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Copper Nanowire Plasmonic Effect for Improving the Performance of Inverted Polymer Solar Cell

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Abstract

Hierarchical structure of copper nanowires (Cu NWs) was formed by using simple solution process through hydrothermal approach, with an average length and diameter of 6 ± 2 µm and 120±15 nm respectively. The size and morphology of Cu NW was dependent on the reaction time. An extinction peak was observed at 560 nm indicate the possibility of Cu NW plasmonic effect. The absorption spectrum shows improvement over a wavelength range of 450 nm to 650 nm, due to the plasmonic effect of Cu NW in PEDOT:PSS with active layer.

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Keywords: Cu Nanowire; Surface Plasmon; Inverted solar cel; metal Nanostructure; Hydrothermal method; Extinction Peak.

Introduction

Surface plasmon resonances in metal are interest for a variety of applications due to local enhancement in the electromagnetic field, which is expected to enhance light harvesting. Specifically, nanomaterials plasmonic resonance wavelength properties were strongly depending on size, shape, and local dielectric environment [1]. Up to date metal nanostructure was used to improve the photocurrent in different type of thin film solar cells. Recently, the cell efficiency has been improved step by step up to 10%. [2] Comparing to the conventional polymer solar cells (PSC), the inverted structure which reverse the nature of charge collection and use a less air sensitive high work function metal was revealed higher efficiency and better stability. Improved generation rate and the dissociation probability of excitons by metal nanostructures resulting in improved short-circuit current density. [3] Wang et al. proposed the effects of Au and/or Ag NPs doped into the TiO2 buffer layer on the performance of inverted BHJ OSCs based on PTB7:PC70BM blending.[4] Among various metals (Pt, Au, Ag) copper (Cu) nanostructures have attracted a lot of interest in recent years for both fundamental research and practical purposes, due to their

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interesting optical properties, low cost preparation, high abundance, less expensive than Au and Ag and many potential applications.

Recently, many studies have focus on the fabrication of Cu-based nanomaterials with different morphologies have been synthesized like nanoparticle, nanowire, nanotube by physical or chemical processes [5, 6]. Among them Cu nanowire are particularly attractive and it has been achieved via various routes, including chemical vapor deposition [7], template assisted electrochemical synthesis [8], vacuum vapour deposition (VVD) [9], and simple complex-surfactant-assisted hydrothermal reduction.[10] However, almost all the reported synthesis processes for Cu NWs have generally often needs relatively expensive equipment. Hydrothermal technique offers interesting advantages in the processing or preparation of nanomaterials, whereas chemical approaches are suitable for experiment carried out in laboratories. A surfactant-assisted hydrothermal reduction process was developed to synthesize copper nanowires with high yield and average diameters of 85 nm and lengths of several tens of micrometers but it consuming longer time (20 h) [11]. In this study, we successfully synthesis Cu nanowire (NW) by hydrothermal method with low temperature and short reaction time. The diameter of the Cu Nanowire is 90 ± 15 nm and length about 6 ± 2 μm The size and morphology of Cu NW was strongly depends on the reaction time. We investigate the effect of Cu NW incorporation in the inverted polymer solar cell and its absorption spectrum shows improvement over a wavelength range of 450 nm to 650 nm, due to the plasmonic effect of Cu NW in PEDOT:PSS with active layer.

Experimental Details

Catechin hydrate (98%) and EDA (99.5%), Copper(II) nitrate trihydrate ($Cu(NO_3)_2$ $3H_2O$, 80%) were directly used as received. In a typical procedure, $Cu(NO_3)_2$ (1 mL, 0.1 M) was added drop wise into a glass vial containing NaOH solution (10 mL, 15 M). The resulting solution was ultrasonicated for 5 min, Next, EDA (0.13 M, 0.5 mL) was added drop wise into the above solution. After being ultrasonicated for a certain time, 20 mg of catechin was added into the solution, the solution was ultrasonicated for 3 min. The solution was heated at 90 ^{o}C for different time (30, 45, 60 min). While heating solution colour was become deeper and a brownish solid mesh precipitated, indicating the successful formation of Cu NWs. The brownish solid mesh precipitate was isolated by centrifugation at 6000 rpm, washed several times with distilled water and the finally obtained nanowires were kept in ethanol at room temperature to prevent oxidation.

Results and discussion

The influence of reaction time on the formation of CuNWs is investigated at 45 and 60 min was shown in Fig 1 (a, b). Fig 1 shows the Field Emission-Scanning Electron Microscopy (FE-SEM) image of Cu NW morphology. The length and diameter of the CuNW are 6 ± 2 μm and 120 ± 15 nm during the reaction time of 60 min at 90 ºC. The mechanism of CuNW formation in a growth solution possibly; Cu^{2+} ions form the Copper hydrocomplexs when adding NaOH and EDA in the aqueous solution. $Cu(OH)_2$ precursor was reduced to Cu_2O by adding a reducing agent Catechin. When subjected to heating the growth solution, Cu_2O endures a rolling process to form Cu NPs and then Cu NWs were formed through the rolling of these lamellar structures from the edges. The reaction temperature can affects the growth rates of Cu nanowires efficiently. Upon heating the growth solution at 90 ºC for 45 min, nanowires attached with distorted cubes as shown in 1 (a). After 60 min, hierarchical Cu NWs were formed much longer and thinner as shown in Fig. 1 (b) and high magnification SEM image were shown in the insect. The morphology of the nanowires in this system is very sensitive to growth time. The insect of Fig 1(a) depicted the corresponding EDS pattern.