Article

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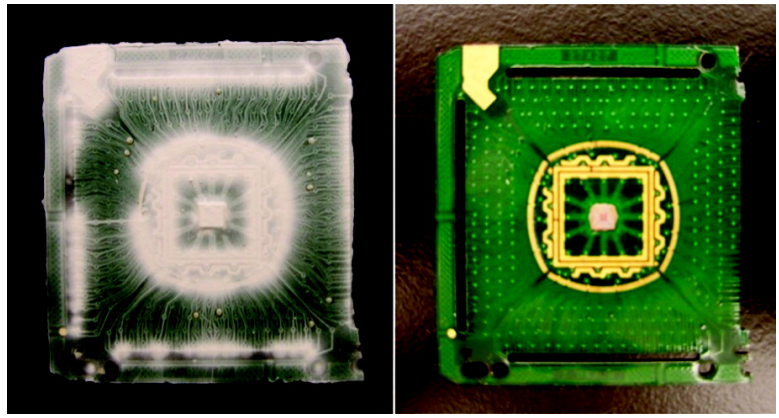

Nanodiamond-Polymer Composite Fibers and Coatings

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ABSTRACT While nanocrystalline diamond is quickly becoming one of the most widely studied nanomaterials, achieving a large fraction of diamond nanoparticles in a polymer coating has been an unresolved problem. In this work, polymer nano- and microfibers containing high loadings of 5 nm diamond particles (up to 80 wt % in polyacrylonitrile and 40% in polyamide 11) have been demonstrated using electrospun nanofibers as a delivery vehicle. The electrospun nanofibers with a high load of nanodiamond in the polymers were fused into thin transparent films, which had high mechanical properties; an improvement of 4 times for the Young's modulus and 2 times for the hardness was observed already at 20% nanodiamond in polyamide 11. These films can provide UV protection and scratch resistance to a variety of surfaces, especially in applications where a combination of mechanical, thermal, and dielectric properties is required.

KEYWORDS: nanodiamond · polymer · nanofibers · electrospinning · composite materials · thin films · coatings

Nanodiamond (ND) powder, also known as ultradispersed diamond (UDD), exhibits unique properties of diamond on the nanoscale and is becoming one of the more widely studied nanomaterials.[1−6] Superior hardness and thermal conductivity of the diamond core is combined in nanodiamond powders with large accessible surface area covered by readily tailorable surface functional groups.[1,7,8] The wide band gap of the diamond (~5 eV) renders it highly absorptive toward UV light, but transparent in the visible and IR range.[1] ND is produced by a detonation synthesis in large volumes and is a relatively inexpensive carbon nanomaterial for a broad range of potential applications, including composites.[9−11] As a powder, ND could be introduced into fibers, coatings, or other shapes to harness its useful properties. One major obstacle for ND composites is the ability to deliver nanodiamond in the form of well-dispersed particles[12] into a polymer matrix. Traditional polymer processing techniques such as casting and extrusion have yielded poor dispersion due to agglomeration/reagglomeration of the nanodiamonds within the polymer matrix leading to a compromise of the properties.[13] Also, the addition of more than several percent of nanodiamond to the whole volume of a polymer component would substantially increase the cost and weight. Therefore, diamond should preferably be used in those places where it is needed, for example as a surface coating.

Electrospinning provides many benefits stemming from the small and tunable fiber diameter. Polymer composites produced *via* the electrospinning method allow for a polymer nanofiber to act as a host for nanoparticles.[14−22] Polymer nanofibers can be used as a coating or appliqués,[23,24] thus delivering nanodispersed particles while effectively preventing their agglomeration. The confinement of the fiber diameter, polymer surface tension, and strong electrostatic force pulling the fiber in the electrospinning process may help in deagglomeration of nanoparticles, similarly as it has led to a debundling of single-walled carbon nanotubes and their alignment along the fiber axis.[15] In addition, as soon as the fiber solidifies upon evaporation of the solvent during electrospinning, reagglomeration of nanoparticles is effectively suppressed; thus, a resulting nanocomposite incorporates uniformly dispersed, size-confined nanoparticles.

So far, various nanomaterials have been incorporated into electrospun fibers. Among them are ceramic nanoparticles,[17,18,21] nanowires,[14] quantum dots,[19,22] nanotubes,[15,20] and others. While there have been more than a hundred of articles published on electrospun polymer-nanotube fibers in the past 5 years, there are no reports on electrospun ND-polymer fibers. At the same time, ND powders, being biocompatible[1,25−27] and having a

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