APPLYING NANOTECHNOLOGY IN EASY-TO-CLEAN HYDROPHOBIC FABRICS AND ITS USE IN AUTOMOBILES.

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Abstract

Upholstery cleaning is one of the main problems regarding the inner maintenance of a vehicle. Finding solutions to the usual brewery spots, grease stains, sausage marks and their smells is complicated due to both the nature of the dirt and the tedious undo of seats.

At the forefront of the nowadays use of carbon fluoride based products, we present here the development of a hydrophobic and stain-resistance fabrics by using nanotechnology.

Hydrophobic fabrics are water-resistant, self-cleaning and guarantee a long lasting protection against dirt.

The addition of nanoparticles into upholstery fabrics result in surfaces which keep the superficial tension of water or dirt drops. Although this method drastically reduces liquid-fabric contacts and enhances the stain-resistance of the upholstery, intrinsic properties of the fabric fibers do not change.

Key words: *Upholstery; Hydrophobic; Nanotechnology.*

1. Introduction

Stain-repellent products currently in the market show low performance or abrasion resistance level. Likewise, it is not possible to find a hydrophobic and stain-repellent combination among the classic products.

The original formulas of those products, such as Scotchgard, contain carbon fluoride, such as perfluorobutane sulfonate (PFBS) and perfluorooctane sulfonates (PFOs).

Many of these products have been banned due to their environmental impact and their relation to perfluorooctanic acid, used as an intermediary in the PFOs production.

Molecular nanotechnology deals with the design of functional structures to atomic scale, where the scale determines properties. Hence, in the textile treatment sector, the desired effect doesn’t come from the chemical properties of the product, but from the molecular structure of the nanoparticle once anchored in the fiber.

Nanoparticles have great affinity towards textile fibers for their high area/volume relation and elevated surface energy. The product penetrates the fiber and the characteristics obtained are more effective, even using less quantity of the product and covering a larger surface in the fabric. This brings higher level of resistance in the nanotechnology-treated fabrics, compared to traditional ones.

2. Objectives

The pursued objective, within the nAUTO project, co-financed by ACC1Ò and by FEDER funds, was obtaining a hydrophobic and stain-repellant product through nanotechnology, to use in the field of automobile industry, one better and more resistant than those available in the market now.

The SEAT Technical Center (project leader), Trèves, Grober, Ascamm, SEAT Chair and the UPC's CRne made a joint work in order to achieve the results presented in this document.

3. Validation Criteria

Fabrics treated with different nanotechnology stain-repellent products were analyzed and compared under the 3 following standards, used by three different automobile consortiums:

(SEAT VW) PV 3356 – Dirtying and cleaning behavior.

(OPEL GM) GMW 3402 - Soil and cleaner resistance.

(NISSAN/RENAULT) NES M0154. Cleanability test method.

3.1. PV 3356 Dirtying and cleaning behavior

This test is intended to simulate a dirtying and cleaning behavior similar to real life practice.

For it, standardized dirt must be applied on the fabric, according to the Martindale process. The movement way follows the Lissajous figure type.

After certain cycles of movement, test tubes are removed and undergo different cleaning processes.

3.2. GMV 3402 Soil and cleaner resistance

This procedure determines the material's resistance to certain "dirtying" agents and how they can be eliminated, using a combination of generic cleaning agents. The method determines which dirtying agents and how much of them should be applied on each test tube. Once applied, they are left to settle for a specific time, after which they are cleaned only using the described cleaning agents. Dirtying agents to analyze are: sewing machine oil, vaseline, instant coffee, ketchup, cola carbonated drinks, soy sauce, mud, salt (saturated solution) and chocolate milk. Cleaning agents are: deionized water, naphtha, mild laundry soap, acetic acid (white vinegar), ammonia and isopropyl alcohol (ethyl alcohol), combined in different ways to clean the dirtying agent.

3.3. NES M0154 Cleanability test method

This standard analyzes how easy to clean are motor oil and lipstick.

Once the samples have been dirtied, they are left to settle for a specific time and tried to clean using mild detergent only.

4. Technology / explored solutions

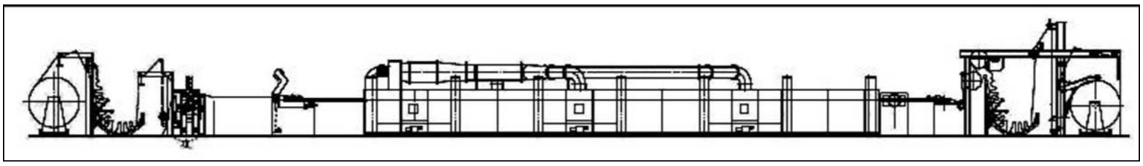
In order to apply nanoparticles on a fabric, three systems have been used: one by direct contact, other biomimetic (both developed in the nAUTO project specifically for this use) and another for indirect use, called vacuum plasma.

The main difference between the direct and the indirect systems is the duration of the process and, evidently, its cost per treated piece. In total, 8 nanotechnology stain-repellent products have been used, out of which 7 have been applied a direct process (direct or sprinkle system) or an indirect system (vacuum plasma, dry process).

4.1. Direct system

This system consists of putting a layer of nanoparticles using two cylinders pressing the fabric. It is a wet application (soaking) where a receptacle contains a solution of the stain-repellent product and the fabric is goes through the receptacle to be soaked. Following, two cylinders eliminate the excess of liquid. A controlled temperature chamber, located after the cylinders, allows stabilizing, drying and guaranteeing a good reticulation of nanoparticles with the fabric structure.

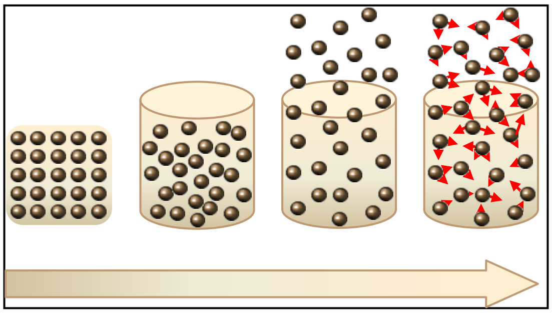
Figure 1: Direct System



4.2. Indirect system

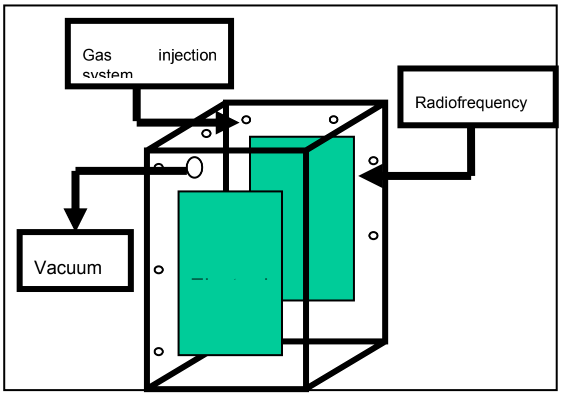
The use of low-pressure plasma technology is a good option, due to its minimal environmental impact compared to the use of the direct system. Through dry treatment, the surface of textile materials is modified on a microscopic scale, without using chemical products. Plasma is known as the fourth state of matter, resulting from partially ionizing a gas. It is made up of a series of ionized, highly reactive particles.

Figure 2: States of matter



In order to ionize the gas in a quantitative, controlled way, in the case of low-pressure plasma, the process is carried out under vacuum conditions (10-2 to 10-3 mbar). Once the vacuum is obtained, the gas is introduced in the treatment chamber and it is ionized using a high frequency generator that uses the energy of an electric field to dissociate it. Thus, plasma is obtained, with a bright blue, pink or violet fluorescent light, depending on the ionized gas.

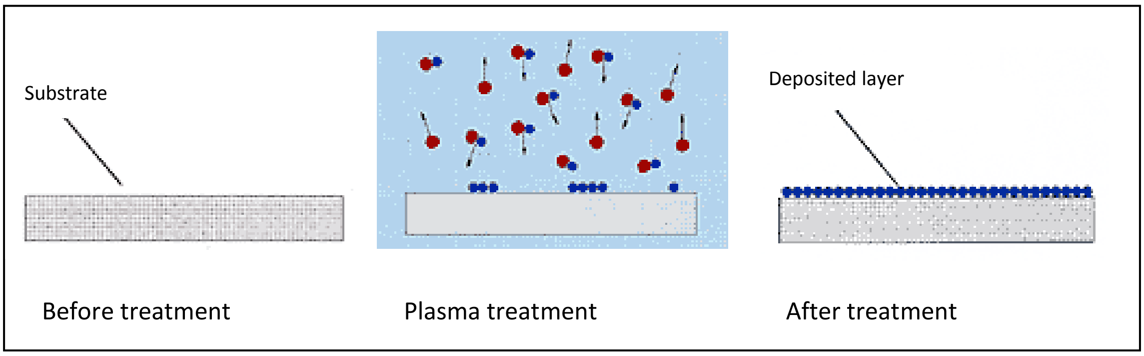
Figure 3: Representation of the treatment chamber



Ionized particles interact with the substrate surface without damaging it, since superficial modification only affects a layer ranging from 10 to 1000 Angström (1 Angström = 10-10 m).

It is a well-controlled, reproducible technique, but due to the long time of the process, this system to get stain-repellent treated products is much more expensive than the direct process.

Figure 4: Plasma Treatment



4.3. Biomimetic System

Eventually, a totally innovating third way to obtain stain-repellent and oleo-hydrophobic coats has been explored, given its excellent adhesive properties and the simplicity of its production.

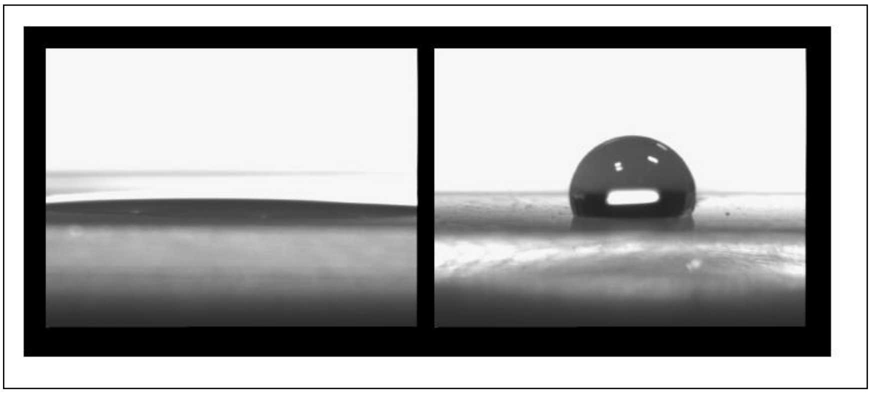
This biomimetic system is based on the excellent adhesive properties of dopamine-derived polymers found in mollusks, functionalized with alkane and fluoride chains.

So far, primary products have been synthetized and the methodology to prepare the adhesive polymeric material has been established.

It has been proven that the coating shows excellent adhesive properties on multiple substrate, including sand, glass, metal, technological substrates such as SiO2 and fabrics.

It has also been confirmed that in every case, the coating grants the material excellent anti-adherent properties.

Figure 5: PES fabric without coating (left) and PES fabric with coating (right)



Perfluoride chains, such as teflon, have been widely used, although one of the limitations still is lack of adherence. That is why the application method is very specific for the material to cover and expensive.

As an alternative to solve this problem, the suggestion is using synthetic-derived substances from mollusks' adhesive proteins. Once polymerized, these strongly join any organic and inorganic surface in watery environments. The aim is obtaining long-lasting anti-adherent pieces, highly resistant to friction and cleaning actions.

5. Testing and validation

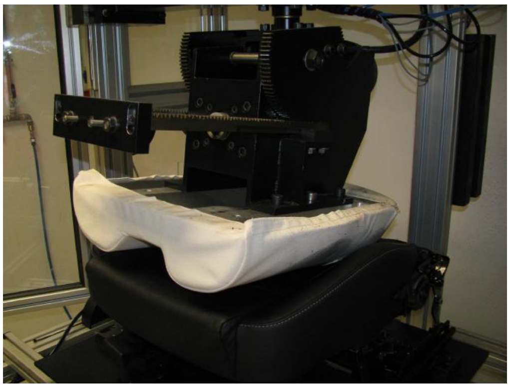
In the fabric validation test battery, those carried out by the SEAT Technical Center, through the Seat Experimentation department (EK-314), should be highlighted. These tests are those every fabric should pass to be able to be considered apt for its introduction in serial models. The tests carried out were:

- Fatigue-trial static test in test bench
- Long-lasting dynamic test.

5.1. Fatigue-trial static test in test bench

This test simulates the fabric's behavior with the friction it undergoes each time the user gets in or out of the vehicle, taking into account the user's weight. Each cycle consists of the simulation of the entrance on and exit from the vehicle, as well as the combined movements of translation and rotation in three axes. A cushion with all its elements and assembly position in the vehicle is placed at the test bench. A piece of steel, simulating the body of the occupant, is placed on it, covered by a canvas to perform the wearing away on the fabric.

Figure 6: Test bench **Figure 7: Testing cushion detail**



A cushion with serial foam is made and covered with a conventional cover. This case has been sewn in a way that the fabric treated for the test is placed in one side, and to the other, the same fabric without treatment, to be able to compare results. This test was carried out with a test tube treated with direct process. From a total of 10.000 cycles the test includes, the first evaluation is made after the first 5.000 cycles. For it, the fabric is stained with products similar to those used in the lab tests (water, milk, coffee, mud, mustard, lipstick, pen and marker pen). In case it is needed, it is cleaned with water or a mix of water and conventional mild soap for clothes.

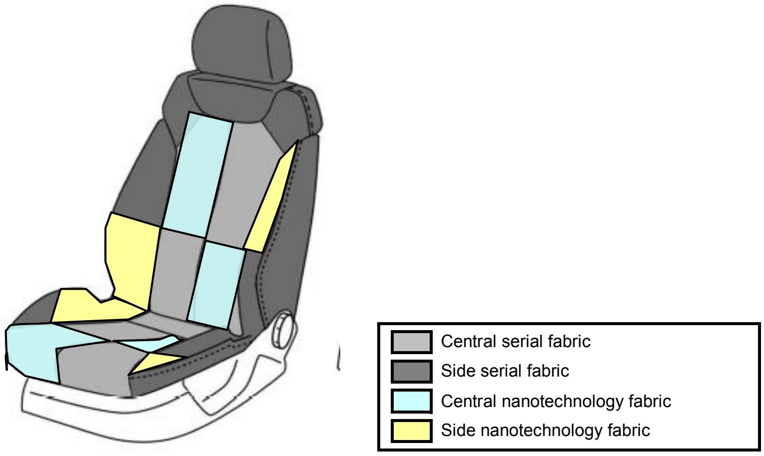
Figure 8: Cushion stained after 5.000 cycles

Figure 8 shows that the untreated fabric (right side of the picture) keeps the stains of some products, mainly mud, coffee, ketchup and mustard. Meanwhile, in the treated side (upper part of the picture) there are no signs of stains, except lipstick. However, using soap for grease, it could be cleaned without any problem. Partial evaluation was considered positive and continued with the rest of 5.000 cycles of the test. After 10.000 cycles, the same products are used to stain, only using water and mild soap to clean.

Figure 9: Cushion stained after 10.000 cycles

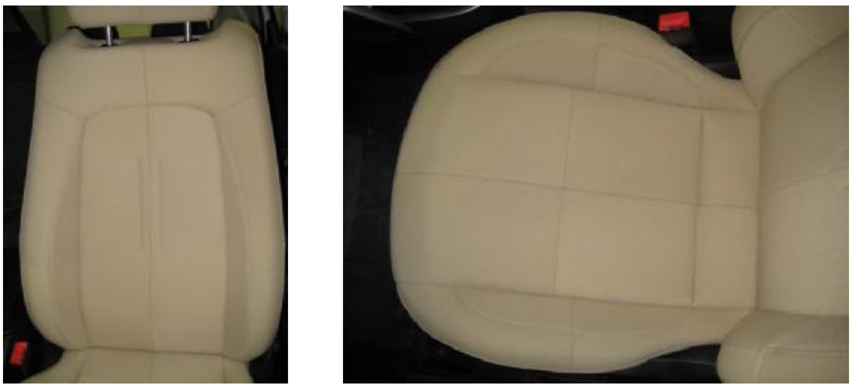
Figure 9 shows the result after the test is finished. The treated fabric (right of the picture) continues without traces of stain and in the case of liquids that do not stain, such as water, the treatment prevents it from penetrating the fabric and reaching the foam. Thus, the spread of microbodies by humidity in the foam is avoided.

Figure 10: Prototype seat configuration



The seat set is assembled, with all its elements in usual position within the vehicle and it is tested in circulation. The test tube treated with the direct process was set up in a SEAT Altea and underwent a total of 15.000 km. The testing circuit used consisted of secondary roads, highways, public freeways and fast lanes (private) to maximum speed.

Figure 11: Images of the prototype seat set in the testing vehicle



Partial controls after the 5.000 and 10.000 km have been made.

- After 5.000 km, some small stains (particles stuck to the seat's surface) show up.
- After 10.000 km, black stains are seen on the back, in the zone in contact with the safety belt, (figures 12 and 13), as well as dirty zones in the right front part of the cushion.

Figure 12: Back, safety belt zone

Figure 13: Upper zone detail

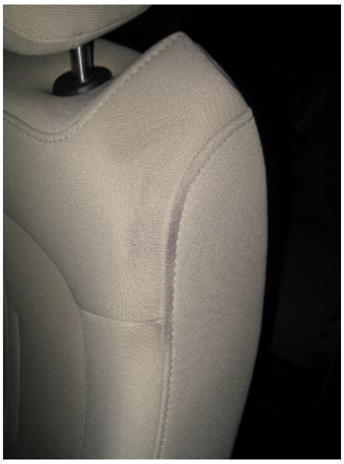


Figure 14: Seat by the end of the test

Figure 15: Detail of the cushion by the end of the test

After finishing the test, the seat is cleaned up using only water and Marseille soap with a cotton cloth.

As it is seen in Figures 12, 13, 14 and 15, the untreated fabric shows a less-defined clean zone and with a big halo of dirt. Once the fabric is dry, this situation worsens.

Meanwhile, the treated fabric shows a clearly defined zone.

7. Conclusion and future opportunities

The permeations have been made correctly, increasing the superficial tension of the fabric. This fact is easily observed when pouring water, which forms spheres over the surface and does not penetrate the fabric.

Carrying out a research on the stain-repellent fabric's behavior compared to the different dirtying agents, it is observed how most of them equal or go over the defined marks for each method.

In the test carried out at the SEAT labs, it was observed that the best results are obtained using the biomimetic coating.

After these results, it has been decided to implement it in series and the validation of the fabric for mass production is under process.

Some results, as well as the chemistry of the treated test tubes, are not presented in this work due to confidentiality reasons.

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