Lecture 7. Applications of Multiwalled Carbon Nanotubes (MWCNTs)

The purpose of the lecture: to provide information on applications of multiwalled carbon nanotubes (MWCNTs).

Expected results: to master the applications of multiwalled carbon nanotubes (MWCNTs).

The outstanding properties of CNTs have opened a new age of advanced multifunctional materials for a variety of applications such as reinforcement in plastic to make them highstrength conducting plastics for electromagnetic interference (EMI) shielding and electrostatic discharge (ESD) applications, CNT-based yarn for structural composites, anodes for lithium ion batteries, fuel cell components, armor materials, self-healing composite materials, and conducting cables for motors.

Polymer Nanocomposites for Structural Applications

Polymer composites consisting of polymers reinforced with various additives such as carbon fibers, graphite fibers, glass fibers or Kevlar fibers, and carbon black are increasingly being used in defense, aerospace, automobile, sports, and electronic sectors as lightweight, high-strength and high electrical and thermal conducting materials. In recent years, nanocomposites, in which the reinforcing additive has nanoscale dimensions have attracted both scientific and technological interest to meet the growing demands for materials with improved properties for challenging applications. CNTs have particularly led to research in the development of advanced polymer nanocomposites due to their unique material properties as discussed earlier, which is comprised of extraordinarily high mechanical, electrical and thermal properties. CNTs, both SWCNTs with diameters 1–2 nm and MWCNTs with diameters 10–100 nm, have a very high aspect ratio and therefore very large surface area. This suggests that small amounts of CNTs as compared to conventional reinforcements can provide a large volume of interface that will significantly enhance the properties of polymers in terms of imparting strength and conductivity to a composite system.

In recent years, most of studies have been carried out to enhance the mechanical properties of CNT–polymer composites. Different polymers, both thermoplastics (e.g., polymethylmethacrylate [PMMA], polystyrene, polycarbonate, and polypropylene and thermosets (e.g., phenolics, polyimide and epoxy) have been investigated as matrices to make CNT-reinforced polymer composites.

Although neat CNT–polymer composites have so far not realized the desired results, an alternate approach is initiated in terms of using a CNT-dispersed resin matrix for fiber reinforced composites.

The high mechanical strength of these nanocomposites could be utilized to make highend sporting goods, such as tennis rackets and baseball bats, thus delivering superior performance.

Recent examples include strong, lightweight wind turbine blades and hulls for maritime security boats and composite wind turbine blades that were made by using carbon fiber composites with CNT-enhanced resin (Figure 1). This can also be useful for the aerospace industry because the main driving force for materials substitution in the aerospace industry is weight reduction at a reasonable cost while maintaining reliability and safety standards. Reducing the weight of the structure allows lifting a greater payload and/or reducing fuel consumption.

CNT Yarn for Structural Composites

As discussed earlier, it is very difficult to properly align CNT in a polymer matrix through conventional composite processing techniques; however, several techniques have been used to draw fibers out of a CNT-dispersed polymer. Not much success has been achieved so far. Recently, dry spinning of CNT yarn is suggested as an alternative form of an aligned bundle of MWCNT. In the long run, it is believed that CNT yarn and laminated sheets made by direct CVD or spinning from CNT forest or other drawing methods will only compete with the carbon fiber-based technologies for high-end applications, especially in weight-sensitive applications. Several researchers have made multiwalled CNT-based yarn by various techniques such as dry spinning, wet spinning, and melt spinning with polymers. A stiffness value of 357 GPa and a strength of 8.8 GPa has been achieved for a few millimeters long gauge length. For centimeters long gauge length, strength values of 2 GPa have been achieved, which equals the specific strength of commercially available Kevlar (DuPont) fibers. Recent advances in preparation allow CNTs to grow up to several millimeters in length, which could be aligned to continuous macroscopic CNT fibers (Figure 2). This provides an opportunity for preparation of superstrong continuous nanotube reinforced composites.

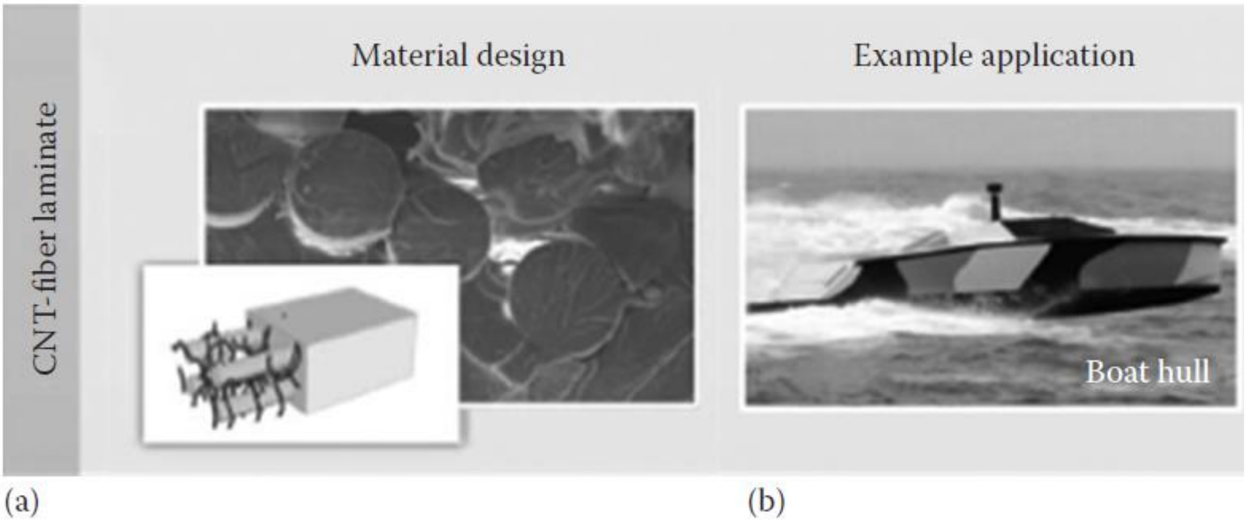

FIGURE 1. Emerging CNTs composites. (a) A micrograph showing the cross section of carbon fiber laminates with CNTs dispersed in epoxy resin and (b) a lightweight CNT–fiber composite boat hull for maritime security boats.

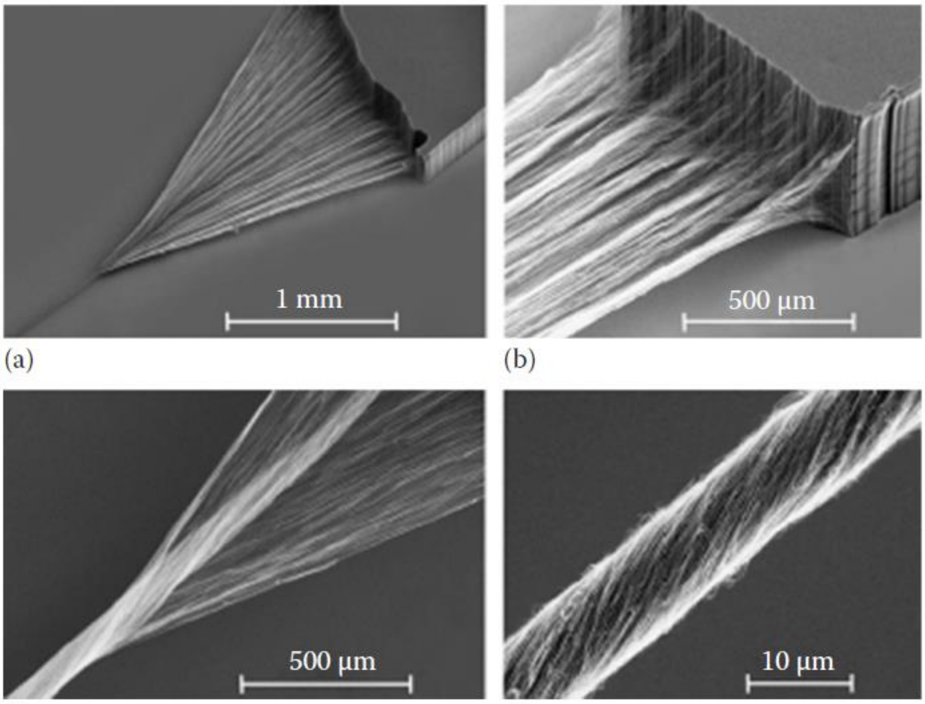

FIGURE 2. SEM images showing a web being drawn from a CNT forest and then twisted into a yarn. (a) Overall view of the process clearly showing the spinning triangle that forms; (b) CNT detachment from the forest edge to form a web; (c) convergence point of the spinning triangle; and (d) the final yarn.