Homogeneous Dispersion of CNT Composites for Improved Conductivity, Bucky Papers

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Overview

Battery and capacitor electrode technologies available in the industry today, are struggling to keep up with rapidly advancing applications that require high power and energy density such as electric vehicles, solar cells and telecommunications systems. One of the leading solutions to this problem are CNT-based films, exhibiting excellent conductivity with potentially moderate costs, yet current methods for their formation are both complicated and expensive or hamper the qualities of the material, causing conductivity reduction. A new technology developed by a group of researchers from the Weizmann Institute of Science is simple and potentially cost-effective, preserves the high electrical qualities of the original CNTs and can be easily used to form large surfaces. This technology involves a simple assembly method of organic nanocrystal combined with carbon nanotubes (ONC)/(CNT) to form self-supporting hybrid films with conductivities as high as 5.78 S/m, and excellent thermal stability (of up to ~300 Â°C). The characteristics of the films enable their use as porous electrodes, with easily adjustable pore sizes. These films can then be straightforwardly incorporated into existing platforms such as solar cells, batteries and super capacitors, improving their energy and power density capabilities. Successful incorporation of electrodes into perovskite solar cells has already been demonstrated to improve its efficiency and photo-stability and promising preliminary results were recently demonstrated for the utilization of ONC porous electrodes as separators in super-capacitors.

The Need

The growing need to provide electrodes that can withstand high electric power density has propelled the industry to seek out better electrode platforms. Key target applications include super-capacitors, batteries and photovoltaic systems. Many of the existing electrode technologies used in photovoltaics (specifically perovskite-based solar cells) and super-capacitors are forbiddingly expensive, exhibit low thermal and mechanical stability and are difficult to process. CNTs are gaining much attention for these purposes due to their excellent conductivity and potentially moderate costs, yet their integration into such systems is prevented by the difficulty to efficiently produce large-scale CNT films with desired characteristics.

proposed hybrid CNT dispersion and self-assembly platform enables large-scale production of CNT films exhibiting high mechanical and thermal stability, while preserving their high conductivity. Films prepared with this method were recently efficiently incorporated into perovskite solar cells, replacing gold electrodes while dramatically increasing the cells photo-stability. This CNT hybrid film production platform is also expected to improve the electrical and stability properties of batteries and super-capacitors.

The Solution

A team of researchers led by Prof. Rybtchinski used readily available, hydrophobic perylene diimide (PDIs) derivatives as the base component for the production of organic nanocrystals (ONCs). The PDIs were mixed and bath-sonicated with either single-wall or multi-wall CNTs, in an aqueous medium, to produce film dispersions with different CNT/ONC ratios. Similarly, CNT/PDI films can be obtained from organic media dispersions. The researchers were able to achieve homogenous dispersion of the CNTs in the ONCs, with CNT content ranging from ~3-8 %wt to >60 %wt. Characterization of the nanocomposite showed excellent thermal stability up to 300 Â°C, along with high electrical conductance of 5.8 S/m even with a CNT content as low as 3% concentration. This dispersion and fabrication technology was used for the production of self-supporting films that can be incorporated into different systems as was demonstrated for multi-layered perovskite solar cells to which a CNT/ONC film was integrated, serving as an electrode.

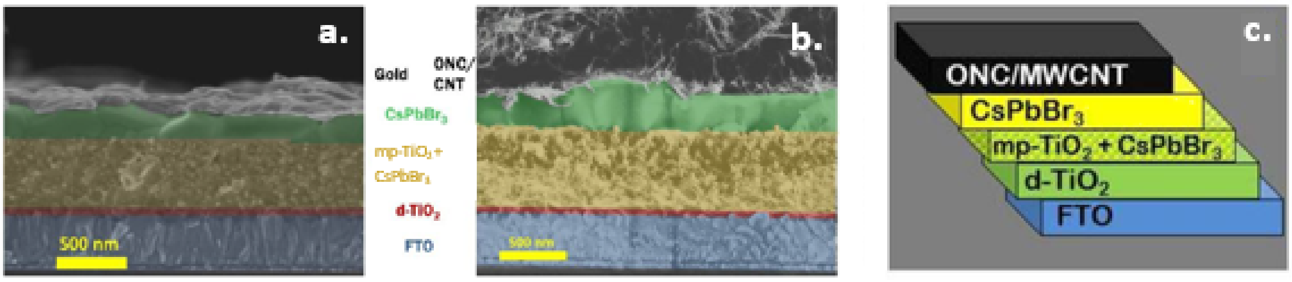

Figure 1. Cross-sectional SEM image of solar cells with a) standard gold electrode and b) hybrid membrane ONC/CNT electrode. Scale bars are 500 nm. c) Schematic presentation of CsPbBr3 perovskite solar cell architecture.

Applications and Advantages

Advantages

- Excellent characteristics for porous electrode applications:
- Tunable CNT content
- High thermal stability (~300 Â°C)
- Excellent conductivity (5.8 Â± 0.5 S/m)
- Straightforward and low-cost production
- Highly controllable pore structure and density, enabling different porous electrode applications.

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Applications

- Porous electrodes in:
- Perovskite solar cells
- Super-capacitors
- Improved batteries (e.g., for electric vehicles).
- Other potential applications:
- A CNT dispersion method
- Chemical sensors
- Water treatment and separation films
- Conductive colorant and optoelectronics systems
- Polymer/CNT composites
- Electromagnetic shielding and microwave absorption.

Development Status

The group of Prof. Rybtchinski has demonstrated a method for easy fabrication of hybrid films combining ONCs and CNTs (Published in: [Adv. Mater. 2018 30 (2) 1705027]() [1]). This method was successfully applied for the production of self-supporting conductive films that were incorporated into perovskite solar cells, which were tested in a 6-week field trial showing a dramatic improvement in solar cell photo-stability. Promising preliminary results utilizing ONC porous electrodes as separators in super-capacitors were recently demonstrated. Additional experiments are to be conducted to incorporate the electrodes into batteries and further investigate their integration into super-capacitor.

Market Opportunity

Energy and power requirements in many emerging technologies have exceeded the capabilities of traditional batteries and capacitors, driving the market to find improved solutions for the batteriesâ€™ limited power density and for the limited energy density of super capacitors. Technologies enabling incorporation of improved porous electrodes with high power as well as high energy density, are highly desirable for rapidly developing markets, such as the super-capacitor industry. According to recent reports, the value of the super-capacitor market is expected to reach USD 2.3 billion by 2023, growing at a CAGR of 20%, through 2018-2023. This is largely attributed to the growing electric vehicle industry and other applications that require high power supply to be found, inter alia, in the telecommunication industry. Similarly, improved electrodes are key to the development of novel solar cells types, such as perovskite solar cells. Limitations relating to stability, cost and power generation capabilities are currently preventing the ability to exploit their full potential and limiting the extensive use of novel solar cells. A technology that dramatically promotes the solar cellâ€™s stability and efficiency can potentially be of a very high value to this market.

Patent Status

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