Carbon nano-tube reinforced thermoplastics

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The progress in science and technology has opened the era of nano-technology. One of the most distinctive characteristic of nano-technology is size-dependent properties of nano-materials. Among the many nano-structured materials, carbon nano-tube (CNT) has attracted considerable attention. CNT is pure carbon cage-like molecule (fullerene), where each atom is bonded to three others as in graphite (see Fig. 1).

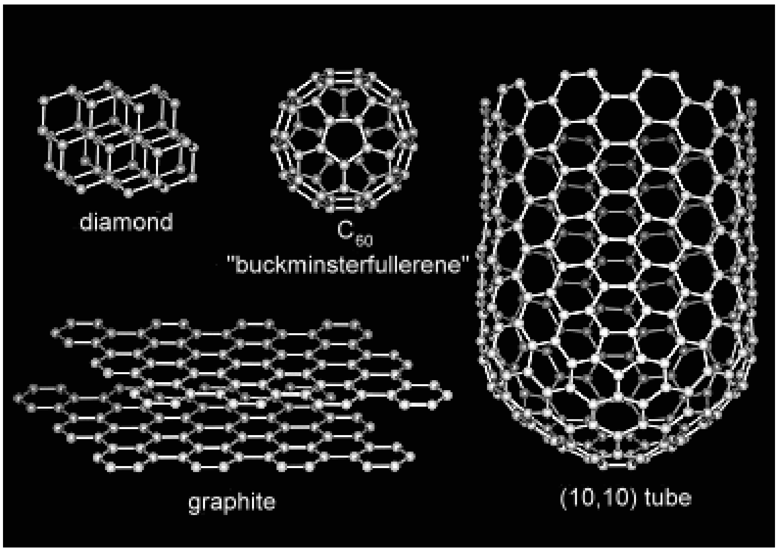
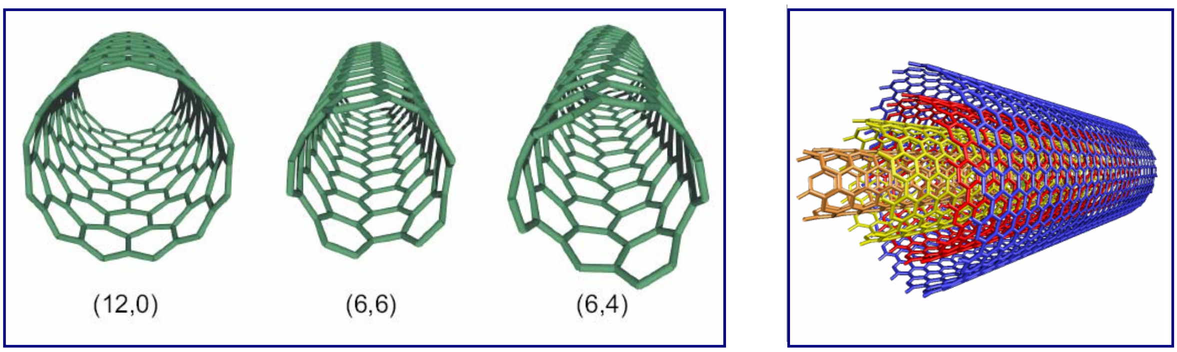


Fig. 1. Fullerenes: Each fullerene – C_{60}, C_{70}, C_{84}, etc. – possessed the essential characteristic of being a pure carbon cage, each atom bonded to three others as in graphite.

It was first observed in the 1970's but not studied at that time and then discovered relatively recently by Iijima (1991) and first synthesized by Smalley (1996). They can be produced by an array of techniques, such as arc discharge, laser ablation and chemical vapor deposition. From the viewpoint of atomic arrangement, CNTs can be visualized as cylinders that rolled from sheets of graphite (there are opened-end and closed-end or "capped" nano-tubes). They assume either single-walled (Single Walled CNT: SWCNT) or multi-walled (Multi Walled CNT: MWCNT) structures and their helicity may also be different (see Fig. 2).



(a) (b)

Fig. 2. Different types of nano-tubes: (a) different helicity; (b) multi-walled nano-tube.

Since the discovery of carbon nano-tubes, much attention has been given to the investigation of their exceptional physical properties. CNTs possess mechanical properties far superior to commercially available carbon fibers, due to their expected structural perfection. Young's modulus (~1 TPa) similar to the in-plane modulus value for high quality graphite and high tensile strength (~ 50 to 100GPa, thus much greater than any other available material) are predicted, and for the modulus experimentally verified. For comparison, the highest strength carbon fiber in industry has a strength of ~ 7 GPa. Due to the extremely small size of nano-materials (diameter in the range of 1-50 nm and length 1-10 μm), the evaluation of their mechanical properties, such as elastic modulus, tensile/compressive strength and buckling resistance, presents major challenges to researchers in nano-mechanics.

The extraordinary properties of carbon nano-tubes have motivated researchers worldwide to study the fundamentals of this novel material as well as to explore their applications in different fields. One of the applications that seem to be very promising is use of CNT as reinforcement in composite materials. Theoretical estimation of properties of nano-tube reinforced composites indicates that the addition of small numbers of nano-tubes may lead to a dramatic increase in the modulus. Use of CNT as reinforcement in polymer materials seems to be particularly interesting. However, some of the experimental studies showed that outstanding mechanical properties can not be utilized in polymer matrix composites due to a number of reasons (poor dispersion of nano-tubes, weak bonding between nano-tubes and polymer etc).

However, difficulties to dramatically improve mechanical properties of polymers with addition of CNT do not mean that nano-tubes have no application in this field. The most important advantage of using CNTs as filler in polymers may not be improvement of mechanical performance but addition and improvement of other physical properties. For example, even small addition of CNTs dramatically improves electrical conductivity of the polymer. Thermal conductivity of the polymer also significantly increases with addition of nano-tubes. This means that the main effort should be directed towards gain of multi-functionality of the material rather than improvement of mechanical performance. Such multi-functionality of CNT reinforced polymer will allow to create smart materials which themselves would also act like a sensors and give feedback needed to adjust material properties (by applying magnetic or electrical field on material, for example). There is huge potential use for such materials, for example clothes that contain nano-tubes can be used in space suites to protect astronauts from different kind of radiation and in the same time used as a sensor for health monitoring and communication device. Polymer material reinforced with CNT can be incorporated in structural materials of space ships and aircraft (and any other vehicles as a matter of fact) and also used as a sensors and shielding materials.

Nevertheless, mechanical properties should not be neglected completely. In most cases addition of new functionality to the material can not justify degradation of mechanical properties. Undoubtedly, there is also an enormous potential for improvement of mechanical performance of polymer by addition of CNTs but the methodology for that is not fully elaborated yet.

The proposed project has the following main objectives (each of the sub-tasks can be studied in separate smaller project):

- Optimization of processing parameter for manufacturing of thermoplastics reinforced with CNTs

- Mechanical characterization of composites reinforced with different types of nano-tubes (single walled, multy-walled, purified, functionalized etc) and with different amount of CNTs.

- Characterization of electrical and thermal properties of thermoplastics reinforced with CNTs and investigation how different amount and quality of CNTs influences these properties.

- Evaluation of feasibility to use thermoplastic/CNT composites in everyday applications from cost/performance point of view.