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Challenges of CVD graphene integration into transparent electrodes for green energy solutions

Graphene materials have been regarded as promising candidates for the new emerging generation of transparent electrodes in several applications such as displays, touch screens and/or solar cells [1,2]. Those materials are generating enormous expectations, and there is no doubt that they have outstanding properties that could fit in well with many research areas, among which energy-generation devices highlight [3,4]. Graphene shares many of necessary desired properties to be used as transparent electrode: high optical transmittance, exceptional electronic transport, outstanding mechanical strength and environmental stability [5]. Recent advances in the synthesis, characterization and transfer of graphene material show its strong potential. As example, the figure of merit of a wet-chemically doped monolayer of graphene grown by chemical vapor deposition (CVD) onto copper substrate reveals a material with a sheet resistance of 125 ohms/sq and transparency of 97.4% [6].
In the renewable-energy sector, it is expected that photovoltaic (PV) industry plays a major role due to the fight against the climate change. Currently, PV market is being dominated by silicon-wafer technology that requires exhaustive technological solutions to achieve thinner and cheaper products. In this sense, silicon-heterojunction technology is emerging as low-temperature reliable solution, where new architectures of transparent conductive electrodes to generate and extract the current in a more efficient way are being required [7]. Taking into account the prominent and unique properties of graphene, several approaches incorporating it are proved to be especially interesting. In particular, hybrids concepts as high-quality electrode solutions have been already demonstrated [8,9].
In the present work, new architectures of hybrid transparent conductive oxides (TCOs) and graphene electrodes incorporating one, two and three atomic graphene layers, respectively in different configurations (see Fig. 1) are fabricated to evaluate the optoelectronic properties of whole structure. Graphene material is grown by CVD onto 4-inch copper foil, and transferred using an automatic transfer system (see Fig. 2) that is suitable for most type of substrates and also adapted for industrial applications [10]. In addition, the TCO materials are deposited in large areas at low temperature using a commercial UNIVEX 450B magnetron sputtering. The challenges of introducing graphene in the transparent electrode structure are evaluated. In particular, the compatibility between process temperatures required in each step, the dependence of the place where the atomic graphene is located as function of the TCO material used or the effect of sputtering deposition parameters on the electrical electrode performance are checked carefully. In this sense, the key parameters for choosing the most appropriated and reliable combination of electrode are determined, as function of its figure of merit. The work undergone so far clearly suggests the possibility to noticeably improve transparent electrodes with this approach and therefore to further enhance silicon-heterojunction technology performance.

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References

[1] S. Pang, Y. Hernandez, X. Feng, K. Müllen, Adv. Mater., 23 (2011) 2779.
[2] J.H. Ahn, B.H. Hong, Nature Nanotechnol., 9 (2014) 737.
[3] Y. Zang, L.B. Li, Q. Chu, H. Pu, J. Hu, H. Jin, Y. Zhang, AIP Advances, 8 (2018) 065206.
[4] K.T. Lee, D.Y. Park, H.W. Baac, S. Han, Materials, 11(9) (2018) 1503.
[5] M. Craciun, T.H. Bointon, S. Russo, IET Circuits, Devices & Systems, 9(6) (2015) 403.
[6] S. Bae, H. Kim, Y. Lee, X. Xu, J.-S. Park, Y. Zheng, J. Balakrishnan, T. Lei, H. R. Kim, Y. I. Song, Y.-J. Kim, K. S. Kim, B. Özyilmaz, J.-H. Ahn, B. H. Hong,S. Iijima, Nat. Nanotechnol. 5 (2010) 574.
[7] M.A. Green, K. Emery, Y. Hishikawa, W. Warta, Prog. Photovolt.: Res. Appl., 24 (2016) 905.
[8] A.G. Ricciardulli, S. Yang, G.-J. A.H. Wetzelaer, X. Feng, P.W.M. Blom, Adv. Funct. Mater., 28 (2018) 1706010.
[9] B.W. An, B.G. Hyun, S.-Y. Kim, M. Kim, M.-S. Lee, K. Lee, J. B. Koo, H. Y. Chu, B.-S. Bae, J.-U. Park, Nano Lett., 14(11) (2014) 6322.
[10] A. Bosca, J. Pedrós, J. Martínez, T. Palacios, F. Calle, Sci. Rep., 6 (2016) 21676.

Figures

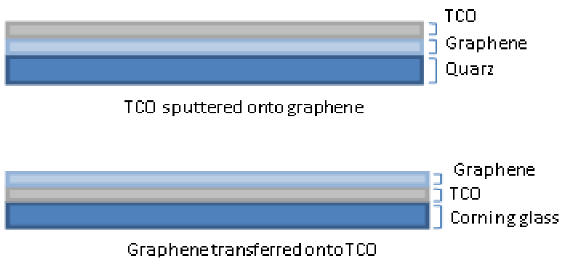

Figure 1: Electrode configurations used in the samples in study

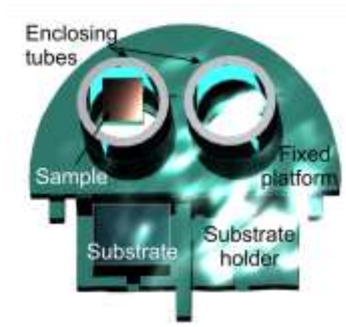

Figure 2: Graphene automated transfer system