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Editorial

Carbon Fibers: From Micro to Nano

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It has been over 120 years since the earliest documented use of carbon fibers in incandescent light bulb by Thomas Edison. After they were replaced by tungsten filament in light bulb applications, carbon fibers disappeared from industrial view for a while until late 1950s. Due to the aggressive demand for lightweight and strong composite materials, carbon fibers then became a commercially important reinforcement agent in high performance engineering materials, which are highly desirable in automotive, aerospace, and sport industries. Carbon fibers are generally prepared from spinning of organic precursors, among which polyacrylonitrile (PAN) accounts for more than 95% of the worldwide carbon fiber market, followed by stabilization and carbonization.

With the worldwide interest in nanomaterials recently, a new area is just emerging with the entry of a new family member of carbon fibers: carbon fibers at nanometer scale. The rapidly developing technique of "electrospinning" provides a straightforward way to make continuous carbon fibers at nano-scale (typically 50 – 500 nm). Similar to conventional carbon fiber production, PAN is the most often used precursor polymer for carbon nanofibers based on electrospinning. Unlike conventional fiber spinning techniques such as dry-spinning, wet-spinning or melt-spinning, electrospinning is driven by electrical force instead of mechanical force and follows a so called "bending (or whipping) instability" [1-4] thinning mechanism with an extremely large elongation or drawing rate. Following similar stabilization and carbonization procedures as their conventional counterpart, carbon nanofibers are successfully prepared with diameters approximately two to three orders of magnitude smaller [5,6].

Individual carbon nanofibers, unfortunately, exhibit weak strength in spite of their potential to become high-strength fiber considering their smaller size and the drawing feature in electrospinning process. This is because PAN macromolecular chains in electrospun nanofibers, especially in the presence of some trace amount of solvent, may relax to some extent after depositing on collector and lose their formerly drawing-lead orientation. It is well known that many structural imperfections in the precursor fibers are likely to be retained in the resulting carbon fibers [7]. The loss of macromolecular orientation in final electrospun PAN nanofibers may be the reason that causes inferior mechanical properties of the resulting carbon nanofibers.

Up to date carbon nanofibers based on electrospinning are mostly restricted to those applications that do not rely on mechanical properties but on their superior physical properties. This type of carbon nanofibers is referred to as functional carbon nanofibers. PAN-based carbon nanofiber membranes have quickly found their uses in the field of adsorption/separation due to their high specific surface area and large inter-fiber porosity. In combination with high specific surface area, great electrical conductivity, and good biocompatibility, carbon nanofibers have also attracted growing attention in the area of sensors and biosensors and catalysis support. However, there may be no other application more than the use of carbon nanofibers as electrode material for energy storage and conversion application. Carbon nanofibers have similar advantages as carbon nanotubes as 1D carbon nanostructure. The adjustable electrical properties of carbon nanofibers from electrospun PAN have been evaluated and confirmed [8], which demonstrated their potentials as efficient electrode materials. An additional merit of carbon nanofiber mat from electrospun PAN is its ease of handling that is resulted from the interconnected nanofiber network structure. This allows the elimination of polymer binders and conductive fillers in electrodes for better results.

The research in developing strong carbon nanofibers from electrospun PAN, however, does not fade out. Instead it is becoming a point of interest due to the potential to overcome current technological obstacles and further improve mechanical strength of carbon fibers. This type of carbon nanofibers is referred to as high-strength carbon nanofibers. The facts that electrospinning makes significantly smaller fibers and electrospun nanofibers bear the potential of macromolecular orientation from the bending instability deserve every single effort to explore high strength carbon fibers from electrospinning. Nonetheless, current endeavor toward high strength carbon nanofibers is very limited due to the reality that carbon nanofibers from electrospun PAN do not possess high mechanical strength as they are expected [9] and methods and techniques to characterize single carbon nanofiber are still under development [10,11].

In summary, carbon fibers have entered into the era of nano. The new class of carbon material with 1-D nanostructure and

concomitant high specific surface area has seen a wide range of applications from energy conversion and storage to catalysis, from sensor to adsorption, and to biomedical applications. More intriguingly, strong carbon nanofibers have been attained through aligned electrospinning of PAN followed by post-spinning stretch and optimized stabilization and carbonization. The current attempts revealed a hope to acquire even stronger carbon fibers than those from conventional carbon fiber industry. It is envisioned that the continuous nano-scale carbon fibers from electrospun PAN are going to shine even greater luster in the family of carbon materials.

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