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Structured textile surfaces for easy-to-clean properties towards dry soil*

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Abstract

Soiling of (textile) surfaces is a big issue as it reduces the users comfort and may decrease the conservation of value of the product. In automotive, interior parts of head lining and side lining are soiled by airborne dust, brought into the car by the ventilation system. To overcome these problems, textiles can be functionalized with anti-soiling finishes. However, commercial anti-soiling products often are very effective against liquid soil but less effective against dry soil. Repellency of this type of soil (e.g. street dust) can be achieved by (nano)structured surfaces which reduce the contact area between textile and dirt particle.
In this research project textile surfaces with easy-to-clean properties for dry soil were prepared. Textile samples were functionalized with mixtures of structuring hydrophilic silica particles (HDK-C10) and binder systems based on silanes. To determine the easy-to-clean effect, samples were soiled with standard soil using a modified filter test rig and were vacuum cleaned afterwards. Scanning electron microscopy (SEM) was used to analyze particle size and distribution. The low viscosity of the components of the binder system enabled film formation around each single fiber. Film properties could be adjusted by different functionalities of silanes. Especially, silica particles in combination with a mixture of a vinylsilane (VTEO) and a mercapto silane (MS) showed good cleaning properties. This effect remains for several soiling and cleaning cycles which demonstrates the permanence of the finishing.

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Keywords: easy-to-clean; dry soil; particles; silanes; functionalization

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1. Introduction

Soiling of textiles occurs permanently and / or accidently during usage, as well as with every other material. This results in loss of comfort and may also mean a loss of value. While clothing can often be washed easily, this is more problematic with textiles for technical applications. Textiles of the automotive interior and also for home-textiles (e.g. sofas, chairs), cannot be cleaned in a washing machine but only by vacuum suction, swabbing or wiping, which is much less effective. Therefore, easy-to-clean properties of these textiles are required to support the cleaning process and prolong cleanness and comfort.

The definition of dirt or soil names any unwanted foreign substance on (textile) surfaces, which changes the surface properties [1]. Dirt normally consists of a mixture of substances, but can generally be classified into two types: liquid soil (e.g. water, juice, coffee) and dry soil (particles, mainly dust). The affinity of dirt to soil a textile surface depends on several parameters, such as textile material, finishing agents and type of dirt.

Soiling with liquids often happens accidently by the consumer, for example, if coffee is spilled. Liquids wet / soil a textile surface in dependency of the surface tension of the textile and the liquid. According to Young's equation, soiling occurs if the surface tension of the liquid is smaller than those of the surface [2]. Easy-to-clean finishes against liquid soil therefore should reduce the surface tension of the textile and result in hydrophobic properties. This can be achieved for example with fluorocarbons, which generate an extremely small surface tension of the functionalized textile [3].

Soiling with dry soil often occurs slowly and without 'help' of the consumer. In automotive interior, one important issue is soiling of the textile by airborne dust, brought to the interior by the ventilation system. Air contaminated with dust and dirt from street is brought into the car and adsorbs to interior textiles. Dry soil adhesion depends on the interface between the textile surface and the surface of the dirt particle (solid / solid interface). Particular adhesion forces such as electrostatic and van-der-Waals-forces are of importance and influenced by surface chemistry and the contact area between dirt and textile [2, 4]. Regarding dust removing, hydrophilic fabrics are stated to be more advantageous than hydrophobic surfaces, because of their antistatic properties which allow an easy remove of electrically charged particles. Additionally, textiles with small contact area for dirt enable an easier cleaning [5]. According to a study of the Volkswagen AG, commercially available products with soil repellent properties are often not effective [6]. This is in accordance with our previous research results (not published). According to this, we decided to develop a textile surface, which allows dirt to adhere, but is easy-to-clean with a normal cleaning procedure using a vacuum-cleaner. For this purpose, the textile surface was (nano)structured with a coating of hydrophilic silica particles in a binder system derived from the sol-gel process using organically modified silanes.

2. Materials and Methods

2.1. Textile

The knitted fabric used in this project consisted of 100 % polyester and was produced by Mattes und Amman GmbH & Co. KG (Meßstetten). The color was patterned grey.

2.2. Chemicals

The silanes Vinyltriethoxysilane (VTEO), 3-Aminopropyltriethoxysilane (AMEO), N-(2-Aminoethyl)-3-aminopropyltrimethoxysilane (DAMO), (3-Trimethoxysilylpropyl)diethylenetriamine (TRIAMO), Methacryloxypropyltrimethoxysilane (MEMO) and Mercaptopropyltriethoxysilane (MS) were purchased from abcr GmbH (Karlsruhe). Hydrophilic HDK-C10 silica particles were obtained from Wacker Chemie AG (München). Standard dust (Arizona Road Dust) according to ISO 12103 was obtained from Ellis Components (Derbyshire, UK) and KSL Staubtechnik GmbH (Lauingen).

2.3. Preparation of surface finishes and application to textile

Preparation of surface finishes started with hydrolyzation of silanes in water using acetic acid or formic acid as catalyst. In a second step silica particles were added and the concentration was adjusted with water. The finishing was padded to the textile, dried at 100 °C and condensated afterwards at 140°C. Samples were stained with standard soil to determine their easy-to-clean properties.

2.4. Analysis

Textile samples were soiled with standard dust (grade A2, according to ISO 12103-1) using a modified filter test rig (Palas GmbH, Karlsruhe). The samples were treated with the dust for 300 seconds. The dust was blown onto the sample with a pressure of 2 bar. Afterwards, the samples were cleaned with a vacuum cleaner in warp and weft direction three times each. To determine the easy-to-clean properties, the cleaned samples were classified according to an internal standard with grade 1 (no visible soil) to grade 10 (very dirty; unfinished reference). Soiling and cleaning were repeated several times to determine the permanence of the finishing.

Freshly prepared samples and selected soiled samples were analyzed by scanning electron microscopy (SEM) (TM 3000, Hitachi, High-Technologies Europe GmbH, Krefeld).

3. Results and Discussion

Structuring of textile surfaces with small particles should reduce adhesion forces to dirt or dust particles and enables easy-to-clean properties. For an industrial application it is necessary to bind the particles permanently on the textile and the finishing must withstand mechanical stress and several cleaning cycles. Silica particles are available in different sizes and with variable surface modifications which makes them to suitable candidates to reach the required surface properties. Binder systems based on silanes are an ideal combination with silica particles as they are chemical relatives. During the condensation process the hydrolyzed silanes form a silicate backbone with hydroxy end groups, which can react with silica particles integrating them into the inorganic network and binding them onto the fiber. Functional groups of the silanes influence the network formation of the hybrid polymer and the binding to the particles [7]. Therefore, different silanes were tested in this project. Preliminary experiments showed (not shown here), that HDK-C10 (C10) particles from Wacker were most promising and thus further experiments were performed using these particles.

3.1. Silanes with C10-particles

Different silanes were hydrolyzed with acetic acid and mixed with C10-particles. The dispersions were applied on the textile. The silane concentration was 2 % while particle concentration was 1 %.

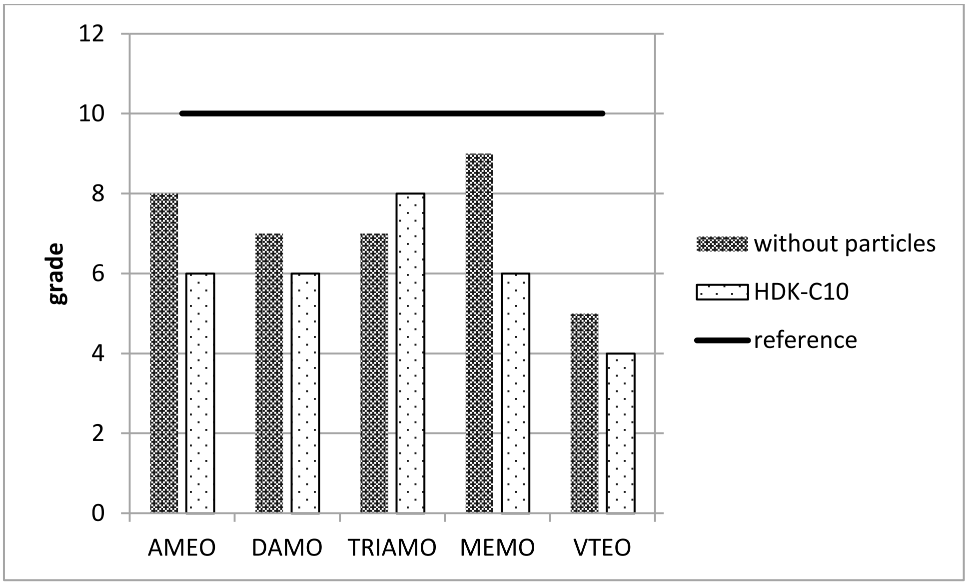

Figure 1: Classification of textiles finished with silanes and HDK-C10 particles.

All functionalized textiles demonstrated better cleaning properties than the unfinished textile (reference). Except in case of TRIAMO, the addition of particles resulted in better surface properties than the silane finishing alone. The best result was obtained with VTEO. Aminosilanes are commonly used as adhesion promoter due to their amino groups which reacts covalently or adsorptive to numerous chemical compounds. It is obvious that this property dominates the surface effects of the functionalized textile and dirt particles easily bound to the textile although these silanes lead more hydrophilic surfaces than VTEO finishes. Structuring with particles reduced this effect. This may have two reasons: first, C10-particles bond to the amino groups and blocked these for dirt adhesion and second, C10-particles structured the textile surface and reduced adhesion forces between textile and dirt as described above [5].

3.2. VTEO with C10-particles

As coatings containing VTEO worked best, further investigations with different silane concentrations were carried out. Results are summarized in table. 1

Table 1: Classification of textiles finished with different VTEO concentrations and HDK-C10 particles (1%).

VTEO conc. (%)	**0.5**	**1**	**2**
grade	2	3	3

Contrary to the experiment described above, VTEO was hydrolyzed with formic acid instead of acetic acid here, which had positive effect on the cleaning properties of the textile. The best result was obtained with the lowest silane concentration of 0.5 %. Adhesion properties towards dirt particles were reduced with low silane concentrations. However, the vinyl group of VTEO possibly tended to crosslink with each other instead of binding dirt, explaining the results from fig. 1. This also may result in better fixation of the C10-particles due to the formation of a homogeneous and stable film of the binder network.

3.3. *VTEO / MS with C10-particles*

For further improvement of the cleaning properties, mercapto silane (MS) was added to VTEO. Different concentrations and combinations were tested. The best finishing contained a mixture of 1.8% VTEO and 0.2 % MS with a total concentration of 2 % silanes and 1 % C10-particles. Herewith, a homogenous particle distribution was obtained and the samples were classified with grade 1-2. After three and even after five soiling and cleaning cycles grade 2 was achieved. In figure 2, SEM images of the freshly prepared sample (left) and a sample soiled and cleaned three times (right) are compared.

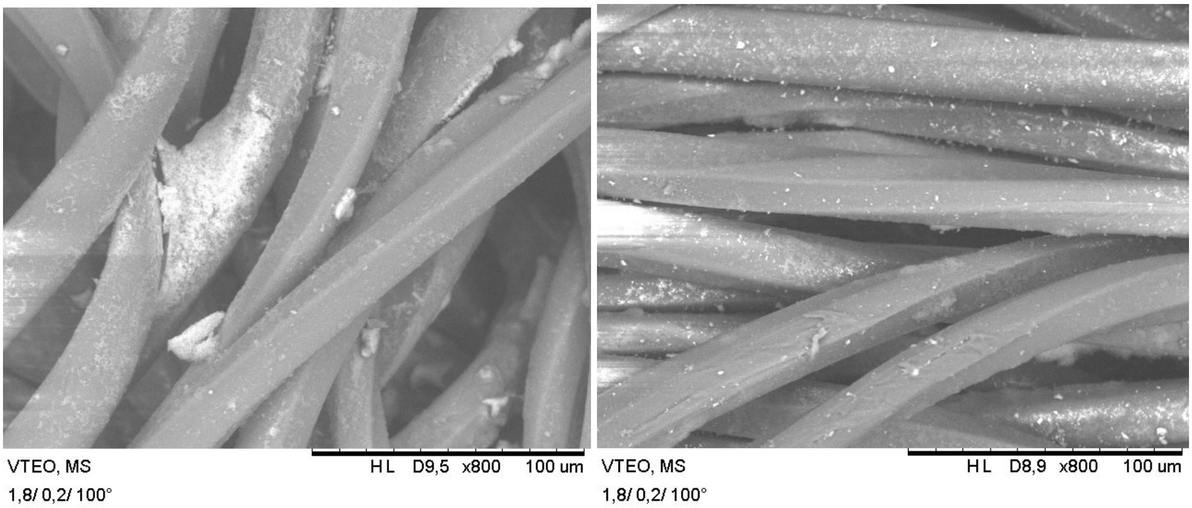

Figure 2: SEM images of samples prepared with VTEO / MS and C10-particles, fresh (left) and after three soiling and cleaning cycles (right).

The SEM images showed a homogeneous distribution of the finishing. After soiling and cleaning no significant amount of dirt particles were visible (right). This demonstrated a high efficiency and permanence of the finishing.

4. Conclusion

The surface of a polyester knitted fabric was functionalized with finishes based on silica particles embedded in a silane binder system. The combination of vinyltriethoxysilane (VTEO) with mercaptopropyltriethoxysilane (MS) with a small amount of HDK-C10 particles of 1 % resulted in easy-to-clean properties which was very effective against dry soil adhesion. This finishing withstood five cycles of soiling and cleaning, demonstrating the permanence of the finishing.

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