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REAL-TIME MONITORING OF LASER POWDER BED FUSION PROCESS USING HIGH-SPEED X-RAY IMAGING AND DIFFRACTION

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ABSTRACT:

Since the first report of using micromechanical cleavage method to produce graphene sheets in 2004, graphene/graphene-based nanocomposites have attracted wide attention both for fundamental aspects as well as applications in advanced energy storage and conversion systems. In comparison to other materials, graphene-based nanostructured materials have unique 2D structure, high electronic mobility, exceptional electronic and thermal conductivities, excellent optical transmittance, good mechanical strength, and ultrahigh surface area. Therefore, they are considered as attractive materials for hydrogen (H2) storage and high-performance electrochemical energy storage devices, such as supercapacitors, rechargeable lithium (Li)-ion batteries, Li– sulfur batteries, Li–air batteries, sodium (Na)-ion batteries, Na–air batteries, zinc (Zn)–air batteries, and vanadium redox flow batteries (VRFB), etc., as they can improve the efficiency, capacity, gravimetric energy/power densities, and cycle life of these energy storage devices. In this article, recent progress reported on the synthesis and fabrication of graphene nanocomposite materials for applications in these aforementioned various energy storage systems is reviewed. Importantly, the prospects and future challenges in both scalable manufacturing and more energy storage-related applications are discussed.

Keywords: HPLC, PDA, stability indication method, drug.

1. INTRODUCTION:

The ever rising world population has led to increasing energy demand with the worldwide power consumption expected to double in the next several decades. Hence, it is imperative for scientists and researchers to develop sustainable, clean, and renewable energy technologies that are economical and environmentally benign to address the growing energy demands and challenges in our society.[1–6] The most common renewable energy sources such as the sun and wind are highly intermittent and thus, require to be coupled with viable high-performance energy storage devices. Super capacitors, high-performance rechargeable lithium (Li) batteries (including Li-ion, Li–S, and Li–air chemistries), sodium (Na) batteries (Na-ion, Na–S, and Na–air batteries), zinc (Zn)–air batteries, and vanadium redox flow batteries (VRFBs), are the most promising energy storage systems on account of their high specific energy, energy and/or power density, long cycle life, excellent rate performance, and design flexibilities.[2,4,5,7–18] Hydrogen (H_2) storage is another promising energy system that is considered as a critical area for its potential applications in sustainable energy without producing harmful byproducts.[19,20] Increased attention to the design and synthesis of nanostructured electrode materials in recent years has proven to be critical for the tremendous advancements in energy storage technologies.[21–24] Particularly, graphene and graphene-based nanocomposites have received great attention and have been extensively investigated as electrode materials for these various energy storage systems.

Graphene is a new class of 2D “aromatic” monolayer of carbon atoms densely packed in a honeycomb crystal lattice. Graphene has attracted tremendous attention since its discovery in 2004,[41] as a promising material for next-generation energy storage devices owing to its superior properties.[22,25,42,43] Graphene offers a unique twofold advantage with remarkably high electron mobility at room temperature and fast heterogeneous electron transfer at the edges, with reported values in excess of 15 000 $cm^2\ V^{-1}\ s^{-1}$. [44,45] In addition, graphene has an ultrahigh surface area of ≈2630 $m^2\ g^{-1}$, which is significantly higher than its –1D (i.e., carbon nanotube, 1315 $m^2 g^{-1}$) and 3D (graphite, 10 $m^2\ g^{-1}$) counterparts. Furthermore, graphene exhibits a high tensile strength with excellent flexibility, which is quite beneficial for building flexible devices. Graphene also has outstanding optical transparency and transmittance, which leads to unexpectedly high opacity for an atomic monolayer, and an intriguing thermal conductivity of 4.84 × 103 to 5.30 × 103 W m−1 K−1 at room temperature.

2. RELATED STUDY:

Although these physical techniques used to synthesize graphene-based materials show promise for fundamental research on material properties and application testing, their applications in practical electronic and energy storage devices require the production of large quantities that demand further exploratory work. In this context, chemical methods including the reduction of graphene oxide (GO), electrochemical methods to treat graphite, non-covalent/covalent functionalization and solvothermal reactions of sodium and ethanol have been developed.[51–54] In addition, physical processes such as exfoliation/re-intercalation/expansion of graphite have been developed to produce graphene with fairly good conductivity and reasonable yield for mass production. The as-synthesized graphenes can potentially be combined with other organic/inorganic materials to develop novel graphene nanocomposites, which include graphene/ polymers, graphene/metals, graphene/metal oxides, and graphene/CNTs, for energy storage devices (Figure). Several techniques in the following discussion show promise for the large-scale production of graphene-based nanocomposites, which spark interest for fundamental investigation of graphene-based nanostructured materials in energy-related applications. Our main thrust in this article is to review the field of energy storage systems and specifically discuss recent development on the use of graphene-based nanocomposites in these energy storage systems as well as various ways to improve the performance of these devices. This review is organized as follows, we first discuss recent results reported in the literature on the application of graphenebased nanocomposites in H2 storage, supercapacitors, Li-ion batteries, Li–S battery, Li–air battery, Na–ion batteries, Na–air batteries, Zn–air batteries, and VRFBs. We then discuss recent development efforts for the commercialization of graphenebased nanopcomposites in these energy storage systems. Finally, we discuss the challenges and issues facing this field followed by summary, conclusions as well as suggestions and perspectives for future research.

3. PROPOSED METHODOLOGY:

The storage of H_2 has been realized in several solid systems including transition metal and light metal hydrides, which display a volumetric density between 0.08 and 0.15 kg m^{-3} . Recently, several H_2 storage studies have focused on MgH_2, because of its relatively low cost and high weight storage capacity (7.6 wt%). The MgH_2 power with the incorporation of 10 wt% of expanded natural graphite has been shown to enhance the thermal exchanges and improve the H_2 storage time. Mg nanocrystals are another class of material with excellent H_2 storage ability, high volumetric storage capacity (i.e., 55 g L^{-1}) and rapid uptake .

The Sc decorated on either armchair of zigzag edges of graphene nanoribbons show >9 wt% of H_2 absorption.[128] Ni atomic dispersion on graphene yields about 3 wt% of H_2 but it is expected to reduce experimentally due to clusterization and nanoparticle formation.[109] In addition to graphene/pure metal nanocomposites, graphene/metal sulfide, such as graphene/ Co_9S_8, [129] has been prepared for H_2 storage. Compared with the traditional metal decorated graphene, the graphene/Co_9S_8 nanocomposites show a much higher H_2 storage capacity and better stability. As mentioned above, graphene has high specific surface area, high surface-to-volume ratio and is lightweight with good mechanical properties. In addition, fascinating architectures of graphene, such as porous, hollow, multilayer graphene nanostructures, heteroatom-doped graphene structures, and different types of graphene-based composites with larger cavities can be obtained, which are indispensable to the physisorption or chemisorption of H_2. As a result, graphene-based systems are among the best nanomaterials for long-term H_2 storage.[92] Although these studies have shown good H_2 storage capabilities, the main challenge here is the synthesis of well-ordered structures on a large scale. Simulations do indicate the advantages of graphene but it has always been a challenge to synthesize the materials with the best properties and low defects.[130,131] In addition, graphene-based nanocomposites for H2 storage still suffer from metal crystal oxidization and relatively low kinetics under ambient conditions.[75,120] The synthesis of graphene flakes with a variety of functionalization techniques and the fabrication of graphene nanocomposites and the development of new techniques for possible bulk production of H2 storage devices have been explored, yet there remain major challenges for H2 storage.[75,120] Another key issue is how to store H2 in a small space using minimum energy. Currently, H2 storage in numerous graphene-based materials with a high energy density form has energetic barriers whose theoretical estimations range in the order of several eV. Seeking suitable catalysts to desorb/ separate the molecular H2 from graphene is still a major challenge that needs further investigations before these materials can be used in practical applications.

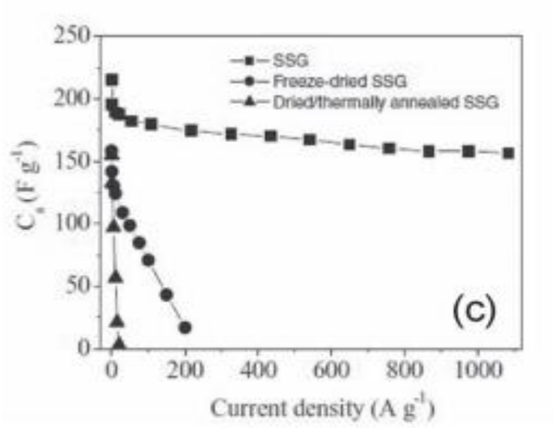

Fig.4.1. Gravimetric capacitances measured at various charge/discharge currents.

5. CONCLUSION:

In this article, we have discussed the recent research progress in graphene and graphene-based nanocomposites for energy storage systems. Although a significant progress has been made, their tremendous potentials for practical applications in advanced energy storage systems still needs further explorations.[208,1026–1028] First, the development of graphene and graphene-based nanocomposites for different energy storagerelated applications are still in early stage where fundamental gaps exist to understand the atomic and molecular level processes that govern operation, limitations and failure of the devices.[22–38,208,1027] Therefore, multidisciplinary approaches are necessary to better understand the correlation between electrochemistry, materials science, engineering, microstructures, properties, and interactions to overcome the significant challenges facing these energy storage systems. These approaches will lead to the efficient use of large but transient energy sources such as solar and wind necessary to solve the worldwide critical energy issues that are heading the list of global challenges. Second, the high surface area of graphene-based materials plays an important role in supercapacitors and H2 storage. Specifically, different types of graphene-based nanocomposites, such as graphene/transitional metal oxide (hydroxide), graphene/transition metal nitrides (or sulfide), and graphene– polymer nanocomposites can give rise to twofold advantages, due to the fact that the combination of high surface area of graphene (EDLC) and pseudocapacitative behavior of these polymers/metal oxides (hydroxides, nitrides or sulfides) can result in a tremendous improvement of the capacitance. Although graphene by itself cannot be utilized for H2 uptake, the use of graphene-based nanocomposites and doped graphene can lead to a high H2 uptake, much closer to the DOE targets. Despite the great advances in the development of H2 storage and supercapacitor systems, there is still room for materials' structure and composition optimizations and for further performance improvements.

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