TITANIA-GRAPHENE ANODE ELECTRODE PAPER

The invention was made with Government support under Contract DE-ACO5-76RL0-1830, awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

TECHNICAL FIELD

This invention relates to nanocomposite materials with unique and useful electrochemical properties. These nanocomposite materials are formed of graphene and metal oxides. The invention has particular utility when used in batteries and particularly in lithium ion batteries.

BACKGROUND OF THE INVENTION

There have been a number of examples of methods for forming nanomaterials using graphene and metal oxides to take advantage of the unique electrochemical properties of graphene. For example, U.S. patent application Ser. No. 12/462,857 filed Aug. 10, 2009 describes nanocomposite materials having at least two layers. Each layer consists of one metal oxide bonded to at least one graphene layer. The nanocomposite materials will typically have many alternating layers of metal oxides and graphene layers, bonded in a sandwich type construction and will be incorporated into a electrochemical or energy storage device.

U.S. patent application Ser. No. 12/553,527 filed Sep. 3, 2009 describes a nanocomposite material formed of graphene and a mesoporous metal oxide having a demonstrated specific capacity of more than 200 F/g with particular utility when employed in supercapacitor applications. These nanocomposite materials by forming a mixture of graphene, a surfactant, and a metal oxide precursor and then precipitating the metal oxide precursor with the surfactant from the mixture to form a mesoporous metal oxide. The mesoporous metal oxide is then deposited onto a surface of the graphene.

These and other prior art devices typically form the nanocomposite materials using a metal oxides in a salt form, such as lithium titanate ($Li_4Ti_5O_{12}$,) as a precursor material. While this $Li_4Ti_5O_{12}$ material has been shown to work well in these applications, it is expensive and thus may not be suited for certain high volume applications.

Many of these metal oxides are widely known as inexpensive materials, but are also widely known as poor electrical conductors. For example, titania of the form TiO_x in its common forms of its anatase or rutile is widely known as an inexpensive material, but is also widely known as a poor electrical conductor. Therefore, those of ordinary skill in the art have not used these metal oxides, such as titania, as an anode material, or in applications where it would be a precursor to an anode material.

Accordingly, there exists a need for low cost metal oxides that can be successfully utilized as an anode material, or as a precursor to an anode material in applications where it would be combined with graphene. The present invention fulfills that need.

SUMMARY OF THE INVENTION

The present invention is therefore a method for forming a nanocomposite material using low cost commodity chemicals as starting materials. The present invention proceeds by first providing metal oxide and graphene in a solvent to form a suspension. The suspension is then applied to a current collector. The solvent is then evaporated to form a nanocomposite material which has at least one metal oxide in electrical communication with at least one graphene layer. Preferably, the solvent is an organic solvent, the metal oxide is titania, and the titania is provided in a particle form wherein the particles have an average diameter below 50 nm, and more preferably below 10 nm.

In one embodiment, the present invention is a method for forming a nanocomposite material that includes the steps of providing metal oxide and graphene in a solvent to form a suspension. The suspension is then applied to a current collector. The solvent is then evaporated to form an anode. The anode is connected to a cathode having lithium ions and an electrolyte to form a battery. The anode is then electrochemically cycled to form a nanocomposite material of at least one metal oxide in electrical communication with at least one graphene layer.

In another embodiment, the present invention is a nanocomposite material formed by providing metal oxide and graphene in a solvent to form a suspension. The suspension is then applied to a current collector. The solvent is then evaporated to form an anode. The anode is connected to a cathode having lithium ions and an electrolyte to form a battery. The anode is then electrochemically cycled to form a nanocomposite material of at least one metal oxide in electrical communication with at least one graphene layer. Preferably, the solvent is an organic solvent, the metal oxide is titania, and the titania is provided in a particle form wherein the particles have an average diameter below 50 nm, and more preferably below 10 nm. The nanocomposite material of the forgoing embodiment may further be formed by the steps of connecting the anode to a cathode having lithium ions and an electrolyte to form a battery and electrochemically cycling the anode.

In another embodiment, the present invention is a battery formed by providing metal oxide and graphene in a solvent to form a suspension. The suspension is then applied to a current collector. The solvent is then evaporated to form an anode. A cathode and an electrolyte are then provided in electrical communication with the anode. The anode is connected to a cathode having lithium ions and an electrolyte to form a battery. The anode is then electrochemically cycled to form a nanocomposite material of at least one metal oxide in electrical communication with at least one graphene layer. Preferably, the solvent is an organic solvent, the metal oxide is titania, and the titania is provided in a particle form wherein the particles have an average diameter below 50 nm, and more preferably below 10 nm.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description of the embodiments of the invention will be more readily understood when taken in conjunction with the following drawing, wherein:

FIG. **1** is a graph of the cycling performance of TiO2/Graphene composite electrodes made by one embodiment of the present invention at various C rates using 2.6 micron graphene.

FIG. **2** is a graph of the charge/discharge voltage profiles of TiO2/Graphene composite electrode at various C rates of between C/10 and 10 C using 2.6 micron graphene.

FIG. **3** is a graph of the cycling performance of TiO2/Graphene composite electrodes made by one embodiment of the present invention at various C rates using 11.6 micron graphene.