1. Introduction

In the present century, there is quite an extensive diversity of hazards involved with growing energy consumption along with increasing population and improving industrialization [1]. Of course, there are potential risks regarding carbon footprint, greenhouse gases, and global warming; the underlying fact is that fossil fuels have irreparable damages to the environment and its shortage must be considered the main objection. The consequential way to tackle this problem is conventional fossil fuels alternate with bio-friendly energy resources. Having increased society's demand, the research is focused on design and organization power sources devices. To fulfill such targets, the main aspect of efforts is producing energy in a greener pathway, as well as storage energy through cost-effective devices for widespread utilization [2]. Producing hydrogen from water is attractive because, in contrast to fossil fuel, it is renewable and bio-friendly, which omits releasing greenhouse gases [3]. Produced hydrogen can be stored in liquid and gaseous, and solid-state phase; the fact is high-pressure compression and liquefaction process is the most impractical aspect of storing hydrogen in liquid and gaseous phase [4] which turn the view to store hydrogen by physisorption process in nanostructured materials, such as carbonaceous and metal organic framework (MOF) [4, 5]. Based on physisorption, the hydrogen spillover mechanism was extensively used in literature by carbon materials [6], zeolites [7], and MOF [8, 9]. In the spillover process, hydrogen dissociation source, receptor and connection are critical factors [10]. Highly distributed metals (hydrogen dissociation source) contribute to increase metal surface area and provide the adequate connection between metal and carbon receptors [10]. It is worth mentioning that the metal NPs overloading adversely affected; the optimized loading was achieved when the surface of the receptor is mainly accessible [11-14]. An excellent receptor provides more host sites for hydrogen adsorption; modification of surface chemistry (doping of receptor by boron, nitrogen) was suggested for improving the surface area. Comparing adding oxygen functional groups documented that surface oxygen groups stabilize the hydrogen and offer bridges [15-17], as a consequence hydrogen atoms can diffuse to the receptor's host site which were inaccessible before [17, 18]. In addition, oxygen functional groups, such as hydroxyl groups, increase hydrophilicity which offer the most effective property for interaction between materials' surface and liquid [19]. The last but not the least factor has been investigated to fulfill intimate contact, the physical loading of metal or metal oxide on carbon receptors suggested as an easiest way to overcome lack of bridges between hydrogen dissociation source and receptor [11, 20, 21].

Graphene oxide (GO), which has a large surface area and different functional groups, is a good candidate as a substrate in various research fields; for instance, catalytic activity [22-25] and energy-storing [26-28]. An overview of the literatures indicates that different components have modified GO as hydrogen storage substrate [29-38]. GO's plate offers good space for hydrogen adsorption, diffusion and storage, besides oxygen functional groups, such as hydroxyl groups, accelerate adsorption of hydrogen on carbon surface materials, [39]. Raising hydrogen storage capacity was achieved by modifying surface's oxygen groups in some ways, among others adding transition metal[40, 41] and metal oxides like TiO_2, ZnO, and ZrO_2 [42-45] is the most convenient way; which could improve the surface area and electrochemical performance [46]. Having unique mechanical, thermal, and structural properties, zirconia (ZrO_2) has been utilized in a diverse range of fields [47]. Metal NPs were exceedingly utilized as adsorbent species in hydrogen storage [1, 28, 41, 48-53]; decorating substrate with nanoparticles is an effective way to promote applications that are unattainable by substrate individually. According to specific properties of Au NPs, it has been used as an improving agent in catalyst application [54, 55], hydrogen production [48, 56, 57] and analytical sensitivity [58]. The approaches to decorate substrate with Au NPs are different in literature: chemical deposition[59], seed-mediated growth [60] and laser ablation in liquid (LAL) [25, 61]; the last one has attracted attention because of its adjustable parameters and eliminating contaminating reagents[62]. Besides, LAL is a physical method to generate NPs by different shapes and morphology[63]. Among deposition methods, electrophoretic deposition (EPD) was extensively used down to its adjustability in parameters and deposition quality [24]. EPD was considered as an effective method for deposition nanocomposite on conductive substrate [64], and these electrodes have the potential to employ in different applications: catalyst substrate [24], oil-water separation [65], anticorrosion industries [66], and ethanol electro-oxidation [67]. Electrochemical hydrogen storage through cyclic voltammetry (CV) is a prevailing method to study adsorption/desorption of hydrogen in detail [1]. Water decomposition was taken place in cathodic direction; consequently, hydrogen was produced from water. The hydrogen atoms are migrated to the surface of electrodes under applying potential and desorbed in anodic sweep [1].

Considering consensus regarding environmental-friendly methods leads us to introduce a new nanocomposite close to this target by using GO as a substrate. To investigate the effect of oxygen functional group on hydrogen storage, zirconia NPs were physically loaded on GO's surfaces via the reflux route. The decorated nanocomposite with Au NPs was accomplished by LAL method to prove Au NPs' influence on hydrogen adsorption performance. Nanocomposites were deposited on stainless steel mesh, a conductive substrate, by EPD, and CV was deployed to assess hydrogen storage on working electrodes in an alkaline medium.

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