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Dispersion and Functionalization of Inorganic Nanotubes by Covalent or Noncovalent Methodologies

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Carbon nanotubes (CNTs), discovered in 1991, are one of the most famous nanomaterials and utilized for various applications such as energy, environment, and health due to their excellent mechanical, electrical, and chemical properties. Analogous nanotubes for CNTs, boron nitride nanotubes (BNNTs), in which carbon atoms of CNTs are substituted by alternatively boron and nitride atoms, have received great attentions in more recent years because of their excellent and unique properties. However, as prepared CNTs and BNNTs are insoluble in any solvent (especially in water) due to their self-aggregating properties caused by strong van der Waals interactions between sidewalls of both nanotubes, and the applicabilities were limited. Therefore, various methodologies to disentangle and disperse the nanotubes are required. In this study, both the nanotubes were successfully dispersed and functionalized by using various molecules and methodologies.

First, the nanotubes were dispersed in aqueous solutions by simple aromatic molecules such as derivatives of naphthalene, anthracene, and pyrene. Their dispersion capabilities were quantitatively investigated by absorption measurements and atomic force microscopy (AFM) observations. The results indicated that numbers of aromatic rings and substituted groups were significant parameters for the disentanglement and dispersion of both nanotubes.

Second, the nanotubes were dispersed and functionalized in aqueous solutions by pyrene-conjugated peptides. Although the peptides showed self-aggregating properties in aqueous phase, well disentangled and dispersed CNTs and BNNTs were observed. Depending on the method for use of the peptide, the dispersion capability and stability were much different. I have successfully found that self-aggregating peptides could be utilized for the disentanglement and dispersion of inorganic nanotubes by suitable methodologies.

Third, noncovalent functionalization of CNTs by CdSe nanoparticles was performed by electrostatic interactions between negatively charged acid-treated CNTs with carboxy groups and positively charged CdSe. The construction of nanohybrid materials was evidenced by various analyses including X-ray diffraction, X-ray

photoelectron, and Fourier transform infrared spectroscopy. Optical properties of the hybrid materials were also investigated by absorption measurements. As a result, the absorption property of the hybrids was different from that of pure CdSe, suggesting that electron states of the surface were redistributed and delocalized by the interactions.

Forth, covalent functionalization of CNTs with the CdSe nanoparticles was performed. Carboxylated CNTs were conjugated with CdSe nanoparticles by three kinds of diamine linkers, which have different length of alkyl chains to form chemical bonding. Photoluminescence spectra of the resultant nanohybrids indicated that their emission properties were dependent on the alkyl chain numbers of the linkers. Therefore, it was suggested that the distance between CNTs and CdSe nanoparticles was important for the functionalization.

In conclusion, I have successfully demonstrated disentanglement, dispersion, and functionalization of CNTs and BNNTs in aqueous solutions by either covalent or noncovalent methodologies using various molecules such as conjugated small organic compounds, biomolecular peptides, and inorganic nanoparticles. These results will contribute to the advancement of inorganic nanotube-based functional materials and diverse promising applications particularly in optical and bio-related fields.