Controlling the Configuration of Nanofillers in Electrically driven Jets for Energy Storage Applications

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Abstract

Controlling the dispersion of nanofillers in a polymer matrix has a significant effect on their properties, such as mechanical, optical, electrical and magnetic properties. Employing circumferentially uniform air flow through the sheath layer of the concentric coaxial nozzles, the gas-assisted electrospinning utilizes both high electric field and controlled air flow which can offer i) enhanced stretching of fluid jet and thus much higher throughput and thinner fibers, and ii) better control of dispersion and configuration of nanofillers in a polymer matrix even at high loadings. The ability to tailor the distribution of various nanofillers (spherical SiO_2 and Si nanoparticles (NP) and rod/tube–like carbon nanotubes (CNTs), and carbon nanoribbons (GNRs)) in a polyvinyl alcohol (PVA) jet was demonstrated by varying air flow rates in gas-assisted electrospinning. The distribution and orientation of nanofillers in the resulting nanofibers were measured by analyzing the transmission electron microscope (TEM) images. Our results reveal that two to three fold improvement in NP distribution can be obtained with the application of high, but controlled air flow. The substantial improvement in the orientation of CNTs and GNRs by additional controlled air flow was also observed, while GNRs exhibit better dispersion with retarded orientation than CNTs due to the increase in their flexibility caused by the unzipping process. These results are validated by the coarse-grained Molecular Dynamics (CGMD) study of nanofillers in a polymer matrix under elongational flow. The enhanced performance by controlling dispersion and configuration of nanofillers in nanofibers has been demonstrated in the directly deposited, Li-ion battery anode application, exhibiting over 2,000 mAh/g of capacity which is about 1,000 mAh/g higher than the anode obtained by conventional electrospinning. Lastly, the direct deposit approach has been extended to the electrospray process, and the resulting anode obtained from air-controlled electrospray of aqueous Si NP/graphene oxide solution exhibits about 1,500 mAh/g of capacity for 200 cycles without capacity loss.