ekers, Dmitry Firsov, Gayane Grigoryan, Eduard Kazaryan, Arsen Khvedelidze, Albert Kirakosyan, Levon Mouradian, Armen Nersessian, Lorenzo Pavesi, William Rhodes, David Sarkisyan, Marat Soskin, Sune Svanberg, Sergue Vinitsky, Stanislav Yurchenko, Ruben Zadoyan, 2016 Journal of Physics: Conference Series Volume 673 Pages 011002 (2016)

15 2nd International Symposium" Optics and its Applications" Yerevan-Ashtarak, Armenia, September 1-5, 2014
Gagik Buniatyan, Maria L Calvo, Narine Gevorgyan, Angela M Guzman, Joseph Niemela, Aram Papoyan, Hayk Sarkisyan, David Sarkisyan, Roman Alaverdyan, Levon Aslanyan, Marcis Auzinsh, Stefano Bellucci, Michael Berry, Aranya Bhattacherjee, Konstantin Bliokh, Dmitry Budker, Vigen Chaltykyan, Miltcho Danailov, Carlos Duque, Vladimir Gerdt, Gayane Grigoryan, Rafik Hakobyan, Alexey Kavokin, Eduard Kazaryan, Arsen Khvedelidze, Albert Kirakosyan, Radik Kostanyan, Takayuki Miyadera, Levon Mouradian, Atom Muradyan, Armen Nersessian, Avinash Pandey, Luis Ponce, Hartmut Ruhl
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