3D Porous Graphene Based Aerogel for Electromagnetic and Sensing Applications

Hossein C. Bidsorkhi, Alessandro G. D'Aloia, Alessio Tamburrano, Giovanni De Bellis, Maria Sabrina Sarto

Department of Astronautic, Electric and Energy Engineering, Sapienza University of Rome
Research Center for Nanotechnology applied to Engineering (CNIS)
Via Eudossiana 18, Rome, 00184 Italy

Recently, there has been a great demand for polymeric materials with excellent electrical performances and high mechanical strength in the electronic industries [1]. Conventional polymeric materials are insulators and can be made conductive by adding large volume fractions of conducting fillers in micrometres size [2]. However, high filler loadings generally result in low mechanical strength, heavy weight, and poor processability. Carbonaceous nanofillers, such as graphene nanoplatelets (GNPs) have been used due to their large mechanical strength and high electrical conductivity. Their large aspect ratios enable the formation of conductive network in the polymer matrix at low filler contents [3,4].

Poly(vinylidene fluoride) (PVDF) is known for its potential technical application based on its mechanical and electrical properties, and it can be used for the realization of structural sensing film devices [5].

The ongoing research activity is aimed at investigating the production of a new porous low-cost graphene based PVDF aerogel composite for electromagnetic and sweat sensing applications.

The graphene based aerogel nanocomposites were produced via solution mixing methods. Briefly, PVDF powder was added to a suspension of GNPs in dimethylformamide (DMF). Then PVDF was dissolved in the resulting mixture through magnetic stirring at 65 °C (A-type samples) or at 85 °C (B-type samples). The so obtained PVDF-DMF-GNP mixture was poured on glass molds and left at room temperature to facilitate polymer gelification. Then, a solution of deionized water and methanol was poured on samples surface to allow DMF removal from samples. Finally, samples were freeze dried at -40°C.

The morphology of the obtained samples has been investigated using the ZEISS Auriga Scanning Electron Microscopy (SEM) available at Sapienza Nanotechnology and Nanoscience laboratory (SNN-lab). The surface SEM images of the produced aerogel nanocomposites are shown in Fig. 1. In particular, Fig. 1 (a) shows a neat PVDF aerogel sample, while Figs. 1 (b)-(d) show PVDF/GNP aerogel samples filled with 7% wt, 11%wt and 15%wt of GNPs, respectively. It is noticed a good integration of GNPs inside the polymer matrix: the GNP surfaces are almost entirely covered by the PVDF polymer matrix and the GNPs clearly interact with the PVDF chains. Moreover, GNPs are visible also inside the spherical particles.

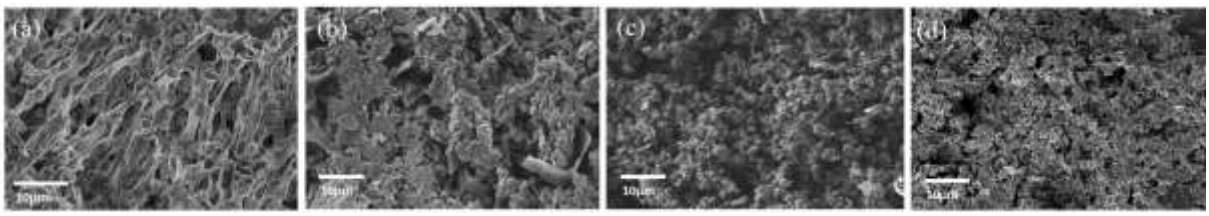
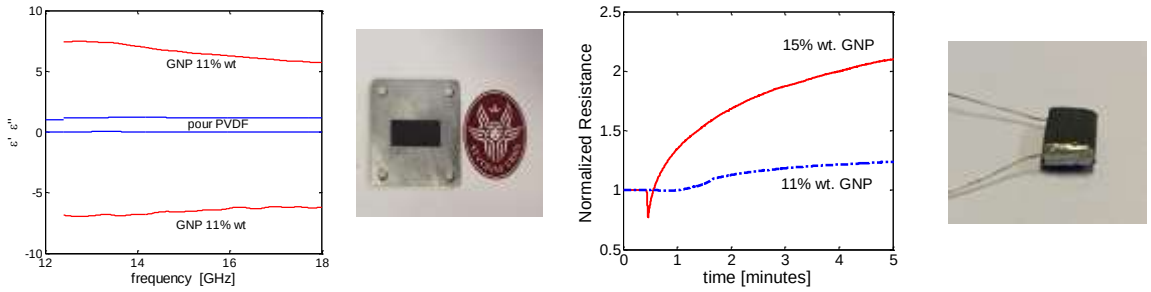


Fig. 1 SEM images of neat PVDF (a), PVDF/GNP aerogel filled with 7% wt.(b), 11% wt. (c) and 15% wt. (d).

The produced samples have been characterized in terms of electromagnetic properties. The measured spectra of the real and imaginary parts of the complex effective permittivity $\varepsilon=\varepsilon'+j\varepsilon''$ are shown in Fig. 2 (a). For sample filled at 11% wt of GNP, it is noticed that $|\varepsilon''|$ and ε' are almost equal in modulus. These results suggest that GNP filled PVDF aerogels are suitable for application in radar absorbing materials for EMI suppression at radio frequencies [6].

The PVDF/GNP aerogel samples were also characterized in terms of dc electrical conductivity. In particular, the variation over time in the electrical resistance due to the absorption of a saline solution reproducing the human sweat has been investigated, as shown in Fig. 2 (c). It is noticed that the solution absorption produces a rapid variation of the resistance, thus the proposed materials can be used for sweat sensing applications [7].



(a) (b) (c) (d)

Fig. 2. (a) Frequency spectra of the real and imaginary parts of the complex effective permittivity of samples filled with 11%wt and (b) aerogel sample prepared for electromagnetic characterization.(c): Normalized electrical resistance as a function of time samples filled with 11%wt and 15% wt. of GNP and (d) sample prepared for electrical characterization.

References

[1] He, L. and S.C. Tjong, Low percolation threshold of graphene/polymer composites prepared by solvothermal reduction of graphene oxide in the polymer solution. Nanoscale research letters, 2013. 8(1): p. 1-7

[2] M.S. Sarto, A.G. D'Aloia, A. Tamburrano, G. De Bellis "Synthesis, modeling, and experimental characterization of graphite nanoplatelet-based composites for EMC applications", IEEE Transactions on EMC, Vol. 54, No. 1, February 2012, pp. 17 – 27

[3] D'Aloia, A. G., et al. "Electromagnetic absorbing properties of graphene–polymer composite shields." Carbon 73 (2014): 175-184.

[4] Marra, F. et al. "Electromagnetic and dynamic mechanical properties of epoxy and vinylester-based composites filled with graphene nanoplatelets." Polymers 8.8 (2016): 272.

[5] Bidsorkhi, H. C. et al. "Nucleation effect of unmodified graphene nanoplatelets on PVDF/GNP film composites." Materials Today Communications 11 (2017): 163-173.

[6] Wang, H., Zheng, K., Zhang, X., Ding, X., Zhang, Z., Bao, C., ... & Tian, X. (2016). 3D network porous polymeric composites with outstanding electromagnetic interference shielding. Composites Science and Technology, 125, 22-

[7] Huang, H. D., Liu, C. Y., Zhou, D., Jiang, X., Zhong, G. J., Yan, D. X., & Li, Z. M. (2015). Cellulose composite aerogel for highly efficient electromagnetic interference shielding. Journal of Materials Chemistry A, 3(9), 4983-4991.

[8] Bidsorkhi, H. C. et al. "Porous Graphene based PVDF Aerogel Composite for Sweat Sensing Applications", IEEE NANO 2018, *accepted in oral session.*