In-situ synthesis of conducting polymers and gold nanoparticles into PMMA

M. L. Martinez-Marco[1], P. J. Rodriguez-Canto [1,*], R. Abargues[2], V. Latorre-Garrido[1] and J. P. Martinez-Pastor[1]

[1]Materials Science Institute, University of Valencia, P.O. Box 22085, 46071 Valencia, Spain
[2]Intenanomat S.L., Catedrático José Beltrán 2, 46980 Paterna, Spain

*pedro.j.rodriguez@uv.es

Hybrid nanocomposites are multicomponent materials in which nanoparticles are dispersed in the polymer matrix. These materials represent an adequate solution to many present and future technological demands, because they combine the novel properties of the nanoparticles with the unique characteristics of polymers (mechanical properties, thin film processing, conductive/dielectric properties, low cost…). In particular, metal nanoparticle-polymer composite materials are generating interest in many fields, such as optoelectronics and photonics, because of the plasmonic effect exhibited by metallic nanoparticles (Au, Ag) hosted in the nanocomposite [1]. Moreover, conducting polymers (CPs) have received much attention due to their interesting electronic and optical properties and potential applications in microelectronics, optoelectronics, photonics, photovoltaics, fuel cells and sensing. The successful application of CPs in many of the above given applications will depend on exploiting their low-cost potential by the innovative design and development of materials for scalable and inexpensive methods to pattern these CPs over different substrates. Thus, the combination of the excellent properties of metal NPs and CPs is of special interest in order to develop new multifunctional advanced materials for the fabrication of more complex devices for the next decade.

On previous works [2,3], we reported on the in-situ polymerization of terthiophene (3T) with $Cu(ClO_4)_2$ inside several host polymers to form an interpenetrating polymer network (IPN). Homogeneous conducting IPN films in the order of 10^{-4} to 150 S/cm were obtained depending on the specific IPN composition. The strong advantage of this approach is to combine properties of the host matrix with those of the in situ synthesized conducting polymers. This was demonstrated using a negative-tone novolak photoresist as a host polymer. Conductive micropatterns were generated by means of UV lithography after proper formulation of a negative-tone Novolak photoresist with 3T and $Cu(ClO_4)_2$.

In this work, we present a novel conducting nanocomposite containing gold nanoparticles. This time, the in-situ polymerization of 3T is carried out using $HAuCl_4$ as oxidizing agent inside PMMA and a negative-tone novolak photoresist. During the bake step, the gold salt is also reduced from Au (III) to Au (0) generating Au nanoparticles in the IPN system. We found that this novel multifunctional resist combines electrical conductivity and plasmonic properties with the potential lithographic capability provided by the host matrix. The resulting nanocomposites was investigated by TEM and UV-Vis spectroscopy. Electrical characterization was also conducted for different concentration of 3T and Au(III) following a characteristic percolation behaviour. We believe this synthetic approach is of potential application to modify the conductivity of numerous insulating polymers and synthesize Au NP preserving to some extent their physical and chemical properties.

References

[1] R. Abargues, K. Abderrafi, E. Pedrueza, R. Gradess, J. Marqués-Hueso, J. L. Valdés ,and J. Martínez-Pastor, New J. Chem., 33 (2009), 1720–1725.
[2] R. Abargues, U. Nickel, P. J. Rodriguez-Canto, Nanotechnology, 19 (2008), 125302.
[3] R. Abargues, P. J. Rodríguez-Canto, R. García-Calzada, and J. Martínez-Pastor, J. Phys. Chem. C, 116 (2012), 17547−17553.

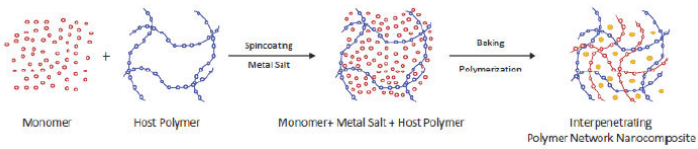

Figure 1: Scheme of in-situ synthesis of the conducting polymer and gold nanoparticle in a host polymer.

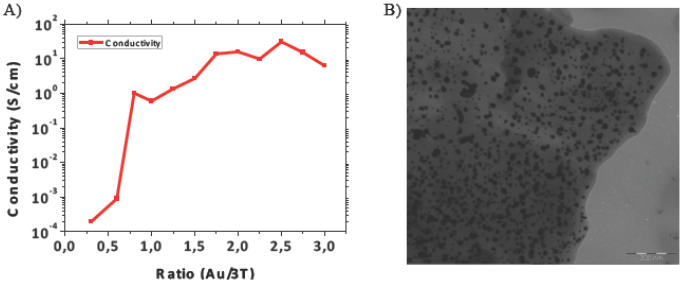

Figure 2: A) Dependency of IPN conductivity on Au/3T molar ratio. B) TEM image of the nanocomposite