Nano-structure Modified Thin-Film Paper Energy Storage Device

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We report on the development of a novel paper thin-film supercapacitor with electrodes made of carbon paper surfaces modified by active nano-structered materials (Figure 1). The device shows a planar capacitance of approximately 2 mF/cm^2 with a specific capacitance estimated to be in the range of 100 - 300 F/g. The developed device is an improvement over similar devices which show comparable electrical performance, but have larger total weight and thickness than our device.[1] These attributes make our device an ideal candidate for applications in portable and inexpensive devices for various applications. A unique combination of nano-structured active materials deposited by simple processes contributes significantly to the electrical performance of our device. The present work is an improvement over other reports on similar devices which employ relatively complex processes to deposit active nano-material on paper substrates. [2]

Initial prototypes of the developed device are thin and lightweight and can charge up to 2V (Figure 2). The developed device employs carbon micro-fiber paper sheets as base material for electrodes (Figure 3A). These sheets are modified by a combination of silver (Ag) nano-particulate ink and multi-walled carbon nanotubes (CNTs) which function as active materials. In the first step, multiple layers of silver nano-ink were deposited by spin-coating (Figure 3B). This is followed by spin-coating a composite layer of Ag nano-ink and CNTs (Figure 3C). The final step involves the deposition of a pure CNT layer (Figure 3D). This layer is formed by casting a solution of CNTs in acetone. SEM images of the electrode surface indicate that the electrode surface is covered by a dense network of CNTs (Figure 3E). The SEM images also show that the micro-fiber network of the carbon paper substrate is penetrated by the active material (Figure 3F). The use of solution casting, a room-temperature method to deposit CNTs on the micro-fiber paper is an improvement over other reports which employed a higher temperature chemical vapor deposition for the same purpose. [3] We anticipate applying our device for portable sensing devices in a homeland security application. We also expect to deploy our device for wearable power applications on military combat uniforms.

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[1] S. Hu, R. Rajamani and X. Xu, Appl. Phys. Lett., **100**, 104103 (2012)
[2] L. Yuan et al., ACS Nano 6, 656 (2012)
L.B. Hu, H, Wu and Y. Cui, Appl. Phys. Lett. , 96, 183502 (2010)
[3] B. Kim, H. Chung, W. Kim, Nanotechnology **23**, 155401 (2012)

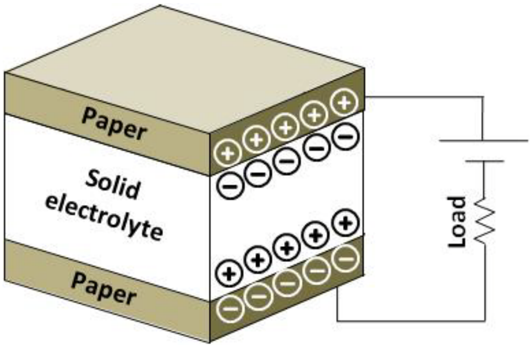

Figure 1: Schematic illustration of the developed paper supercapacitor (not to scale).

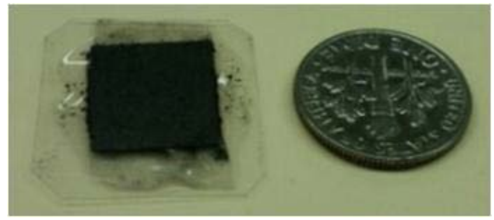

Figure 2: Photograph of the developed paper supercapacitor packaged by lamination. A typical unpackaged device has total thickness of 1.1 mm and total weight of 0.4 gm.

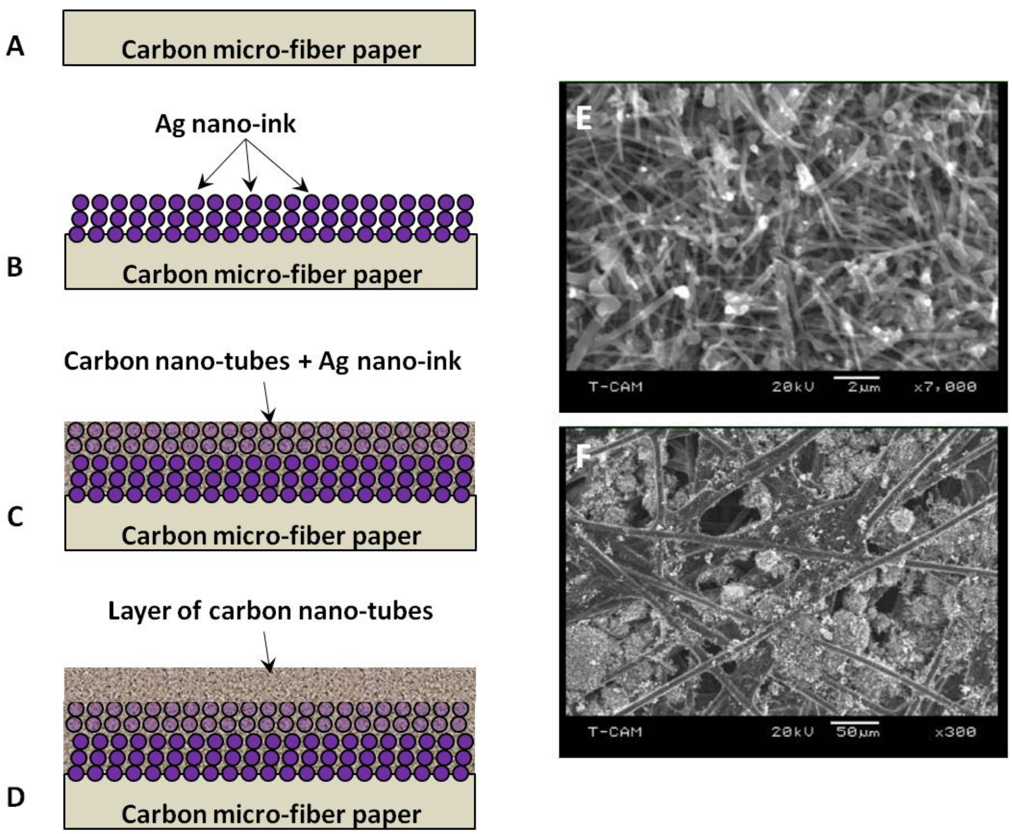

Figure 3: Schematic diagram of electrode fabrication showing (A) a carbon micro-fiber paper; (B) spin-coating of Ag nano-ink layer; (C) spin-coating of CNT/Ag nano-ink composite; (D) solution casting of CNTs. SEM images of (E) electrode surface; (F) the paper's micro-fiber network.