Polymeric blends containing exfoliated graphene as flexible substrates for photovoltaics

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Epitaxial III-V semiconductor layers and solar cells have been successfully transferred from their original GaAs substrate to flexible, mechanicallly and thermallly resistant and cheap PMMA (poly methyl methacrylate) + PVC (polyvinyl chloride) + DOP (dioctyl phthalate) polymeric blends containing exfoliated graphene (EG). Both the optical properties of the semiconductor material and the performance of the solar cells were unaffected by the substrate transfer procedure. The developed blend containing EG is an optimal candidate as a substrate for III-V solar cells, indicating a new opportunity for reducing the price of these high efficiency devices and broadening the application range of photovoltaics.

It is predicted that the photovoltaic market share for high efficiency multiple junction solar cells should reach 70% by 2050, in case major breakthroughs come along in reducing the substrate costs, which now, can represent up to 80% of their fabrication cost. Cheaper and rigid substrates such as Si are extensively investigated, as well as flexible ones. The flexible ones mostly found in the market and explored in research are PET and Cu tapes or electro deposited Cu. Another alternative for cheap flexible substrates are different polymer blends which can have better mechanical and thermal properties and are tolerant to UV radiation. As previously reported, introducing the rigid and stiff PMMA into the somewhat plasticized PVC with DOP, plasticizes it even further and improves its mechanical and thermal resistance [1]. However, not to the point of withstanding 120ºC, temperature required for its (together with the III-V material) removal from the glass temporary substrate, without deformation. In order to improve even further the mechanical and thermal resistance, EG was introduced in the blend. Several compositions of the blend were investigated in terms of resistance to the different steps of the transfer procedure and by Dynamic Mechanical Analysis. The composition of the flexible blend with best thermal and mechanical properties is PVC:PMMA:DOP (3:1:1) with the addition of 20 mg of EG. An extraordinary increase in storage modulus with the addition of EG to the PMMA + PVC + DOP blend can be observed in Fig. 1. The interaction of the EG with the polymeric chains is modeled by *ab initio* calculations using the Density Functional Theory (DFT). The results shine light into the physical role played by the EG in improving the thermal stability and the storage modulus of the PMMA + PVC + DOP + EG proposed blend, to be addressed in detail.

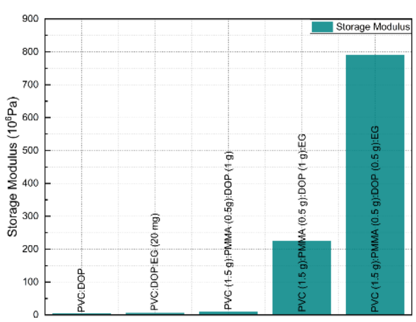

Fig. 1 Storage Modulus for different investigated blends.

An InGaAsP/GaAs heterostructure and a GaAs solar cell have been transferred from their original GaAs substrate to the optimized PMMA + PVC + DOP + EG blend. Both the intensity and the shape of the photoluminescence spectrum of the heterostructure on the flexible blend remained the same as on the rigid original GaAs substrate. The current *vs* voltage curve of the GaAs solar cell also did not suffer any harm with the substrate substitution.

[1] R. Chakrabarti, M. Das and D. Chakraborty, J. Appl. Polymer Science 93, 2721, 2004.