

Poptube Technology, enabling multifunctional hybrid composites for next generation aircrafts

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Purpose

The purpose of this study is to use a novel nanoengineering technique, Poptube technology, to manufacture multiscale, multifunctional structure composites with superior mechanical performance and durability. The PopTube technology is a scalable, highly energy-efficient and cost effective approach to fast grow CNTs on reinforcing fibers in large volume. In this technique, only a single chemical is used to provide both the carbon source and catalyst of CNT growth. Microwave is used to directly heat carbon fibers/fabrics to provide fast and energy-efficient heating. This technique takes only 15-30 seconds to grown CNTs under the microwave irradiation at room temperature in the air, with no need of any inert gas protection, and additional feed stock gases, typically required in chemical vapor deposition (CVD) approach.

Background

Fiber reinforced polymers (FRPs) have been extensively implemented in the fields of aerospace, automotive, electronic, renewable energy, civil infrastructure, and sports equipment for their higher specific strength and stiffness, lighter weight, and better fatigue and corrosion resistance. A typical FRP composite consist of reinforcing microfibers/fabrics, polymer matrix, and an interphase zone developed between the fiber and matrix. Since the matrix and the interphase zone are much weaker than the fibers, the matrix and interphase-dominated properties of FRPs are often poor, including the transverse tensile strength and longitudinal compressive strength, fracture toughness, the interlaminar shear strength, and the load threshold for damage initiation. These poor properties severely limit the overall performance and applications of FRPs. Extensive studies have been conducted in last decade to reinforce FRPs using carbon nanotubes (CNTs) because of CNTs' extraordinary mechanical properties and excellent thermal and electrical properties. The excellent thermal and electrical properties of CNTs can also provide materials with functional advantages such as self-sensing abilities, flame retardancy, wear resistance, electrical and thermal conductivity, electromagnetic interference shielding, and improved thermal stability.

Existing research so far has focused on demonstrating the great potential of CNTs to improve the performance of FRPs at laboratory set-up. For real structural application, however, existing techniques to integrate CNTs into FRP composites must be scaled up for large-scale manufacturing/processing. A processing technique which meets need of large-scale manufacturing capacity is

nonexistent.

To meet the need of real, large-scale applications of CNTs in FRP composites, this study proposes a simple, highly energy-efficient, and highly cost-effective nanoengineering technique to grow CNTs on fibers/fabrics. This research will lead to a new paradigm of integration of CNTs with conventional micro-size fiber reinforcements to form high-performance, highly durable, multifunctional, hierarchical hybrid structural composites. The novel PopTube technique provides a much-needed solution for real application of CNTs reinforcement in large-scale structural composites for next generation aircrafts. Armed with these new materials, the next generation aircrafts will be lighter, harder, more durable, and multifunctional, leading to higher fuel efficiency, lower carbon dioxide emission, and enhanced aircraft safety. This innovative idea has also great potential to possibly eliminate the high cycle fatigue (HCF) problem by tough, thermally stable materials that show significantly enhanced dynamic damping properties for engine blade vibration and sound control without degradation in the thermal stability of the materials.