Chapter 9

Silicon Nanostructures–Graphene Nanocomposites: Efficient Materials for Energy Conversion and Storage

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ABSTRACT

Global demand of energy is increasing at an alarming rate, and nanotechnology is being looked at as a potential solution to meet this challenge (Holtren, 2007). Although the efficiency of energy conversion and storage devices depends on a variety of factors, the overall performance strongly relies on the structure and properties of the component materials (Whitesides, 2007). Compared to conventional materials, silicon (Si) nanostructures and graphene nanosheets possess unique properties (i.e. morphological, electrical, optical, and mechanical) useful for enhancing the energy-conversion and storage performances. Graphene can enhance efficiency of nano-Si based solar cells and battery due to its high electronic conductivity, ultrahigh mobility, high transparency, and strong mechanical property. This chapter provides a comprehensive review of recent progress and material challenges in energy conversion (solar cells) and storage (batteries/supercapacitors) with specific focus on composites of Si nanostructures–graphene nanosheets.

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INTRODUCTION

The increasing energy demand due to increase in population, industrial activity, etc. led to decrease in fossil fuel. According to US energy information administration (EIA), for the year 2011, energy consumed for electricity generation from fossil fuel is about 87% and 13% from renewable energy (Figure 1) [http://www.eia.gov/electricity].

Among renewable energy sources, solar energy is the most important because the amount of energy that reaches the earth surface in one hour is about 18TW, and the global consumption of energy per year is about 15TW (Kalyanasundaram, 2012). Solar energy has to be converted to different convenient forms of energy and the conversion efficiency is the measure of practicality of this energy source. Materials and devices to convert solar light energy into electrical energy efficiently are the immediate concerns. Most of the conventional solar cells in the market are based on Si p-n junction diodes and their efficiency had reached 25% (Green, 2009). Advantages of Si are high abundance (second most abundant element in the earth crust), non toxic, and long term stability. But the main disadvantage of Si is that the process of making ultrapure crystalline Si is very costly, but also it is an indirect band gap semiconductor, so for absorbance of sunlight a very thick layer of Si is required. To reduce the cost of the solar cell, researchers started to evaluate heterojunctions of Si. Among the heterojunctions, Schottky diode holds advantage over p-n junction diode. In Schottky diode the thickness of Si layer can be decreased, that eventually decreases the cost of the device. The condition for Schott-

Figure 1. The percentage of electrical energy generation from different resources (Source: U.S. Energy Information Administration, Annual Energy Outlook 2013 Early Release, December 5, 2012)