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Carbon nanotube dispersion in nematic liquid crystals: An overview

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ABSTRACT

The aim of present review article is to present a comprehensive and current overview of scientific advancement in liquid crystal and carbon nanotube suspension. Particular attention has been paid to the recent developments and fundamental understanding of carbon nanotube dispersion in nematic liquid crystals. The dispersion and interaction of carbon nanotube in liquid crystal matrices and more elaborately the effect of dispersion on the properties of liquid crystalline materials has been extensively discussed. Recent progress has shown that even a very minute concentration of carbon nanotube in liquid crystals can have a reflective impact on the electrical and optical properties of liquid crystals. Liquid crystals provide a distinctive environment for controlling the alignment of carbon nanotubes whereas carbon nanotubes are important for the enhancement and fine-tuning of liquid crystalline properties. Potential applications of liquid crystal and carbon nanotube suspension are briefly discussed. Conclusion and future perspectives of this rapidly emerging field is provided at the end.

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1. Introduction

A key issue or challenge about the applicability of carbon nanotubes (CNTs) is their propensity to form aggregates [1–5]. Most of the production methods for CNTs result in bundles of tubes or randomly oriented tubes. The random orientation and the entanglement of these tubes thus average out their anisotropic properties. Since most of the properties mechanical, electrical or optical are prominent along the tube length, the applications of CNTs in sensors, solar cells, field emission devices, probing devices, ultra-capacitors, electro and mechanical devices, etc. [6–11] are often more useful when they are uniformly aligned and disentangled. Several methods have been devised to align these CNTs – alignment during synthesis (using metal catalyst) and post synthesis techniques (application of electric and magnetic field, etc.). But all of these methods suffer with their own limitations and a high degree of orientation has not yet been achieved. One of the alternative ways to align these nanotubes is to impose the self organizing characteristic of liquid crystals (LCs) to CNTs. Even though the aspect ratio of CNTs is much higher than the LCs, at low concentration of CNTs in LCs, the mesogenic molecules are capable to slot in these tubes into its own orientation. The recent works clearly figure out how effective the LCs are in aligning these nanotubes, both thermotropic and lyotropic LCs [12–17]. Also the surface orientation of CNTs can be decorated by outlining the orientation of LC molecules either parallel to the surface (Homogenous Alignment) or perpendicular to the surface (Homeotropic Alignment) or twist alignment. The director reorientation of LCs can be superimposed to CNTs in LC/CNT suspension by elastic interaction with the application of electric or magnetic field of sufficient strength. Therefore, LC provides an environment for controlling the alignment of CNTs.

The improved optical contrast, observed by Heilmeyer and Zanoni [18] in 1968 laid the foundation for the enhancement of properties of liquid crystalline materials by the dispersion of guest entities. This method has been established as a much easier way to perk up the properties of liquid crystals than to synthesize a new liquid crystalline material. In the last few decades the dispersants include polymers [19,20], nanoparticles [21,22], ferroelectric nanoparticles [23,24], quantum dots [25,26] and nanotubes [27,28] along with dyes [29–31]. In all the classes, CNT dispersed LC represents a very versatile system for the stepping up of mechanical, electrical and electro-optical properties of LCs and also the orientation of LC molecules on CNT surface. The shape anisotropy of the molecules of LC and CNTs make them a compatible companion. The configurational likeness of CNTs and LCs (both having rod like structure) escorts LCs to integrate CNTs into its own configuration effortlessly. This leads to potentially applicable and an interesting anisotropic composite system with improved physical properties, having low operating voltage and faster electro-optical response than pristine LC. Even small concentration of nanotubes in LC has shown to lead to large nonlinear optical effect [32,33]. Enhancement of electro-optical effects [34,35] as well as enhancement of dielectric and electrical properties [36,37] has also been reported, in recent years. Some new physical effects such as memory [38],

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