Effect of nanoparticle dispersion on the properties of textile coatings

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Abstract

A current trend in textile coating and finishing is the addition of nanoparticles to obtain novel materials properties. Examples are UV resistance, electrical conductivity, antibacterial or photocatalytic properties. Nanoparticles can behave different than the bulk materials due to their small size and resulting large surface area. Additionally, the implementation of nanoparticles in a very fine dispersion allows for less material to be used.

An important issue is to control the dispersion of the nanoparticles in the polymer matrix of the coating. For one, these particles often have the tendency to agglomerate, so that their actual size lies in the range of several µm or even higher. Such particles no longer behave like nanomaterials. In this paper some important parameters influencing the dispersion of nanoparticles in textile coatings as well as the resulting properties will be discussed and demonstrated for selected nanoparticle systems.

Introduction: use of nanoparticles for textile coating

Polymeric coating layers are often applied to textile materials to add functionality or change their properties. This may involve alteration of surface properties such as affinity to printing, adhesion promotion, hydrophobic properties…

In literature, one can find a variety of materials which, in the form of nanoparticles (NP), are envisioned to be able to realise different applications on textiles. Some examples are UV resistance via ZnO or TiO_2; fire retardance via SiO_2; electrical conductivity via Carbon NanoTubes (CNT) or graphite nanoplatelets; increased mechanical strength via CNT; antibacterial via Ag; photocatalytic activity via TiO_2. For all clarity: we speak about nano-sized objects when at least one dimension of the object is below 100 nm.

The use of such NP has some key advantages. Briefly summarized:

- *very large surface area*. The surface area is much larger as in bulk form. This means that the (chemical) reactivity of a material is different. E.g. gold in bulk is very inert but NP of gold can be used as a catalyst;
- *small amounts of active product needed*. For certain applications only a very small amount of active material is needed to impart the functionality (e.g. an antimicrobial effect);
- *very uniform distribution of active product in coatings*. Typically, a coating on textile material consists of a binder which contains the active product. If the active product is available in NP form, it can be distributed very homogenously in the coating.

However, a fundamental challenge relates to keeping these NP well dispersed, i.e. to prevent that they agglomerate together. The reason is that, in general, a material tends to minimize its surface area in order to minimize the surface energy. The main characteristic of NP is their large surface area. So, the particles tend to agglomerate together (as shown on the picture below) in order to reduce their total surface energy.

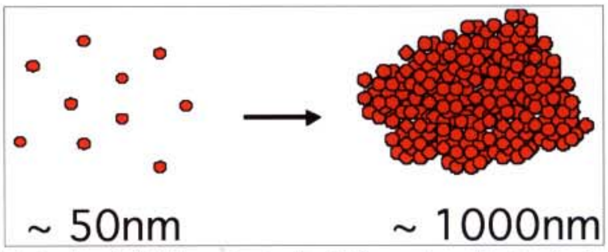

Fig. 1. fundamental challenge: keeping the NP from agglomerating together in larger "lumps"

Hence, to fully exploit the NP properties, it is crucial to maintain the NP very well dispersed from production till they are applied and immobilised in the coating on the textile substrate. As will be discussed in the next section, this is not straightforward.

Importance of stable NP dispersion

Applying a coating to a textile substrate typically comprises the following steps: (i) preparation of the coating paste; (ii) application of the coating paste on the fabric; (iii) post-deposition heat treatment (e.g. drying for removal of solvent/water and/or curing for hardening and fixing the coating to the substrate). If we want to end up with a coating embedding well distributed NP, we need to ensure that we control the agglomeration tendency of the NP at each step.

Preparation of the coating paste

If we want to make a paste containing NP, we need to add a NP dispersion. First requirement is that this dispersion is stable on itself. In principle, this is not an issue for a textile finisher as such a stable NP dispersion stems from chemical suppliers. In spite of product claims made, it is not always easy to find a dispersion that will remain stable until it is used. The main trick is that one needs to balance very well the use of dispersing agents: too little leads to agglomeration of NP (which can give rise to sedimentation and thus a non uniform dispersion), too much dispersing agent can result in unwanted foaming.

But the requirement of a stable NP dispersion is not sufficient; the dispersion also has to be compatible with the other coating paste ingredients. In general, a paste contains ingredients like a binder (e.g. polyacrylate, polyurethane, latex,…), a pH regulator (NH_3, NaOH,…), a thickener and possibly also other functional additives. Therefore, one has to ensure that the stable NP dispersion does not lead to any unwanted effects (e.g. flocculation, sedimentation, formation of unwanted by-products,..) when combining it with the other coating paste ingredients.

Application of coating and post-treatment

Once the paste is optimised, it still has to be applied to the textile. In general the mechanical forces on the paste during application are not critical but the heating step afterwards can be as this gives thermal energy to the NP, which can lead to agglomeration.

Examples of NP functionalized coated textile

Here, we discuss three examples of textile coatings comprising nanosized particles.

Use of Al_2O_3

In the figure 2 the tensile and the tear strength of two acrylic coated PES-fabrics are compared. The measurement of the tensile strength of the coated fabrics is done according to EN ISO 13934 part 1, tear strength measurement according to ISO 13937 part 2. The amount of coating added is, in both cases, 60 g/m². The first sample is a plain coated PES-fabric, while the second sample contains 5% nano-Al_2O_3 in the coating. The addition of the nano-additive does not have a negative influence on the tensile strength, which often is the case when additives are added. However, the nano-Al_2O_3 leads to a significant increase of the tear strength of up to 40 % (from 22,2 N to 32,0 N).

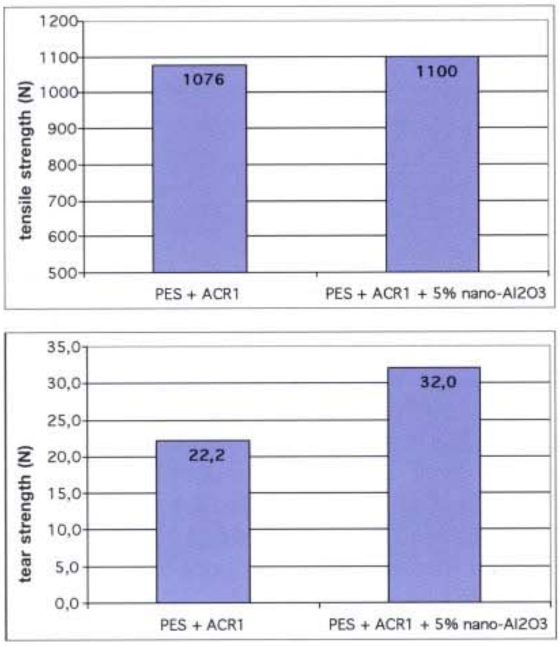

Fig. 2: adding nano-Al_2O_3 to acrylic coated PES: tensile and tear strength

Use of SiO_2

A polyamide fabric was coated with a thickness 60 g/m² using a water based dispersion containing SiO_2. The main aim was to improve the fire retardance. The effect was evaluated by measuring the Peak Rate of Heat Release (PRHR). Although the PRHR decreased with about 10% (from ca. 190 to 170 kW/m²) the actual burning tests (EN532) did not show a relevant improvement.

Use of ZnO

Using a polyurethane binder, a polyester fabric was coated with a thickness of 30 g/m² with a water based dispersion containing ZnO NP. Because of its band gap ZnO is ideally suited to absorb UV radiation and, by doing so, preventing the fabric from UV damage. As a test, samples were submitted to 200 hours of UV illumination (using a QUV apparatus). The figure below shows the positive effect of adding ZnO. Before UV ageing the pull strength is slightly higher than 1100 N, after UV illumination this value drops to about 700 N for the fabric coated with PU but when adding 20 wt% ZnO the strength after illumination is still ca. 1000 N.

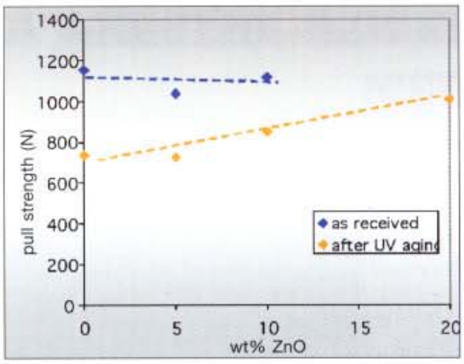

Fig. 3: influence on the UV ageing of the pull strength of applying a polyurethane coating containing ZnO NP on a polyester fabric

Environmental, Health and Safety issues (EHS)

Recently, the concern about the use of nanotechnology and NP has become a major issue, even reaching the main press; see e.g. recent news items about the use of CNT or nano-Ag. Disregarding the hype part of this, it is a positive evolution as nobody wants products that are potentially hazardous. Also environmental considerations are justified.

In order to briefly review these EHS (Environmental, Health and Safety) issues, we look at the different stages in the lifetime of the NP used for a textile product. First, the NP are produced and processed into dispersion. This requires the handling of the NP powder and poses a great exposure risk. But, this part is done by chemical suppliers and should not be a worry for textile finishers. Once the NP are in dispersion, the risk for exposure is very low as they can no longer move freely. This means that for the next steps in the process, the preparation of the coating paste containing the NP and the application of it on the textiles, the exposure risk is very low. This is good news for textile finishers. Once the product is finished, it will be used by the end-users. This poses a potential danger as cleaning or use of the product can lead to a degradation of the coating, possibly leading to emission of NP. This topic still has to be researched in more detail. The final step is the disposal of the textile product. Here, the preferred option is not to discard but to recycle. The issue of how the incorporation of NP in the material influences e.g. the recycling also remains to be investigated.

Conclusions

When coating textiles with formulations containing nanoparticles, an important issue is to control the dispersion of the nanoparticles because these particles often have the tendency to agglomerate. If agglomeration occurs, the actual particle sizes lie in the range of several µm or even higher, so that the typical properties of nanosized objects might be lost. Apart from this, also some environmental, health and safety aspects remain to be further investigated. In spite of these, it is clear that the addition of nanoparticles in coatings for textiles bears great promise for a wide range of applications, e.g. improved tear strength or UV protection.

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