Functional nanoparticles for preventing wool yellowing

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Abstract. Core-shell TiO$_2$@SiO$_2$ nanoparticles (NPs) were fabricated and characterized in this study. This novel structure endowed TiO$_2$ NPs with high transmittance, strong UV-shielding ability, and low photocatalysis properties, which are ideal for protecting wool against photobleaching from sunlight.

Introduction

Wool fiber is well known as a superior natural textile material, but the photodegradation caused by sunlight makes the fiber weak and yellow [1]. To solve the problem, UV absorbers have been applied to wool. However, the protection of wool against photobleaching under sunlight has not been satisfactory so far due to the limitations of UV absorbers. For inorganic UV absorbers, such as ZnO and TiO$_2$ NPs, the photobleaching process of wool treated with ZnO/TiO$_2$ can be accelerated by reactive radicals due to their strong photocatalytic activity [2]. Therefore ZnO/TiO$_2$ is not suitable for application to wool directly though they are less toxic, more stable and effective than the organic ones.

This study aims at fabricating core-shell structured TiO$_2$@SiO$_2$ material with high UV absorbance and low photocatalytic activity, which will improve the photostability of wool greatly.

Experiments and results

In this work mono-dispersed rutile TiO$_2$ NPs were prepared by a hydrolysis process of tetrabutyl titanate firstly. And then silica shells were coated onto the surfaces of synthesized particles by stöber method (Figure 1).

![Figure 1. Schematic of the preparation of TiO$_2$@SiO$_2$ NPs.](image)

The average size of generated TiO$_2$ NPs was around 25 nm in diameter and 100 nm in length as shown in the TEM image below (Figure 2), and the rutile crystal-type was proved by XRD.

![Figure 2. TEM images of (a) mono-dispersed rodlike rutile TiO$_2$ NPs and (b) TiO$_2$@SiO$_2$ NPs. The insert is the XRD spectrum of synthesized TiO$_2$ NPs.](image)

These TiO$_2$ NPs exhibited higher UV absorption and transmittance, and much lower photocatalytic activity than that of commercial TiO$_2$ NPs (e.g. P25). Their photocatalytic activity was further reduced at subsequent silica coating step, while the UV absorption and transmittance were slightly decreased. The treatment of TiO$_2$@SiO$_2$ NPs indeed retarded the yellowing rate of wool fabrics, and the whiteness was improved along with the increase of NPs concentration (Figure 3).

![Figure 3. a) UV-Vis spectra and b) photocatalytic activity of Degussa P25 NPs as well as the mono-dispersed rodlike rutile TiO$_2$ NPs before and after silica coating.](image)

The treatment of TiO$_2$@SiO$_2$ NPs indeed retards the yellowing process of woolen fabrics over untreated fabric, and the whiteness is improved along with the increase of consumption (Figure 4).

![Figure 4. Photographs of woolen fabrics treated with (a) TiO$_2$@SiO$_2$ NPs and (b) untreated fabric.](image)
Figure 4. Yellowness and Whiteness of wool fabrics treated with TiO$_2$@SiO$_2$ NPs before and after 240 h simulated solar irradiation.

Conclusion

Core-shell structured rutile type TiO$_2$@SiO$_2$ NPs have been prepared successfully. These structured nanoparticles have high UV absorbing ability and low photocatalytic activity, as well as good transparency. After 240h simulated solar irradiation, they have been found to greatly retard the photoyellowing rate of wool fabrics.

References
