Property-structure relationship and design of carbon nanotube based corona phase molecular recognition for biomolecules

By

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Technical Summary

The emerging field of nanomaterials has a great potential in a wide range of applications. Depending on the application, the versatile properties of nanomaterials derived from its innate small scale can be further expanded and fine-tuned. This process of nanomaterial functionalization requires an accurate analytical tool to capture their physicochemical characteristics. However, the main advantage of being nanoscale poses as a key hurdle to precisely characterize the nanoparticles, which have mainly resulted in methods that are costly, time consuming, and inaccessible to many researchers. To address this challenge, this thesis focused on the development of new characterization technique for dispersed nanoparticles. Molecular Probe Adsorption (MPA) analysis quantitatively measures open surface area of nanoparticles stabilized by dispersants in aqueous solution. The surface area of the nanoparticle is particularly useful in that many nanoparticle-based applications such as nanocatalyst or nanocarrier are mostly based on the interaction with other molecules on the nanoparticle surface. We explored several types of nanomaterials with different aspect ratios along with various kinds of dispersants using MPA analysis. We also summarized how the MPA analysis can be utilized to understand structure-property relationship of nanoparticle which has been a main challenge especially in nanoscale.

Nanoparticle-based sensing can be applied in various fields including pharmaceutical and agricultural industries. Among the nanoparticles discovered so far, there have been extensive studies on the engineering of molecular recognition site with single-walled carbon nanotube (SWCNT). Nanoparticle corona is a layer of adsorbed molecules formed at the surface of a nanoparticle in solution by non-covalent interactions. The unique three-dimensional conformation of the corona phase can become a molecular recognition site where an analyte is selectively adsorbed in a non-covalent manner. Corona phase molecular recognition (CoPhMoRe) refers to a corona phase around a nanoparticle in solution, such that the combined construct is capable of molecular recognition, to a degree where neither can do independently. High selectivity of the CoPhMoRe and the excellent optical property of the SWCNT make the CoPhMoRe sensor promising for analyte detection with high accuracy. This thesis elaborates design principles of SWCNT-based CoPhMoRe sensors to optimize their interaction with the analytes. We aimed to construct CoPhMoRe sites by synthesizing newly designed polymers. We specifically focused on detecting carbohydrates and phytohormones using the sensors, which have huge implication in agricultural and food industries. Ultimately, this thesis demonstrated a plant nanobionic application of the SWCNT CoPhMoRe sensor for real-time monitoring of the phytohormones in living plant roots. For example, gibberellins (GAs) are one of the major phytohormones responsible for root elongation in plant seedlings. We showed that our sensors can capture GA uptake and its induction from the plant roots. With the real-time monitoring of the phytohormones having been conventionally performed using genetic engineering, our highly selective, and novel CoPhMoRe sensors paved a new way of studying plant biology. We envision that in-parallel approach of fundamental understanding of nanoparticles along with their application as biosensors will broaden our knowledge on the field of nanotechnology, and provide future research directions to improve functionality of the nanoparticles for enhanced applications.

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