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Graphene Oxide electrode based Perovskite as Photodetectors

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Abstract

Graphene oxide and Perovskites have recently developed remarkable progress in the field of optoelectronics. It found effective for visible light region second; a graphene-oxide based hybrid electrode was realized to overcome the limitations of existing alternative transparent electrodes for flexible optical devices. Even though the incredible progress in the performance of optoelectronic devices based on hybrid materials, some aspects such as stability have so far not been thoroughly gabbed. The reasons why perovskites can get so much attention are accredited to their novel material characteristics. This including high optical absorption coefficient, low exciton binding energies, long-range charge carrier diffusion lengths, and easy tuning of the band gaps via simple interchanges of the precursor components.

Keywords: Perovskite, optical devices, hybrid electrode,etc.

1. Introduction

The field of materials for photovoltaics (PVs) has recently been enhanced by an unearthing of organic-inorganic halide perovskites as light electron/hole transporters and absorbers [4]. Likewise, worldwide climate change and rapidly rising energy demand require society to move toward sustainable and renewable energy resources. Among all energy resources, solar energy has potential [5]. However, the use of Perovskite solar cells (PSCs) is stalled by the degradation of the Perovskite when exposed to illumination and moisture, especially at high temperatures [1,2]. According to the state-of-the-art survey, 90% of the photovoltaic products in the world market are based on first-generation crystalline silicon wafers with power conversion efficiency (PCE) between 15 to 20% on the module level of 16 m^2 [3]. However, these cells are overpriced due to the high cost of the processing and raw material of Si. To overwhelmed these problems, researchers need to sightsee new materials for next generation photovoltaics. At present, Perovskite solar cells have engendered broad interest due to their rapid PCE improvement [4]. Similarly, the finding of graphene (rGO and GO) and more broadly thin materials has caused a wealth of research in optoelectronics, telecommunication, plasmonics, sensing and solar harvesting [5-8]

2. Materials and fabrication of Graphene Oxide based Photodetector

Graphene can be obtained using different methods. The first and most tactic method is micro-mechanical cleavage of bulk graphite [9]. The Brodie method was modified by Staudenmaier who replaced the oxidizing agent by a mixture of sulfuric acid and nitric acid. In 1958, Hummers and Hoffman reported hazardous and more efficient method using a water-free mixture of sodium nitrate, potassium permanganate and concentrated sulfuric acid, the method most commonly used today [10]. In order to form hybrid and heterostructures with graphene and graphene oxide and other materials includes different coating techniques such as spin, spray, dip, slot-dye, etc. [11]. However, these methods results in certain defects so, we focus our attention towards the non-destructive techniques and deposition. This allows the proper heterostructure and enhanced the light absorption of the device. To avoid the reason we consider to adopt the technique; spin coating and slot-dye.

3. Light detection in Graphene Oxide (GO) based devices:

The different mechanisms responsible for the functionalized and hybrid graphene photodetectors (PDs) can be categories: photovoltaic (PV),

photogating (PG), and photothremoelectric (PTE) effects [12].

3.1 Photoelectric Effect (PV):

It has been commonly used by the solar cell research community to define the absorption of photons, generation of excitons, separation into free charge carriers and collection of free charge carriers at electrodes sequentially takes place. However, within the research field the PV effect refers to the process of separation of photogenerated carriers by a built-in electric field [13, 14].

3.2 Hybrid and Heterostructure Photodetectors:

The responsivity of a typical hybrid graphene phototdetector depends on three terms: the first is comprised of physical constants while the second and third terms relate to the quantum efficiency and gain of the system respectively. The maximum quantum efficiency of a pure graphene device cannot exceed 1. Such limit can be overcome if a gain mechanism is present. A way to attain this is to combine graphene with a photoactive material and use the high mobility of the graphene channel to extract one photoexcited carrier [12]. We used different light-sensitizing materials used in graphene-based PDs, including quantum dots (QDs), perovskites, organics and TMDs (transition metal dichalcogenides).

4. Methodology:

4.1 Chemicals used:

The chemicals used during synthesis of device we used liquid soap (labolene), double distilled water (DDW), Acetone, Iso-Propanol, dimethyl sulfoxide (DMSO), synthesized GO, Methylamine Iodide (CH_3NH_3I), Lead Iodide (PbI_2), Titanium Dioxide (TiO_2) and P3HT of AR grades from standard chemical agencies like LobaChemie and Sigma Aldrich.

4.2 Experimental

4.2.1 Preparation Perovskite Solution: PbI_2 powder has been dissolved in DMSO as a solvent and sonicated till the powder gets completely dissolved. Similarly, we have been added CH_3NH_3I powder in the solution during solution. This leads the formation of Perovskite solution (0.85 M).

4.2.2 Preparation of GO solution: 0.45 gm of GO powder dissolved in 3 ml Isopropanol solvent.

4.2.3 Deposition of TiO_2 layer: We have deposited the electron transport layer (ETL) of using spin coating method at 1000 rpm for 5 min. We repeat the same procedure for five cycles.

4.2.4 Deposition of Perovskite layer: Place TiO_2 deposited substrate on substrate heater, heating up to 100 ^{0}C (deposition temperature). Feed the solution with flow rate of 5ml/hr with syring pump in slot die. Place the slot die vertical to the substrate at 1 mm distance. Allow the Air blower to flush air.

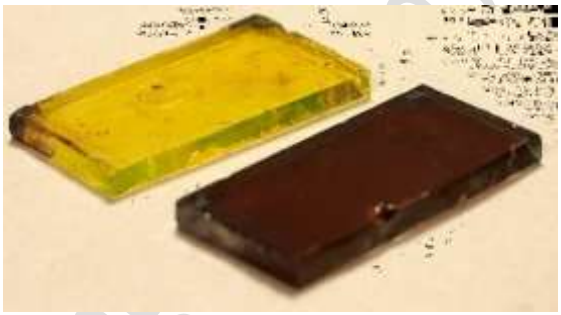


Figure: 1: Device formation Layers

Thin film was formed as slot die precisely moved in horizontal direction. Post annealing was done for making uniform deposition and completely drying the films.

4.2.5 Deposition of P3HT: The P3HT layer deposited followed by the Perovskite as hole transport layer (HTL) using the spin coating method with 1000 rpm for one minute.

4.2.6 Deposition of GO as back contact: Similarly, the final layer of GO deposited via spin coating method.

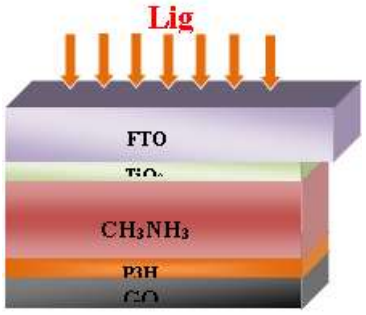


Figure 2:Band structure for the device

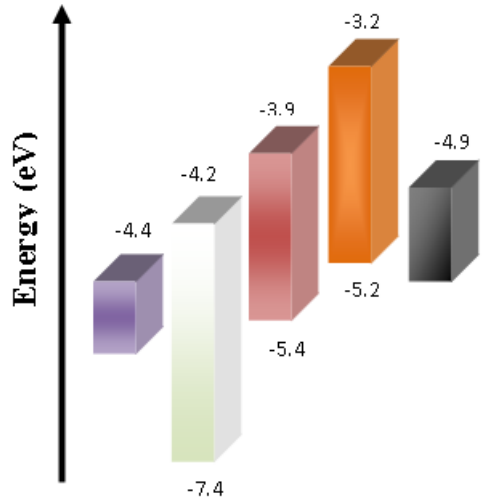


Figure: 3: Deposited thin films

5. Results and Discussion:

The absorption spectra of the Perovskite films formed on GO is shown in figure 4. The absorption spectra of the Perovskite films exhibit at 790 nm and a shoulder band at 480 nm [15, 16].

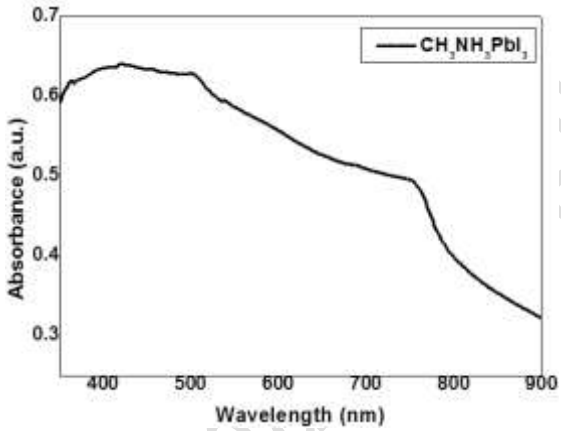


Figure 4: UV for Perovskite layer

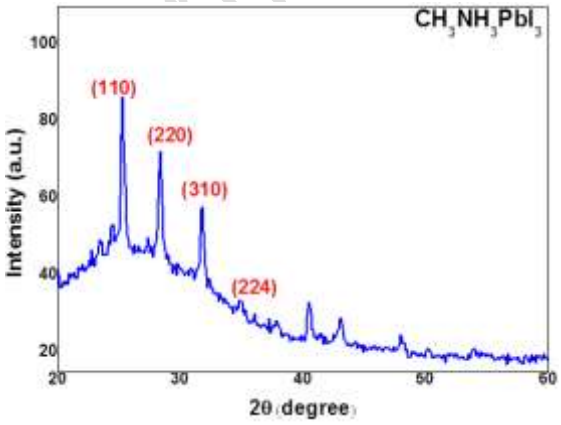
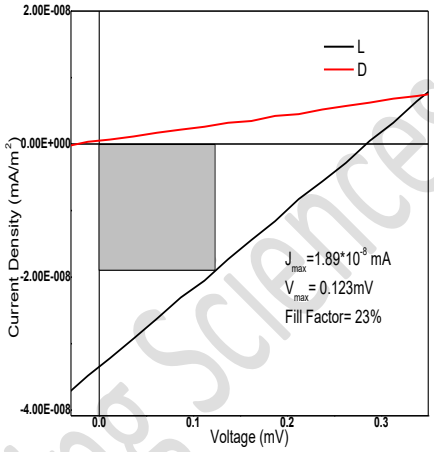


Figure 5: XRD pattern for Perovskite film

Figure 5 shows the XRD pattern of the Perovskite films. The strong peaks at 14.02^0, 28.41^0 and 31.85^0 corresponds to the (110), (220) and (310) planes of the Perovskite films. A stronger peak assigned to the (110) plane of the Perovskite film.

Device Performance:

J-V Characteristics



We further tested the performance of the device. Fig.16 shows the current density and voltage curve (j-v) based on P3HT and GO devices. Its short-circuit current density is 1.89 $*10^{-8}$ mA cm^{-2}, and the open circuit voltage Voc is 0.123mV and filling factor of 0.23% and shows 0.000175% device conversion efficiency. Since the introduction of GO will increase the serial resistance of the device, which becomes the main factor of the device's efficiency decline. As the number of GO layers increases, the device efficiency decreases, which is caused by the decrease of transmittance and the increase of resistance caused by the increase of thickness.

In short, we attribute the improvement of device efficiency to GO's effective transmission of holes and shielding of electrons, which reduces the charge composition and has a significant impact on the open circuit voltage Voc and the filling factor FF of the battery. After the introduction of GO, a barrier layer can be formed between FTO and P3HT to prevent the corrosion of the transparent electrode and improve the conductivity of the electrode.

Conclusion:

We have concluded that the perovskite and graphene oxide thin film deposited successfully by using spin coating and slot die technique respectively. In a word, we successfully adopted

GO/P3HT as the hollow transmission material (HTL) of planar heterojunction Perovskite solar cell. GO can effectively extract holes from perovskite and prevent charge recombination in P3HT/FTO layer. Meanwhile, All the information indicates that we can use GO/P3HT hybrid bilayer as whole transport layer to prepare Perovskite solar cell.

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