Nanowire Lithium-Ion Batteries as Electrochemical Energy Storage for Electric Vehicles

Investigators

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Abstract

Nanowires offer advantages of a large surface to volume ratio, efficient electron conducting pathways and facile strain relaxation. We will explore these advantages in a nanowire battery architecture for high energy and high power battery for electrical vehicles. In the past two months since funded by GCEP, we have made progress on synthesis of nanowires and are testing their performance as battery electrodes.

Introduction

The rechargable battery is a promising technology for reversible electricity storage in electric vehicles. Current electric vehicles are powered by lead-acid, NiCd or nickel-metal hydride batteries, which are limited by their energy density and calendar lifetime. The existing Li-ion battery technology, which uses $LiCoO_2$ as cathode, lithiated graphite (LiC_6) as anode, and $LiPF_6$-organic solvent as electrolyte, has been the most important power source for portable electronics. However, the high cost and low production volume due to the scarcity of Co are the major hurdles to their wide applications in light duty vehicles. The solution is to decrease the cost and maximize the performance. The electrolyte in general does not limit the Li-battery technology. We identify the following as the most important areas to improve: 1) Use alternative cheaper and higher energy density cathode materials to replace scarce Co oxides; 2) Replace the anode with higher energy density and cheaper materials; 3) Maximize the performance by optimizing battery device architecture. To realize electrochemical energy storage for electric vehicles, we are working on a nanowire battery architecture combined with selection of appropriate materials. We will explore the following advantages of using nanowires: 1) Nanowires have a very large surface to volume ratio to contact with electrolyte. 2) Nanowires form continuous conducting pathways for electrons through the electrodes. 3) The nanowire geometry can promote facile strain relaxation during battery operation.

Background

Within the last two months since funded, there has not been much external developments on nanowire battery electrodes. We are probably the first ones to work on the nanowire battery concept.

Results

In the last two months since funded by GCEP, we have been making progress on the synthesizing silicon nanowires (SiNWs. Figure 1 shows a scanning electron micrograph (SEM) of SiNWs grown off a Si substrate. We have also been successful in growing

SiNWs on stainless substrates, which can be used for battery electrode testing. We are now dong battery testing on these SiNWs.

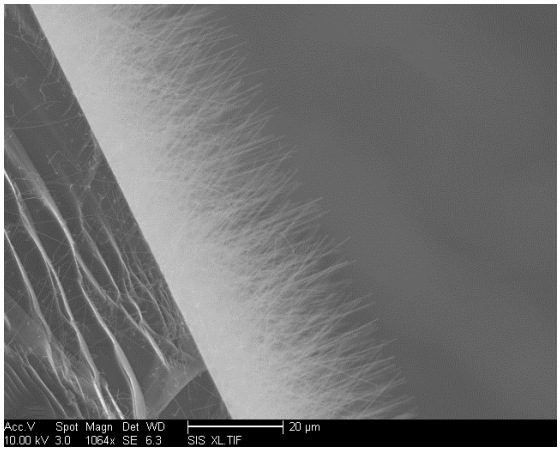

Figure 1: A SEM of SiNWs grown off a Si substrate.

Progress

Transportation accounts for a quarter of global carbon dioxide emissions from energy use, which is expected to approach one-third over the coming decades as the mobility of the world's population increases. The progress achieved will allows to test the nanowire battery design concept towards high energy and high power Li battery for electrical vehicles. Our proposed nanowire Li battery devices inter-convert electrical and chemical energy with nearly 100% efficiency and can provide a carbon-free energy option for electrical vehicles. This can allow significant reductions of greenhouse gas emissions in the transportation sector, provided the electricity is produced with low net greenhouse gas emissions. We believe that if our research is successful, the global greenhouse gas emission can be substantially reduced over the long term.

Future Plans

We plan to carry out the following studies to realize our nanowire battery: 1) Test the SiNWs for high energy anodes; 2) Develop the synthesis for high energy metal oxide nanowires and test their performance as cathodes. 3) Understand the fundamental structure, electronic transformation during charging and discharging.

Publications

1. (*Invited talk*) "Nanowires for Nanoelectronics and Energy Conversion"Hysitron Inc., Minneapolis, Minnesota, Mar. 5, 2007.
2. (*Invited talk*) "Solar Cells and Batteries with Inorganic Nanowires" ACS spring meeting, One-dimensional Nanomaterials Symposium, Division of Inorganic Chemistry, Chicago, Illinois, Mar. 28, 2007.

References

None.

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