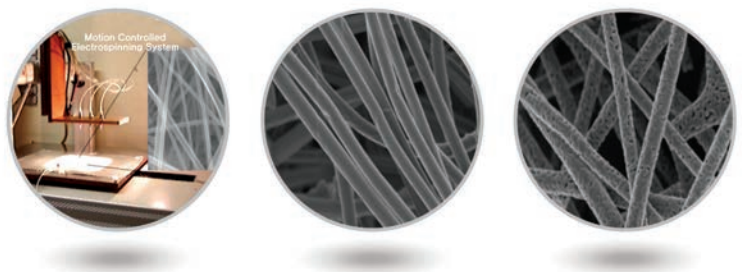
High-capacity and Long-cycle Lithium-Oxygen Batteries

Il-Doo Kim & Seokwoo Jeon (Department of Materials Science & Engineering)

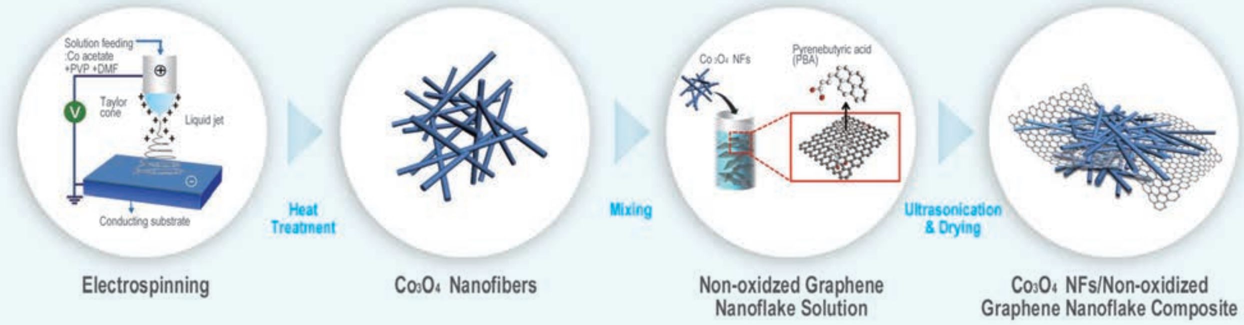


Synthesis of Nanofiber Catalysts and High Performance Lithium-Oxygen Batteries

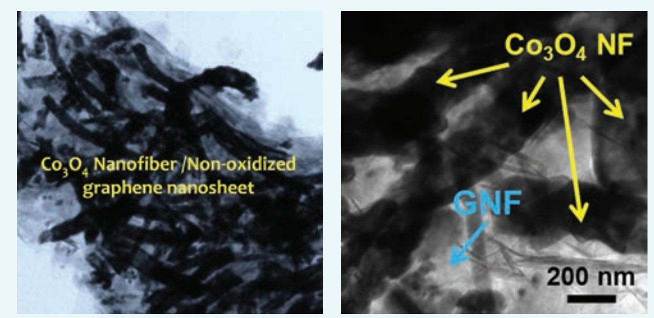
To solve global issues regarding shortages of fossil fuels and greenhouse effects due to abrupt carbon dioxide emission, the development of eco-friendly, next-generation, electric vehicles has been drastically accelerated. In 2030, lithium-oxygen batteries using high performance and cost-effective catalysts will have been successfully developed and electric vehicles composed of new lithium-oxygen battery systems will be able to make 800 km round trips without recharging. By significantly reducing the purchase cost of electric vehicles, such vehicles will gradually spread to the general public, thereby relieving more and more environmental issues such as abnormal climate change.

Lithium-oxygen (Li-O_2) batteries, which involve a unique operating mechanism ($2Li + O_2 \longleftrightarrow Li_2O_2$) related to the formation and decomposition of solid lithium peroxide (Li_2O_2) products onto carbonaceous electrodes, have received a lot of attention due to their energy density that is five to ten times higher than that of Li-ion batteries. However, Li-O_2 batteries often suffer from poor performance due to the low electron conductivity of the insulating Li_2O_2 products that accumulate on the surface of the electrodes after discharging. Therefore, current Li-O_2 batteries have several major problems such as low efficiency, extremely poor cycling, and limited rate capability, and these issues should be resolved so that these batteries can be used for impractical applications. Many studies have thus focused on developing highly efficient and cost-effective catalysts for O_2 cathodes in order to significantly improve the reaction kinetics of Li-O_2 batteries.

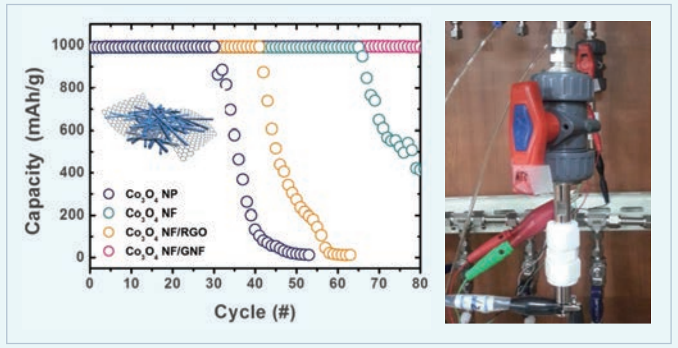
This study focused on the development of high aspect ratio, one-dimensional (1-D), Co_3O_4 nanofibers attached to 2-D non-oxidized graphene nanoflakes as a highly efficient catalyst of an oxygen electrode for high capacity and long cycle Li-O_2 batteries. In tailored hybrid nanocomposite catalysts, 1-D Co_3O_4 nanofibers provide a high degree of catalytic activity for both the oxygen evolving reaction and the oxygen reduction reaction; 2-D non-oxidized graphene nanoflakes offer high surface area and excellent electronic conductivity. In this regard, Li-O_2 batteries that are composed of hybrid nanocomposite catalysts delivered a high 1st discharge capacity of 10,500 mAh/g and superior cyclability for 80 cycles with a limited capacity of 1,000 mAh/g. The 1-D Co_3O_4 nanofibers attached to 2-D non-oxidized graphene nanoflakes exhibited superb performance as highly efficient catalysts for high capacity and long cycle Li-O_2 batteries; this performance is in contrast to that of previously reported nano catalysts.



(Figure 1) Schematic illustration of the synthetic strategy of Co_3O_4 NF/graphene composite



(Figure 2) Morphologies of Co_3O_4 NF/GNF composite



(Figure 3) Cycling data of Co_3O_4 NF/graphene composite and photograph of Li-O_2 battery cell

Expectation Effectiveness

The 1-D Co_3O_4 nanofibers attached to 2-D non-oxidized graphene nanoflakes can be introduced as a high performance and cost-effective catalyst for Li-O_2 batteries instead of expensive, existing catalysts, such as platinum or gold. The Li-O_2 battery system, which is optimized for next generation electric vehicles will enable us to drive a 800 km round trip without recharging. Furthermore, electrospinning as a most suitable synthetic route for mass-production of 1-D structures, can be successfully applied to fabricate diverse classes of nanofiber catalysts for Li-O_2 batteries.

Research Funding

· This work was supported by the Center for Integrated Smart Sensors funded by the Ministry of Science, ICT & Future Planning as Global Frontier Project and National Research Foundation

Research Results

- Patents Pending: one patent
- Published paper: W. H. Ryu, T. H. Yoon, S. H. Song, S. Jeon, Y. J. park, I. D. Kim, Nano Letters 13, 4190-4197 (2013) (Impact Factor = 13.025).