博 士 論 文 の 内 容 の 要 旨

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論文題目	**The fabrication and application of nanoparticle-based multifunctional composites** (ナノ粒子を用いた多機能複合材料の創製と応用)

（博士論文の内容の要旨）

Nanomaterials are materials that have the size between 1 to 100 nm at least in one dimension, and usually made up of carbon, metal, metal oxides, or organic matters. Nanomaterials may have different shapes, such as nanorods, nanoparticles, and nanosheets, based on their dimensionality. The unique properties of nanomaterials are explored for application in many fields like medicine, catalysis, renewable energy, antibacterial material, environmental remediation, and so on. Among all nanomaterials, nanoparticle composites have attracted scientific attention due to the distinguished set of properties and applications. The properties of nanoparticles are dependent on the component size and structure. Therefore, the synthesis of nanoparticle composites with well component size, nanostructure, and morphology have attracted great interest. However, the controllable fabrication, and particular desired shape of nanoparticle-based composites are still a challenge. This thesis focuses on exploring the size-controllable, shape-controllable, and applications of nanoparticle-based composites. The nanostructure formation, properties and applications of composites are well discussed.

This thesis focuses on the fabrication and application of nanoparticle-based composites, and their structural analysis. The synthesis and functional properties of shape-controlled silver/graphene oxide nanoscroll composites (Ag/GO nanoscroll composites) were investigated. The Ag/GO nanoscroll composites were fabricated by a one-step method at room temperature. The GO sheets were cut into pieces by the AgNPs due to their catalytic activity, and then the GO pieces rolled up, resulting from the intermolecular hydrogen bonds. The transmission electron microscope (TEM) images show that the Ag/GO nanoscroll composites have open-ended tubular hollow structures. The Escherichia coli (E. coli) was used to evaluate the antibacterial activity of synthesized nanoscroll composites. After against the E. coli for 3 days, the inhibition rate of Ag/GO nanoscroll composites can still up to 99.99%. This attributes to the open-ended tubular hollow structures, providing abundant channels and space to prevent AgNPs from aggregating and oxidizing. The result exhibits that the Ag/GO nanoscroll composites have the potential for long-lasting antibacterial activity.

Then, the Ag/GO nanoscroll composites were used as a recyclable photocatalyst. The π-π continuous surface provides an abundance of pathways for AgNPs transfer during photodegradation. To demonstrate the recyclability of the synthesized photocatalytic composites, methylene blue aqueous solution was photodegraded under optimal conditions over ten consecutive photocatalytic cycles. The result shows that the Ag/GO nanoscroll composites are able to mineralize methylene blue to colorless within 10 min in each cycle, and no decomposition was detected after ten cycles. The Ag/GO nanoscroll composites could be used as a recyclable photocatalyst in wastewater treatment applications.

Continually, the size-controlled copper nanoparticles (CuNPs) intercalated into GO sheets (CuNPs@GO composites) were synthesized with high temperature antioxidant stability. CuNPs have been widely studied because they are cheap and easy to be obtained. However, it is challenging to be long-term storage because of their oxidation in the air easily. To prevent the oxidation of CuNPs, the CuNPs@GO composites with sandwich structure were fabricated via the liquid-phase reduction method. The limited GO interlayer distance controls the CuNPs growth during the reduction process, and the GO sheets serve as the protective cover to prevent CuNPs (~ 10 nm diameter) from oxidation. In addition, the large surface area of GO layer provides enough space for CuNPs against their aggregation. To confirm that the sandwich structure can protect CuNPs from oxidation, the air stability and high temperature stability of CuNPs@GO composites were evaluated. The result shows that the composites exhibit no oxidation sign following exposure to dry air for at least 21 weeks or 90 °C. Simultaneously, the conductivity result of the synthesized composites shows no change after exposure to dry air for at least 21 weeks. This sandwich structure provides a potential research direction for fabricating size-controllable CuNPs with high antioxidant stability and stable conductivity.

In summary, three types of nanoparticle-based composites have been successfully fabricated and their properties, structural analysis, and applications have been well discussed.