Self-Healing Coatings In Interior Design & Furniture Between Fact And Fiction

Dr. Nermin Ahmed Sabry Helal
Interior Design & Furniture Department, Faculty of Applied Arts, Helwan University, Egypt

Abstract:
The interior designer always looks forward to beauty, and aspires it in his designs. No matter how carefully he tried to do so, there are some things that cause problems troubling him and may distort this beauty. These things are **cracks** and **scratches**, which spoil the impression of newness. The dream of self-healing coatings; where cracks and scratches simply disappear, has come true with this emerging application of nanotechnology, and designers have become not far away from the days when materials of Interior Design & Furniture possess the ability to heal cracks in buildings closing on their own, or scratches on furniture recovering their original shiny appearance; by filling them and reforming bonds across damaged surfaces and then hardening again, leading to self-repair them, or at least inhibit further growth. So, this research aims to identify the innovative self-healing technologies, and their promising potentials in overcoming cracks and scratches in Interior Design & Furniture field.

The study has reviewed what is seen as a topic of particular interest to the developing countries such as Egypt, to facilitate knowledge on how these coatings can be used by incorporating them in interior design and furniture finishing works, because of the significantly effectiveness in improving the performance of their surfaces over the long run by fixing cracks and scratches aphid, therefore providing solutions to reduce the cost of damages occurring during their life cycle.

Keywords:
self-healing, self-repairing, damage control, and smart materials.

1- Introduction:

Usually, certain properties of any engineering material such as metals, polymers, ceramics, cementitious, elastomeric, and fiber-reinforced composite materials degrade over time due to environmental conditions, or due to damage incurred during operation. This damage is requiring periodic inspection and repair to avoid them growing and causing failure.[2]

Fig.1: Cracks that appear in walls around architectural openings like doors and windows over time.[3],[4],[5],[6]

Fig.2: Scratches and corrosions that appear on surfaces.[7],[8]

Learning from nature, where all living things can recover themselves from small injuries, and a good example is the skin, which the organism heals by renewing the cells in the cut[9], researches in the last decade have led to the development of self-healing polymeric materials that mimic some of these features found in biological systems[10]; where the ability to heal after wounds and injuries. Thus, the inspiration of self-healing materials comes from these biological systems, and self-healing materials address the degradation through this ability.

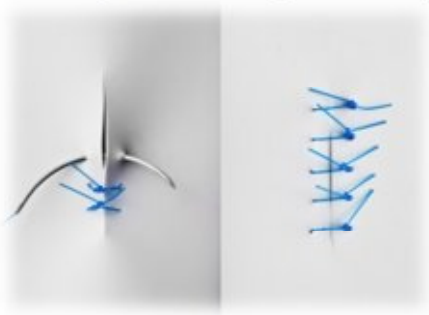

Fig.4: An artistic view of a self-healing material at work attempting to mimic the unique ability of biological tissues to self-heal after receiving a wound.[11]

The importance of this study comes for offering a review on the nascent self-healing technologies, and the potentials of using them in Interior Design & Furniture to achieve Sustainability- which is one of the current issues- from the economic and ecological perspective; by increasing the life span of building materials and providing them with long-term durability, minimizing repair and maintenance efforts, limiting the downtime associated with recoating, reducing substrate renew costs, thereby saving time and money, in addition to reducing waste.

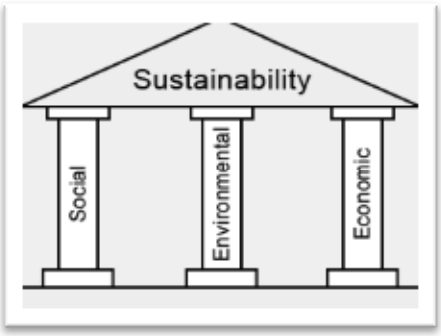

Fig.3: The Three Pillars of Sustainability.[1]

Virtually, all materials are susceptible to the following:

1) Natural degradation with time, which can often be attributed to a number of root causes, such as:

- Subsidence of walls resulting from the load of their constituent structural materials, furthermore the difference between adjacent materials (as concrete& brick, or wood& brick) and their separation from each other, thus contributing to appear cracks and fissures in walls, particularly around architectural openings like doors and windows.
- Furniture exposure to weather elements, especially the harsh environmental conditions, thus contributing to change the properties of their coatings and the occurrence of corrosion as the case in metallic outdoor furniture, and also metallic accessories like handles of doors and windows.

2) Artificial degradation, which results from different causes such as:

- Damages that occur to the interior design elements like walls and floors during their operational lifetime because of the movement of building occupants from different categories including elderly people and disabled with their wheelchairs, in addition to the bad behavior of children towards these surfaces.
- Wearing away the attractive finishing that occur to wooden furniture edges like tables and chairs during daily use, or while moving furniture pieces across hard floors, leading to old look appearance.

This study assumes that prolonging the service lifetime of a material can be done by mitigating

the mechanism leading to cracks and scratches in it, and preventing their increase to protect surfaces from outright degradation until the time of repair. As well as using self-healing coatings in Interior Design & Furniture field can essentially contribute to achieve sustainable development in the developing countries such as Egypt.

Objective:

The research aims to identify new kinds of coatings, and highlight their properties for the purpose of applying and implementing them on walls, floors, and furniture of public buildings, when durability and scratch resistance are required, and where repair is not possible, notably in high traffic areas that are susceptible to scratches such as entrances and corridors. Therefore the study has adopted
the inductive approach for convenience to attain the required results.

2- Self-healing Technologies:

2-1- Definition Of Self-healing Phenomena:

Self-healing can be defined as the ability of a material to heal (recover/repair) damages automatically.[12] In other words, self-healing materials exhibit the ability to repair themselves and to recover functionality using the resources inherently available to them, whether the repair process is autonomic or externally assisted (e.g., by heating), the recovery process is triggered by damage to the material.[13] Many common terms such as self-repairing are used to define such a property in materials.[12]

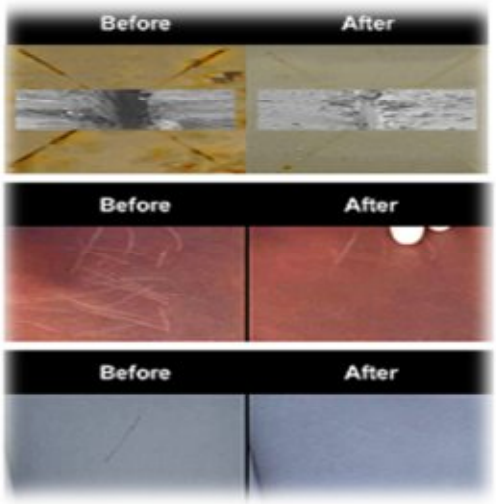

Fig.5: Photos show how cracks and scratches can be healed.[14],[15]

2-2- Historical Overview:

Self-healing materials only emerged as a widely recognized field of study in the 21st century. The first international conference on self-healing materials was held in 2007. However, some of the simpler applications have been known for centuries, such as the self-repair of cracks in concrete; where related processes in concrete have been studied microscopically since the 19th century, and a form of self-healing mortar was known even to the ancient Romans.[16]

2-3- Self-healing Types:

Self-healing process is classified as follows:

2-3-1- Autonomic Healing:

It is self-healing that occurs automatically without human intervention.[13] This means that it is fully self-contained and requiring no external intervention of any kind.[17]

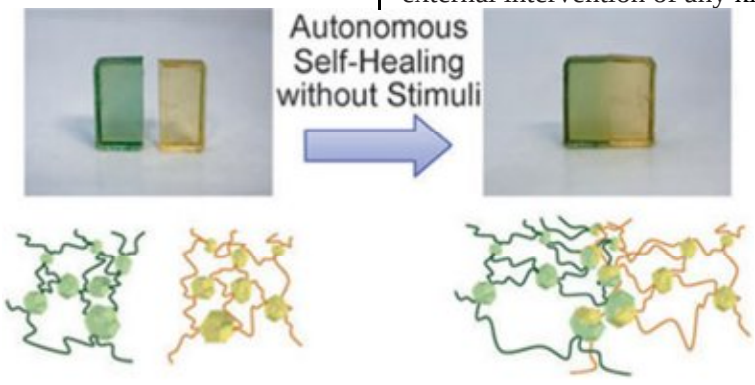

Fig.6: The gel is continually releasing free radicals that allow the material to repair damage without additional energy.[18]

2-3-2- Non-autonomic Healing:

It is self-healing that needs human intervention or external triggering.[12] This means that it is partially self-contained, because healing capability is designed into the material, but additional external stimuli such as heat or UV-radiation is required for the healing to occur.[17] This can be represented through paints which self-heal when warmed up (for example, when exposed to the summer sun).[9]

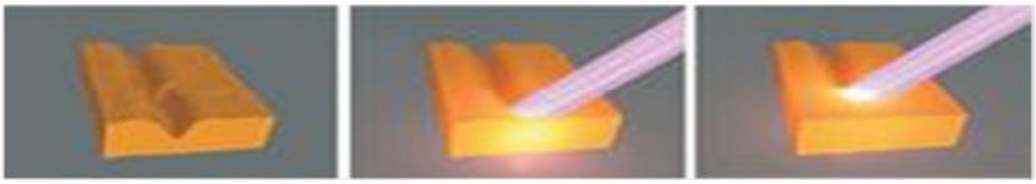

Fig.7: The material can fill up cracks with ultraviolet light, then it solidifies.[19]

2-4- Self-healing Mechanism:

2-4-1- Steps Of Self-healing Mechanism:

The biological healing process in living organisms; where damage to organs and tissues can be repaired through cellular activity fueled by the nutrients available in the circulatory system.[20] The autonomic healing response of these living biological systems at the site of injury often occurs by:

- Secreting various liquids when the system is injured.
- Causing filling, healing.
- Regeneration at the damage location.

For example, the highly hierarchical structure of skeletal bone enables biological fluids containing clotting agents, nutrients, and stem cells to flow from the network of blood vessels into a fractured region upon injury, facilitating over time the development of fibrocartilage, which calcified into fibrous bone, and then dense lamellar bone. This process forms new bone that is essentially indistinguishable from uninjured bone tissue.[10]

Self-healing materials follow a three-step process very similar to that of the biological response:

- In the event of damage, the first response is triggering or actuation, which happens almost immediately after damage is sustained.
- The second response is transport of materials to the affected area, which also happens very quickly.
- The third response is the chemical repair process, which differs depending on the type of healing mechanism that is in place.[16]

2-4-2- Classification Of Self-healing Mechanisms:

Self-healing materials can be classified broadly into three groups:

Capsule based, vascular, and intrinsic.

Each group differs by the mechanism used to sequester the healing functionality until triggered by damage, and the type of sequestration dictates the damage volume that can be healed, the repeatability of healing, and the recovery rate for each approach. In other words, each approach differs according to the method by which healing functionality is integrated into the bulk material, and each approach has demonstrated healing for different damage volume regimes: Intrinsic systems are relegated to small damage and can potentially heal at the molecular scale. Vascular systems have healed much larger damage volumes and can potentially extend the upper limit for self-healing systems. Capsule-based systems span the gap between intrinsic and vascular approaches. For all self-healing systems, material stasis is achieved when the rate of healing is equal to the rate of damage.[13]

The different mechanisms of self-healing process are as follows…

2-4-2-1- Capsule-based Self-healing:

This self-healing utilizes healing agents sequestered and stored in discrete capsules until they are ruptured by damage or dissolved. When the capsules are ruptured by damage, the self-healing mechanism is triggered through the release and reaction of healing agents in the region of damage. After release, the local healing agents are depleted, leading to only a singular local healing event.[13]

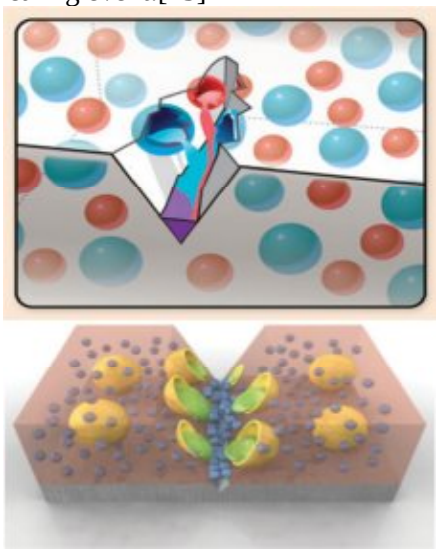

Fig.8: Schematics show capsule-based self-healing process.[13],[14]

2-4-2-2- Vascular Self-healing:

This self-healing utilizes healing agents delivered to the damage by an embedded vascular network in the form of capillaries or hollow channels, which can be interconnected

one-dimensionally (1D), two-dimensionally (2D), or three-dimensionally (3D). The healing agents are stored in these hollow channels or fibers until damage ruptures the vasculature and releases the healing agents.[13] After one of these capillaries is damaged, the network can be refilled by an external source or another channel that was not damaged.[11] This refilling action allows for multiple local healing events. Meaning that access to a large reservoir of healing agents and the ability to replenish the network enable repeated healing of multiple damage events.[13]

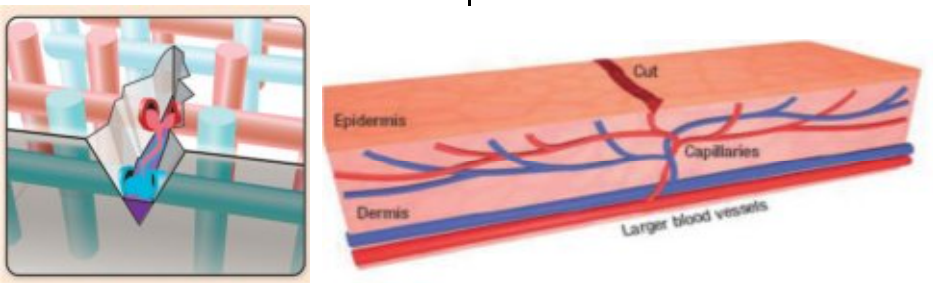

Fig.9: Schematics show vascular self-healing process.[12],[13]

2-4-2-3- Intrinsic Self-healing:

This self-healing utilizes the latent materials' abilities which don't have sequestered healing agents, but possess latent self-healing functionalities that are triggered by damage or an external stimulus such as heat, light, or pressure. These materials rely on chain mobility molecular diffusion and entanglement, reversible polymerizations, melting of thermoplastic phases, hydrogen bonding, or ionic interactions to initiate self-healing. Because each of these reactions is reversible, multiple healing events are possible.[13]

3- Applications Of Self-healing Coatings:

There are many favored places for using self-healing coatings as protective coatings to their interior design elements and furniture, for example, but not limited:

- ⇒ Public service buildings such as shops, restaurants, and cafeterias.
- ⇒ Educational buildings such as schools and colleges.
- ⇒ Administrative buildings such as ministries and institutions buildings.

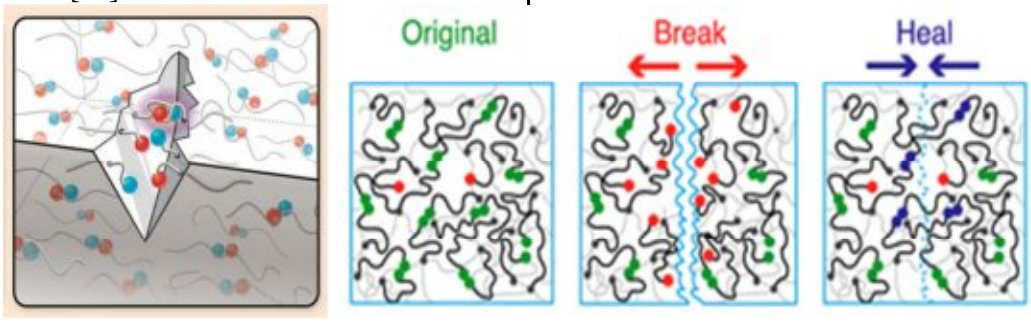

Fig.10: Schematics show intrinsic self-healing process.[13],[21]

Fig.11: Examples to some suggested places (whether internal or external) for using self-healing coatings.[22],[23]

4- Conclusions:

This study reviews a topic of particular interest to the developing countries such as Egypt, to facilitate knowledge on how these coatings can be used by incorporating them in interior design and furniture finishing works, because of the significantly effectiveness in improving the performance of their surfaces over the long run by fixing cracks and scratches aphid, therefore providing solutions to reduce the cost of damages occurring during their life cycle.

However, there are many technical challenges that must be overcome in order to realize the benefits, so the research recommends the following:

- Further studies should seek to develop the qualities of self-healing materials so that they are all completely self-sufficient without the need to any additional external stimuli.
- mechanisms should be developed to solve some problems such as short supplies of healing agents and the consequent of locally depletion after a single damage event, as in capsular self-healing method, or the difficulty of incorporating them into the matrices of materials in spite of their ability to heal large volumes of damages and for multiple times, as in vascular self-healing method, or the difficulty of chemical reactions inside the materials and the consequent of healing small volumes of damages, as in intrinsic self-healing method.
- Eventually, more studies must be carried out to allow for these materials to be commercially available.

5- References:

1. http://www.thwink.org/sustain/glossary/Sustainability.htm
2. Hüsnügül Yılmaz Atay, Leyla Eral Doğan, and Erdal Çelik, **"Investigations of Self-Healing Property of Chitosan-Reinforced Epoxy Dye Composite Coatings"**, Journal of Materials, Volume 2013, Research Article, Article ID 6137017, Hüsnügül Yılmaz Atay et al, 2013, p.1, from: http://www.hindawi.com/journals/jma/2013/613717/
3. http://www.nachi.org/tile-roofs-part4-143.htm
4. http://www.concretejack.com/slab-floor-leveling/
5. [http://www.mrcrackfix.com.au/interior-wall-cracks/
6. http://buildingdefectsspain.com/indications-of-building-defects-in-spain/
7. http://www.rgbstock.com/bigphoto/mrXqvQW/Metallic+bench+1
8. http://timbertownaustin.com/home-improvement/hardwood-flooring-for-dog
9. Lutz A., I. De Graeve, and H. Terryn, **"Self-healing coatings and their electrochemical analysis"**, Research Group of Electrochemical and Surface Engineering, Vrije Universiteit Brussel, Belgium, from: http://www.vub.ac.be/phd/documenten/Lutz.pdf
10. Kessler M R, **"Self-healing: a new paradigm in materials design"**, SPECIAL ISSUE PAPER, Department of Materials Science and Engineering, Iowa State University, Proc. IMechE Vol. 221 Part G: J. Aerospace Engineering, USA, 2007, p.480, from: http://www.emich.edu/public/coatings_research/smartcoatings/related_articles/NewParadigm.pdf
11. http://opfocus.org/index.php?topic=story&v=14&s=4
12. Swapan Kumar Ghosh, **"Self-healing Materials: Fundamentals, Design Strategies, and Applications"**, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2009, pp.1,2,8,9, from: http://shakeel.host22.com/current%20issues/self%20healing%20materials.pdf
13. Blaiszik B.J., S.L.B. Kramer, S.C. Olugebefola, J.S. Moore, N.R. Sottos, and S.R.White, **"Self-Healing Polymers and Composites"**, The Annual Review of Materials Research, 2010, pp.180,181,182,187,193,205, from: http://autonomic.beckman.illinois.edu/nrs097.pdf
14. Cho Soo Hyoun, Scott R. White, Paul V. Braun, and Adv. Mater, **"Advanced materials, Self-Healing Polymer Coatings"**, WILEY-VCH Verlag GmbH & Co.KGaA, Weinheim, 2009, p.645, from: http://autonomic.beckman.illinois.edu/pvb080.pdf
15. https://www.fix-my-stuff.com/how-to/before-after-gallery/

16. http://en.wikipedia.org/wiki/Self-healing_material
17. **"SELF-HEALING POLYMERS"**, Encyclopedia of Polymer Science and Technology, John Wiley & Sons, Inc, 2010, p.2, from: http://braungroup.beckman.illinois.edu/pvb096.pdf
18. Laura Howes, **"Radical approach to self-healing materials"**, Chemistry World, Royal Society of Chemistry, 2011, from: http://www.rsc.org/chemistryworld/News/2011/November/09111101.asp
19. http://www.kurzweilai.net/self-healing-polymers-fix-scratches-using-light-rather-than-heat
20. Jeong-Ho Park and Paul V. Braun, "Coaxial **Electrospinning of Self-Healing Coatings"**, Beckman Institute, Department of Materials Science and Engineering, University of Illinois, WILEY-VCH Verlag GmbH & Co.KGaA, Weinheim, USA, 2009, p.1, from: http://www.thefutureisnear.org/student_research/current_research/documents/drugencapsulation/pvbweb17.pdf
21. http://www.chem.unc.edu/news.html?division=6&news_type=Research
22. http://www.google.com/imgres?biw=1366&bih=501&tbm=isch&tbnid=inT
23. http://www.woodscape.co.uk/street-furniture-products/oval-seat-lime-grove-court-manchester-university/