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Electrophoretic deposition of carbon nanotubes using new dispersing and charging agents

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The dispersion of carbon nanotubes (CNTs) is of great importance in both industrial and academic areas. Various methods were proposed and investigated for the dispersion, including the use of surfactant and polymers as dispersing agents. However, such method requires relatively high dispersant concentrations. Polymers bring about bridging flocculation CNTs. Chemical modified CNTs have soluble groups in its structure and can be dissolved in water or ethanol. However, the functionalization process can cause the structure damages and hence the conductivity of CNTs is reduced. Therefore, new methods have to be explored to disperse CNTs with high efficiency and stability and less structure damages.

The aromatic molecules can adsorb on the surface of CNTs by the π-π stacking mechanism. Because of the adsorption, the aggregation of CNTs can be broken and a homogeneous suspension can possibly be obtained. Pyrene was proved to be a good dispersant for CNTs in non-polar solvent for its adsorption on CNTs surface, which directly proves this mechanism. This mechanism can be used for choosing dispersing agent working in polar solvents, e.g. water and ethanol.

Aromatic organic molecules with charged soluble groups can be used as dispersants for CNTs in polar solvents. And an example of this kind of molecules is pyrenebutyric acid (PBH), which has pyrene group for attaching CNTs and carboxylic acid for dissolving in water. Because PBH is insoluble in water, it has to be protonated using sodium hydroxide firstly and then the PB^- works as dispersing agent for CNTs, (Fig.1) so the dispersed CNTs is negatively charged and hence anodically deposited through electrophoretic deposition (EPD).

In the proposed deposition mechanism deprotonated PBH forms insoluble PBH at anodic electrode. Due to the anisotropic property of PBH, a preferred growth direction exists and hence a self-assembly needle shape particles formed, which can also be found in the CNTs film formed by EPD from suspension with high PBH concentration. The existence of PBH particles in the CNTs film directly proves the co-deposition of PBH and CNTs and hence indicates the adsorption of PBH on CNTs.

Composite film with finely mixed CNTs and MnO_2 nanoparticles can be obtained using PBH as dispersant through EPD. Due to the good mixture between MnO_2 and CNTs, this composite film exhibits excellent capacitive performance. However, the specific capacitance is very sensitive to the concentration of PBH in suspension, especially at high scanning rate. The

increase of PBH concentration can effectively reduce the specific capacitance of composite film, where the PBH needle shape particles can also be identified. So it is suggested that the existence of PBH particles reduces the conductivity of composite film and hence the specific capacitance decreases.

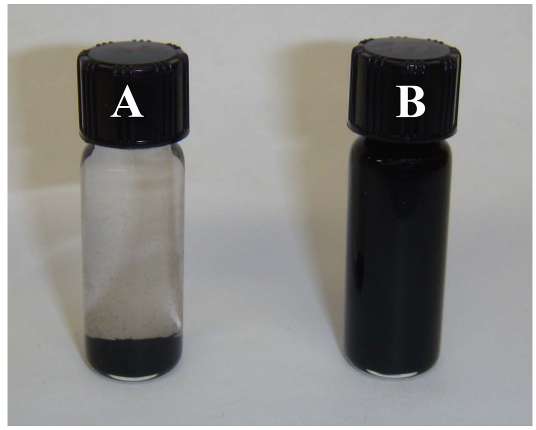

Fig1. Suspensions of (A) CNTs, (B) CNTs with PBH in water.

Cathodic deposition offers advantages compared with anodic deposition. To achieve a cathodic deposition, positively charged dispersant is necessary. An advanced dispersant with aromatic rings forms cations in water, which makes it a good dispersant for cathodic EPD of CNTs. Another advantage of using this dispersant is that graphene can also be dispersed in water and cathodically deposited through EPD. (Fig.2)

This dispersant can also be deposited itself through ELD, and its SEM image shows self-assembly nanoparticles with a cylinder shape, which is also caused by the anisotropic property of dispersant molecules. These particles can also be identified on the surface of CNTs and graphene particles once they are deposited from suspension through EPD, which directly proves the adsorption of dispersant molecules on CNTs and graphene.

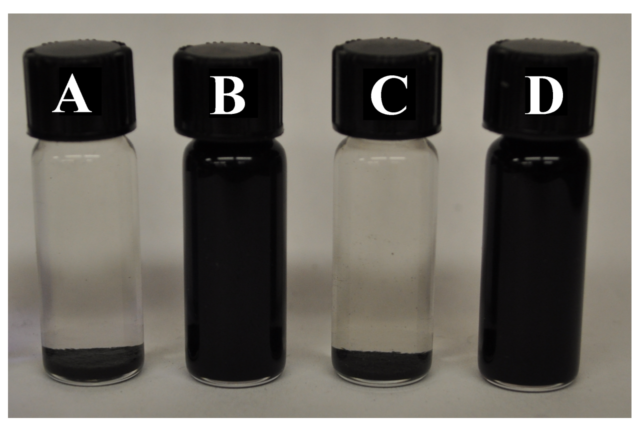

Fig.2 Suspensions of (A) CNTs, (B) CNTs with dispersant, (C) graphene and (D) graphene with dispersant.