Graphene Hybrid Materials for Energy Storage and Actuator Devices

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Abstract

In this study, we report several novel routes *via* microwave irradiation to synthesize graphene flakes, metal nanoparticle-decorated graphenes, and graphene-based 3D carbon nanostructures[1] for energy storage and actuation devices. The discovery of mono-layered graphene, achieved through an experiment by Geim to synthesize a free standing 2D lattice material, garnered global attention due to its outstanding mechanical, electrical and thermal properties. These properties have been exploited in a wide range of applications including supercapacitors, actuators, sensors, reinforcing materials in high performance polymer composites and hydrogels, etc. As another approach, researchers have tried integrating carbon nanotubes with graphene to obtain synergetic effects in applications such as actuators, super-capacitors, mechanically compliant films, fuel cell batteries, solar cells, nano-composites and biomedical devices. Herein we report a simple microwave-based technique to synthesize graphene-CNT-M(Fe, Ni, Co, Pd) nano-hybrid structures based on organometallic materials and solvent-based metal catalysts. Our proposed method is not only fast, but can also yield high volume production of the functionalized nano-hybrids at a fraction of the cost of CVD methods.

Recently, we succeed in synthesizing bio-inspired hierarchical graphene-nanotube-iron three-dimensional nanostructure[2] as an anode material in lithium-ion batteries. The nanostructure comprises of vertically-aligned carbon nanotubes grown directly on graphene sheets along with shorter branches of carbon nanotubes stemming out from both the graphene sheets and the vertically-aligned carbon nanotubes. This bio-inspired hierarchical structure provides a three-dimensional conductive network for efficient charge-transfer and prevents the agglomeration and re-stacking of the graphene sheets enabling Li-ions to have greater access to the electrode material. In addition, functional iron-oxide nanoparticles decorated within the three-dimensional hierarchical structure provides outstanding lithium storage characteristics, resulting in very high specific capacities. The anode material delivers a reversible capacity of ~1024 $mAhg^{-1}$ even after prolonged cycling along with a coulombic efficiency in excess of 99%, which reflects the ability of the hierarchical network to prevent agglomeration of the iron-oxide nanoparticles. Furthermore, the some hybrids are magnetically active and can be used in a wide range of applications including supercapacitors, lithium ion batteries, shape memory and electroactive artificial muscles.

We try to produce novel high-performance electroactive polymers or artificial muscles[3-6] based on graphene and graphene-based hybrid materials. We will show some demonstrations of electroactive polymer actuators and discuss the possibility of real applications such haptic and reactive devices, soft robots, energy harvesters and braille display.

References

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Figures

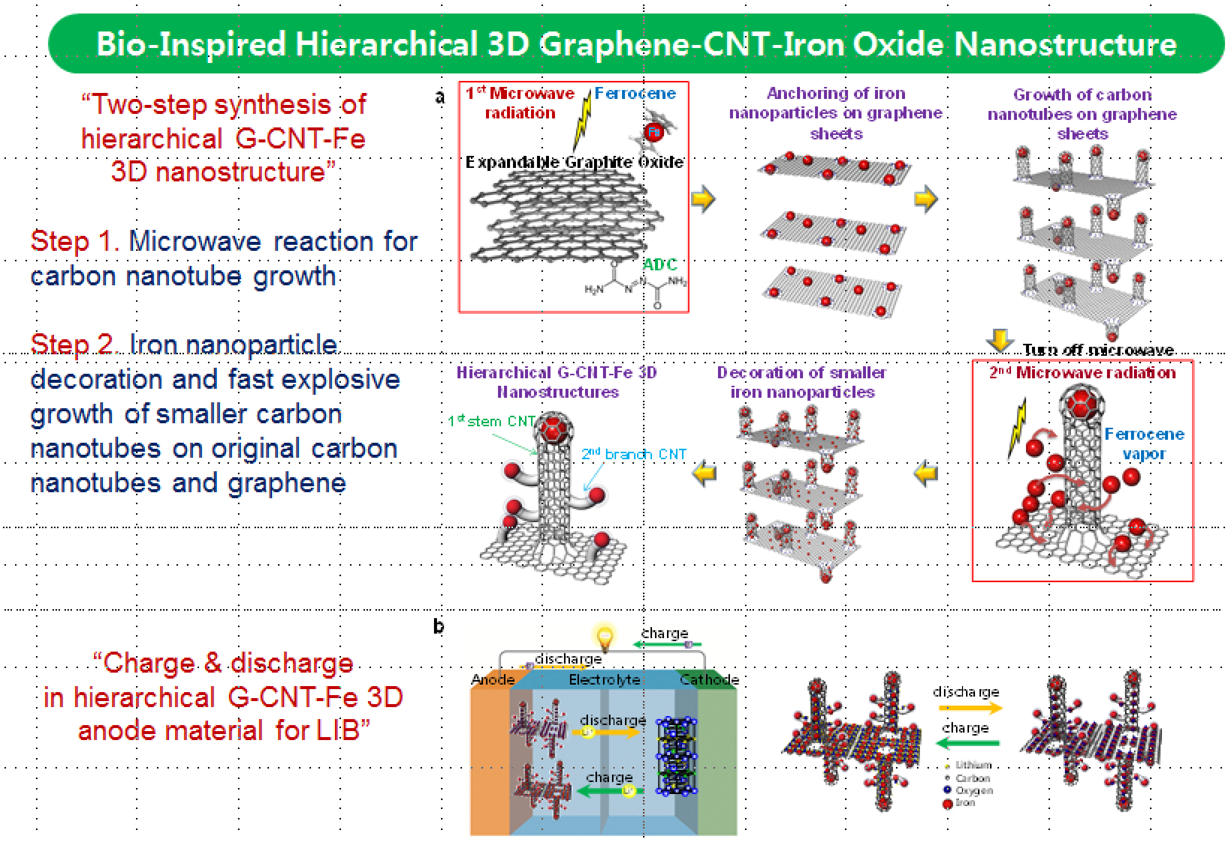

Fig. 1. Bio-inspired hierarchical graphene-based 3D carbon nanostructures for anode electrode in lithium ion battery.