SELF-HEALING COATINGS FOR TEXTILE

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ABSTRACT

Self-healing materials have the capabillity to repair (in an early stage) damage, that would finally lead to material failure. This repair or self-healing occurs with the help of a minor external stimulus or autonomously. Depending on the type of application one or the other is more interesting.

Nature is the major source of inspiration for his type of research: living organisms already possess the property of autonomous repair of damage (wound healing, recovery of broken limbs). Although the phenomenon of self-healing has been recognized in materials throughout history, especially with regards to biological systems, it was only a few years ago that the property of self-healing was seriously considered as a desirable function for man-made materials. As such several research lines have been set up to investigate the possibilities for various application.

Centexbel has looked into the possibilities of a self-healing coating suitable for textiles. In a feasibility study some commercially available products were screened to see their potential as self-healing agents in textile coatings. There was also a need to develop a method enabling to damage the textile coatings in a reproducible way.
In this paper the results obtained will be presented. Eventually a textile coating formulation was developed showing autonomous self-healing properties. It was seen that this coating can also be used on non-textile substrates.

1. INTRODUCTION

The use of self-healing coatings has found a way in multiple industrial branches like automotive, construction,… The introduction of such a self-healing concept into the textile industry can have great benefits. In many cases the textile material gets damaged due to e.g. abrasion, scratches and cuts. The lifetime of a textile material can be prolonged if the repair intervention can be done, automatically and autonomously, at an early stage of the damage formation.

Self-healing can be achieved, among others, via reversible non-covalent crosslink interactions (hydrogen bond formation) in the polymer matrix of the coating.
Functionalised polymers can be used for this purpose. Another type is supramolecular polymers, which are formed by the reversible association of low molecular weight prepolymers. They behave as crosslinked at room temperature (polymer-like viscoelastic behaviour) but show self-healing properties at elevated temperatures due to their liquid-like properties. The effectiveness of such types of self-healing coatings for textile applications was examined.

2. MATERIALS AND METHODS

2.1. Materials

SPH4 SupraB is a supramolecular polymer made by SupraPolix [1].
Bayhydrol U XP 2750 is a hydroxyl functionalized polycarbonate ester-polyurethane made by Bayer Material Science. It is known for its ability to form hydrogen bonds and very high reflow behaviour after dry- or wet-scratching.
Impranil DLC-F is a standard water based polyurethane binder used for textile coatings made by Bayer Material Science.
Fabric: plain woven polyester, 105 g/m².

2.2. Coating of textile

Paste formulations are produced with an IKA-Werke overhead stirrer RW-16 basic.
Labscale samples (A4 format) of the coated material are produced with a Mathis Labdryer type LTF.

2.3. Evaluation of the self-healing properties

2.3.1. Scratch boy

In order to evaluate the self-healing properties of a coating, the coating is damaged and the recovery of the damage is followed over time via microscopy (optic light microscope - episcopic light).

A motorised Pencil Hardness Tester was modified in order to be able to scratch in a reproducible way: the 'Scratch boy' (Figure 1, left). This device enables to scratch at a fixed speed and a set pressure (0N up to 10N), which is not possible when the scratch is done manually.

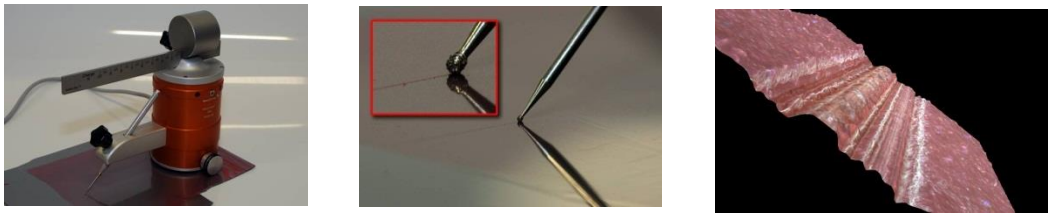

Figure 1: left) Scratch Boy; middle) Diamond wheel point;
right) cross-section single scratch

The pencils of the original device are replaced by a diamond wheel point, which is indestructible (Figure 1, middle). Pencils and needles for domestic use are not indestructible, resulting in a variable contact surface, which has an influence on the shape and depth of the damage. Further the device ensures a fixed angle between the coating surface and the wheel point. By placing the diamond wheel point each time at the same manner in the pencil holder identical scratches can be produced, which allows comparison of the healing properties of different samples.
The wheel point resembles a medieval morning star. Several scratches with various depths are made simultaneously. In this way the influence of the depth of the

damage on the self-healing properties can be visualised on a single test piece (Figure 1, right).

2.3.2. Hydrostatic head

Waterproofness is measured with the Textest FX 3000 Hydrostatic head tester according to standard EN 20811 (Textile fabrics – Determination of resistance to water penetration – Hydrostatic pressure test).

3. RESULTS AND DISCUSSION

3.1. SupraB

The SPH4 SupraB polymer beads were dissolved in heated *N,N*-dimethylformamide and the paste was applied onto the polyester fabric via knife coating. Direct coating did not give satisfactory results: during drying of the coating layer (1 min at 80°C and 1 min at 105°C) the polymer started to penetrate the textile. In order to circumvent this problem, the coating layer was applied onto transfer paper and laminated onto the polyester fabric.
The material shows a restorative effect after heating. At elevated temperatures the viscous component becomes predominant and gives the material its flow characteristics. Self-healing occurs at 140°C (Figure 2); at an oven temperature of 100°C no restorative effect was observed.

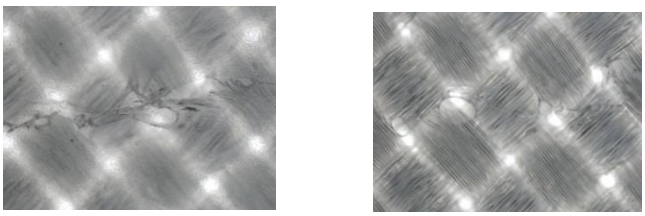

Figure 2: left) initial scratch; right) SupraB after heating to 140°C

This type of self-healing effect is not suitable for textile applications. The flow of the polymeric material, generated upon heating, not only heals the damage, it provokes penetration of the coating material into the textile which can be seen in Figure 2. This results, among others, in a loss of flexibility of the textile, which is not wanted.

3.2. Bayhydrol U XP 2750

After mixing the Bayhydrol with Impranil DLC-F in a ratio of 80/20 a coating layer was produced via direct coating (knife-over-roll) onto the polyester fabric.
In order to evaluate the effect of the self-healing coating on a needle puncture the hydrostatic head was measured (Table 1). After heating the damaged area with a heat gun a slight improvement in waterproofness was observed, which means the puncture has partially repaired.

Table 1 : Hydrostatic head measurements

	Before damage	After damage	After healing
Bayhydrol coating 100 µm	350 cm	18 cm	54 cm

An external stimulus (heating) is needed in order to activate the self-healing which is less attractive in textile applications.

3.3. Self-healing agent

A self-healing agent, based on the formation of hydrogen bonds, is inserted in several types of textile binder materials. Textile materials were coated (knife-over-roll) with these formulations.
No self-healing effect was observed in polyurethane binders, whereas in a certain type of acrylic binder the damage was partially restored. Most of the repair was already observed after 2 days at room temperature; after 1 week no changes were detected anymore.
Small scratches were able to heal completely. On those places where the binder material was completely removed during damaging (bigger scratches), obviously no full self-healing occurred (Figure 3).

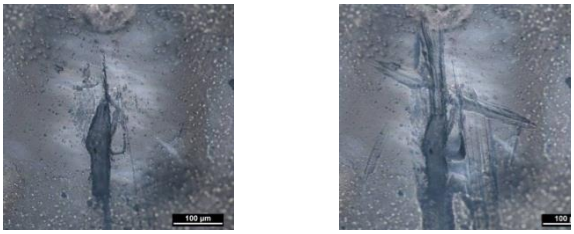

Figure 3: left) polyester fabric - initial scratch;
right) polyester fabric - 1 week healing at room temperature

This self-healing functionalised coating system can be applied both on flexible as on hard substrates such as polycarbonate plates (Figure 4).
A basic requirement is flow behaviour of the functionalised binder material at room temperature. If the binder material can close the gap by flowing, additional healing is obtained due to hydrogen bond formation.

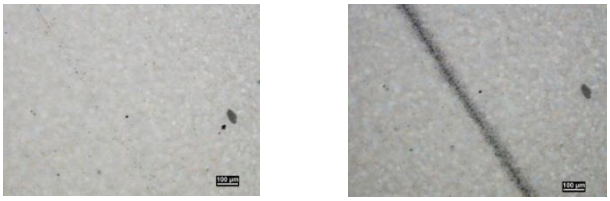

Figure 4: left) PC plate - initial scratch;
right) PC plate - 1 week healing at room temperature

4. CONCLUSION

Self-healing coatings can be implemented in the textile industry. The lifetime of a coated textile can be prolonged if the damaged coating can be healed at an early stage. Centexbel developed an autonomous self-healing coating, based on hydrogen bond formation, which is able to repair small scratches in the coating layer at room temperature. Self-healing coating systems which need external heating as activation

are not recommended for use in textiles as they cause penetration of the coating material in the textile upon heating and tend to change to fabric properties.

REFERENCES

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