Practical Production and Functionalization of Carbon Nanotubes for Energy Devices

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To efficiently use renewable energy at larger scale and support society, energy devices should be produced at lower cost using abundant chemical elements. Carbon nanotubes (CNTs), which are composed of carbon, are attractive due to their properties including high specific surface area, fairly high electric conductivity, lightness, flexibility, thermal/chemical stability, and good compatibility with solution processing. We focus on their use as passive electrode materials in combination with various active materials in energy devices.

Transparent conductive films (TCFs) are an attractive target, which uses only 5−10 mg CNTs per 1 m^2 and thus is cost effective. But such small amount of CNTs need to carry sufficient current. We have proposed the repetitive dispersion-centrifugation process to overcome the quality-quantity trade-off and realized >90% conversion of CNTs into TCFs of 80% transmittance and 50 Ω/sq resistance with HNO_3 doping [1]. We used such solution-processed CNT-TCFs to fabricate CNT-Si heterojunction solar cells and realized ~10% photoconversion efficiency with flat n-Si wafer with HNO_3 doping and with textured n-Si wafer without doping (Fig. 1) [2]. This technology will be combined with our large-grain Si films fabricated rapidly in 1 min by vapor deposition [3] toward low-cost, stable, and flexible CNT-Si solar cells.

Battery/capacitor electrodes are another attractive target in which carbon black and carbon nanofibers have been used as conductive fillers. Small-diameter CNTs show unique self-supporting nature, and we are trying to replace heavy 2D metal foils with light-weight 3D CNT sponges for current collectors. We use >99 wt%-pure, submillimeter-long few-wall CNTs by fluidized bed [4]. 1 wt% CNTs realized self-supporting $LiCoO_2$ cathodes and graphite anodes via simple co-dispersion and co-filtration, which minimized the use of metal foils in lithium ion batteries (Fig. 2) [5]. Si is an emerging material having a huge theoretical capacity. We have realized a-few-s synthesis of Si nanoparticles by gas-evaporation and realized high-capacity, self-supporting Si-CNT electrodes [6]. CNT-sponge based S cathodes will also be presented.

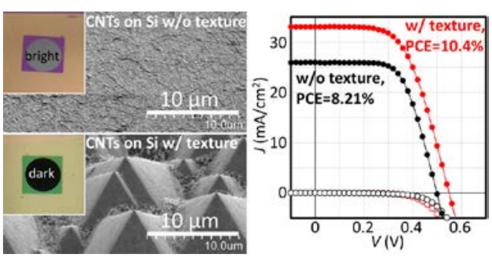

Fig. 1: Si-CNT solar cell [2].

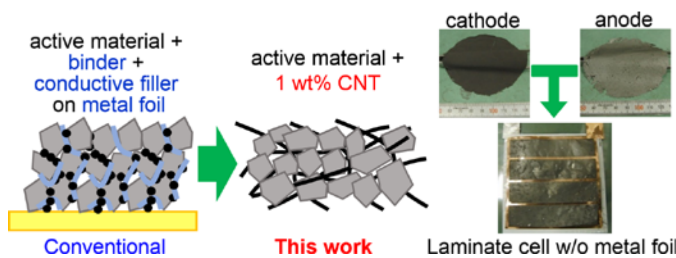

Fig. 2: LIBs based on 3D CNT current collectors [5].

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