Advanced Sciences and Technology Journal

ASTJ vol. 1 (2024) 1001
10.21608/astj.2024.289128.1001
https://astj.journals.ekb.eg/

Eco-Friendly Materials and Their Role in Achieving Sustainability in Product Designs

Rofaida Ahmed Shawqi Ali El-Naddar

Product Design Department, Faculty of Applied Arts, October 6 University, Egypt

ARTICLEINFO

Article history:
Received 12 May 2024
Revised 8 July 2024
Accepted 3 August 2024
Available online 4 August 2024

Handling Editor:
Prof. Abdelrahman Ragab

Keywords:
Sustainability
Recycled Materials
Renewable Materials
Natural Materials
Advanced Materials
Materials for Energy Efficiency

ABSTRACT

With the increasing demand for products, it has become necessary to integrate the idea of sustainable design into the products design process in order to achieve sustainable development of the environment, society and economy. Hence, this research provides an overview of the concept of sustainable products design and sustainability concepts and how to achieve this through the selection of materials, sustainable design, eco friendly materials, their classifications and applications of eco friendly materials. research problem lies in the use of materials that are not reusable or recyclable as basic materials for building products, in light of the crisis of materials used, which have become an economic burden on societies. How can this problem be addressed through sustainability, sustainable design, eco-friendly materials, and the technological development that the world is witnessing to achieve the sustainability of industrial products? research aims to achieve sustainability in product design. The research relies on the descriptive analytical method and came up with a classification of eco-friendly materials, some possible solutions have also been found to limit the spread of agricultural waste and factory waste that had a negative impact on the surrounding environment. eco friendly materials and Its role in achieving sustainability in product design is not just a moral necessity, but rather an opportunity for inspiration, innovation and leadership in an era defined by environmental challenges. Our commitment to this cause will define the legacy we leave behind – a healthier planet, a vibrant economy, and a brighter future for all.

1. Introduction:

Kyle Michaud says in the introduction to his book The Importance of Sustainability “We know that teaching and educating citizens on planet Earth is the only way to achieve sustainability”.

Design concepts were primarily focused on form and function, and now this concept has changed to paying attention to the environment and raising the slogan “Design follows the environment” as a result of the increased environmental awareness among humans more than before, they have become able to know the value of resources and natural materials and appreciate the importance of living in a healthy environment and We are friends of the environment by preserving its resources instead of depleting them without account and polluting them unconsciously, all in order to restore the natural balance to existence. Hence, modern design trends emerged that take care of this idea and set determinants and considerations for it, such as green design, sustainable design, and eco friendly design, and these design trends were applied. This research adopts the eco friendly design trend with the aim of arriving at the design of eco friendly products based on an analysis of various design methods for manufacturing products in which the considerations are applied the environment.

The research deals the basic concepts:
•New, innovative and eco friendly materials in product design.
•materials produced from agricultural waste.
•Advanced, Recycled, Renewable, Natural, Smart, Nano and Materials for Energy Efficiency.

1.1. Research problem:

The research problem is summarized as follows:
In light of the crisis of used raw materials, which have become an economic burden on societies and through the unjust exploitation of materials present in society and the environment and threatening the environment with pollutants and harmful waste resulting from manufacturing, design and use, problem of the research can be summarized in the following question:

How Can the Concepts of Sustainability, Sustainable Design, New Eco-Friendly Materials and The Technological Development Witnessed by The World Achieve the Sustainability of Industrial Products?

1.2. Research objectives:

The research aims to identify some methods achieve sustainability in product design by using eco friendly materials, whether “recyclable materials - Materials for Energy Efficiency - Advanced Materials - Natural Materials - Renewable Materials ...etc” and contributing to reducing and treating environmental impact and on the other hand, contributing to support sustainability, explain their importance and connection to the field of product design in all its aspects in all activities related to it, from its practical practice to its scientific and philosophical research.

1.3. Research methodology:

The research relies on the descriptive and analytical approach, through the descriptive and analytical study of sustainability and sustainable design of some sustainable and innovative materials and clarifying the impact of using eco friendly and sustainable materials in achieving sustainability in product design.

1.4. Research Importance:

- Focus on the environmental dimension in product design as an essential aspect, like functional and aesthetic dimension.
- Emphasizing the mutual relationship between environment and design, each of which affects the other.
- Focusing on the necessity of having a design philosophy for eco friendly products based on fixed foundations and standards.
- Emphasizing the role of using technology in opening new horizons for designing eco friendly products.
- Emphasizing the importance of the functional, artistic, aesthetic and environmental values of products designed from eco friendly material.

1.5. Research plan:

The research plan includes a set of integrated stages:
First Stage: Investigation and information gathering stage. In this stage, the available pieces of knowledge and information about the research topic are collected, the most important of which are:

Firstly: Sustainability
• Sustainability Definition.
• Sustainability and How it is Achieved Through Choosing The Material.
Secondly: Sustainable Design
• Sustainable Design Definition.

• Sustainable Design Outcomes.

Thirdly: Eco Friendly Materials

• Eco Friendly Materials Definition.

• Eco Friendly Materials Classifications.

• Explaining The Classifications of Eco Friendly Materials.

Second Stage: in this stage, the data collected in the previous stage is classified and explained.

Third Stage: The stage of forming patterns and deduction. This was achieved by integrating data and linking information in the previous stages, in which patterns are formed, results are derived, and the dimensions and aspects of the relationship are understood.

Fourth Stage: in this stage, the visualization results, recommendations, discussion and conclusion are presented.

2. Structure

2.1 Sustainability:

2.1.1. Sustainability definition:

Sustainability is an adjective of something that can last and capable of being sustained at a certain level. Ultimately, sustainability can perhaps be viewed as the process(es) by which something is maintained at a certain level. Its principle includes that present generations Working to manage resources that directly affect the lives of individuals and the quality and efficiency of their lifestyle in order to ensure the right to share them with future generations.

2.1.2. Sustainability and how it is achieved through choosing materials:

- **Fitness for purpose:** in addition to meeting the necessary structural performance criteria (e.g. strength and deflection) material selection should take into account materials that require minimal maintenance, that can accommodate future adaptation and that can significantly reduce their environmental impact during their lifetime.
- **Environmental Impact / Recycled Content:** The use of life cycle analysis and environmental product declarations allows us to assess the potential cradle of the hazardous impact of building materials. This will include issues such as raw resource consumption, embodied carbon, water consumption, pollution impacts etc.
- **The end of life / deconstruction:** This is an aspect of the design process that is often overlooked or considered an afterthought, but end of life management of materials can have a significant impact on the overall impact of a structure and it must first be considered whether the materials can be reused in their original or reused.
- **Manufacturing process:** Consider how the structure is built to ensure that construction waste is minimized through the use of Pre-manufacturing units and standard material modules.
- **Efficient design:** By efficiently designing and selecting materials the demand for materials will be reduced to a minimum thus equating a lower environmental impact.

2.2. Sustainable Design:

2.2.1. Sustainable design definition:

Sustainable design is any form of design that limits the harmful effects of the environment by integrating them into life processes. It is the intention to reduce or completely eliminate negative environmental impacts through thoughtful designs. This concept can be applied in all areas of design, such as the design of buildings or products.

2.2.2. Sustainable design outcomes:

- Reducing energy and water consumption throughout the entire life cycle - from manufacturing to daily use to disposal.
- Minimizing the impact on climate change by reducing greenhouse gas emissions through carbon neutralization activities.
- Reducing resource consumption through waste-free manufacturing, preferring renewable resources, and emphasizing recycled materials.
- Give preference to non-toxic materials and those that will contribute to the health and well-being of humanity.
- Reducing the amount of natural resources and materials used in design, but without affecting the quality of performance and durability of the products.

2.3. Eco-Friendly Materials:

2.3.1. Eco-Friendly materials definition:

Eco-friendly materials are defined as materials whose extraction, manufacture, or use, or the energy required to complete any of these stages, do not harm humans or the surrounding environment. They also do not pollute the internal environment, especially when compared to competing raw materials because they are manufactured from natural materials, often Environmental materials are called “eco friendly or eco preferable materials”.

2.3.2. Eco-Friendly materials classifications:

Types of Materials	**Examples**	
Recyclable Materials	**in a Direct Way**	Such as (glass containers and cardboard), which can be used to create pieces of furniture or other product designs while retaining their characteristics without changing.
	indirect Way	Recycled plastic - paper and cardboard - metal - glass - sawdust - rubber.
Renewable Materials	Wood-based materials such as “plastic lumber” - organically degradable plastic that is based on vegetables - environmentally friendly liquid wood alternative to plastic.	
Natural Materials	**New Natural Materials**	Bamboo plant - natural cork.
	Natural Agricultural Waste	The panels are made from “hemp fibres, corn stalks, wheat stalks, coconut husks, and rice straw”.
Materials for Energy Efficiency	High-strength and light aluminum alloy.	
Advanced Materials	**Smart Materials**	Piezoelctric materials - electrically resistant materials - shape memory alloys – electrolytic materials - sensitive and temperature changing materials.
	Nanomaterials	Materials made from nanometer-scale materials can be used as coatings or products design and manufacture.
	Self-Healing Materials	They are divided into self-healing polymers and non-self-healing polymers.

2.3.2. Explaining the classifications of eco-friendly materials classifications:

Recyclable materials

Recyclable Materials Classification		Recyclable Materials Definition
Indirect Method of Recycling: This is after introducing the waste of manufactured materials into a new production process to produce another product, so that these materials are transformed within precise practical and industrial processes into products of a higher level or into lower products. This process is evident in the recycling of many of the waste of materials manufactured from materials that pass through many special stages which varies from one product to another.	**Direct Method of Recycling:** Such as reusing things such as glass containers and cardboard, as they can be used in designing products while retaining their shape and characteristics without changing. By preserving the product's shape, structure, and high value after maintaining, recycling, and reusing it for the same or other functions.	Recycling is the process of collecting and separating waste or products that have been used before and have served their useful life for the consumer, and remanufacturing the good ones and converting them into products or materials that can be reused again.

Applications

Examples of Recyclable Materials	Description	Recycling Stages	Applications on It in The Form of Products with Explanations
Recycled Plastic	It is the process of recovering different types of plastic materials in order to reprocess them into various other products.	-Sorting -Wash -Crushing and cutting -Endearing. There are several methods for forming, including "extrusion" -cooling	The Endless Chair, made of recycled plastic from refrigerators by cutting it into horizontal strips and pressing them together, and the 4RD Chair, handcrafted by the cohda studio, in which the designer remanufactured the plastic in the form of strips in an innovative way that intertwined together randomly. Then it was exposed to a high temperature and treated in a special way, designed by (Dirk Vander kooij).  Fig.1. The Endless Chair.
Sawdust	It is a mixture of crumbled materials that are assembled using glue and are used to make compressed wood.	-Assembly. -Removal of metal impurities. -Grinding. -Mechanical mixing. -Packing -Leave the boards. -Sandpaper.	- Design of a coffee table and chair made of sawdust. These designs were awarded the Design Award at the Milan International Fair 2009.  Fig.2. coffee table and chair made of sawdust.

Paper and Cardboard	It is a material in the form of thin sheets made from the cellulosic fibres of vegetables and wood.	Plural. -Sorting. -Shredding. -Washing. -Mixing and kneading. -Bleaching -treatment -Pressing. -Formation. -Drying and heaviness.	 Fig.3. Design of a chair made of recycled Paper and Cardboard designed by Vadim Kibardin.
Rubber	- It is a material that has mechanical properties that make it more flexible under pressure than others and can return to its previous size and shape without any permanent change.	-Sorting and removing impurities. -Shredding. -Sieving and separating. -Packing.	 Fig.4. Design of a chair made of recycled rubber.
Metals	- These are natural, solid, inorganic materials that have specific chemical components.	-Plural. -Processing and classificatio n. -Shredding. -Molten casting.	 Fig.5. Design a seat made from the remains of soft drinks and metal signs.

Renewable Materials

Definition	Classification	Definition of Examples
A renewable material is a material made from natural resources that can be renewed generation after generation. Wood products are renewable because trees "grow back" when forests are managed sustainably, and trees grow, and replant more than they harvest.	**Organic Biodegradable Plastic That is Based on Vegetables**	Bioplastic is a type of plastic, some of which, but not all of it, is designed to decompose organically, that is, in natural conditions. It is manufactured from biological sources such as cornstarch and orange peels instead of fossil fuels derived from petroleum and other harmful materials. It is renewable and recyclable, as it replaces sugarcane polyethylene. By 30% or more of the oil that could have been used in the manufacture of plastics, it also works to reduce carbon emissions.
	Environmental Liquid Wood	- It is very durable. This is achieved through an alloy consisting of 50% sawdust and 50% binder. Durability increases with an increase in the percentage of binder.

Applications

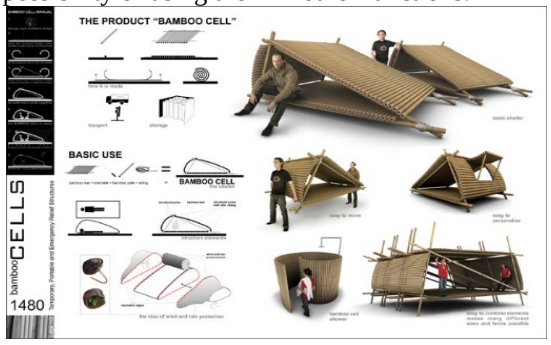
Renewable Materials	Materials Advantages	Applications on It in The Form of Products with Explanations
Environmental Liquid Wood Alternative to Plastic Its scientific name is "Arboform"	Liquid wood is not wood and is not liquid, but it is made from materials composed of wood and can be softened by heat. It is the best environmental alternative to plastic.	 Fig.6. liquid wood into the design shape chair.
Organic Biodegradable Plastic That is Based on Vegetables	Renewable material. - Reduces the environmental footprint of carbon dioxide. - Reduced fossil fuel consumption. - It consumes less energy in its manufacture. - It does not cause any harm or harm to human health.	 Fig.7. Converting orange peels into organic plastic to design cups using 3D printer technology.

Natural Materials

Natural Materials Definition	Natural Materials Classification	
	New Natural Materials	**Natural Materials from Agricultural Waste**
- It is any physical product or material that comes from plants, animals, or the earth. The types include: - Biomaterials, Wood, Natural Fibers and Inorganic Materials etc..	- materials found in nature with little or no human intervention. Natural materials include untreated wood, natural cork, cane, and bamboo, as well as all natural fibres.	materials are defined as everything that is produced incidentally or secondary during the production of field crops, whether during harvesting or during the preparation for marketing or manufacturing of these crops.

Applications

Natural Materials		Natural Materials Advantages	Applications on It in The Form of Products With Explanations
Natural Materials from Agricultural Waste	**Boards Made from Corn Stalks**	- Do not use in the manufacture of volatile organic compounds such as (formaldehyde). These panels give a natural appearance that blends in with the environment because they are made of natural materials.	 Fig.8. Design of a Kirei Board storage unit made of corn stalk panels.

	Boards Made from Coconut Shells	-These panels are made from coconut shells and give a natural appearance that blends in with the environment. -Varied in colours, between dark, light, prominent and recessed, which gives its surface a high aesthetic value.	 Fig.9. Design of a chair made of coconut shells.
New Natural Materials	**Bamboo Plant**	-Bamboo wood is a sustainable material that can remain as it is for approximately one hundred years. It is little affected by weather factors such as temperature and humidity. Its colors also vary between yellow, sugar, and brown, which are earthy colors from the spirit of nature. Bamboo can be dyed to any desired colors by using dyes that are resistant to weather factors. However, it is preferable to leave it on its color to give a feeling of nature harmony.	The design of the bamboo hive is the design of a multi-purpose mobile unit that can be stored and used as an outdoor pavilion. It consists of bamboo sticks tied with strings with the possibility of adding metal links. This design is characterized by zero waste, as parts can be disassembled and installed again in a different way, with the possibility of using them in other functions.  Fig.10. multi-purpose mobile unit
	Natural Cork Plant	-Natural cork is extracted from the outer bark of the oak tree. Cork is considered an eco friendly material because it is a constantly renewable resource. When the outer bark is harvested, the cambium layer is left intact so that the tree can grow without harm, so that we can harvest from it another outer bark after a while.	 Fig.11. The introduction of natural cork into the design of a chaise longue.

Materials for Energy Efficiency

Materials for Energy Efficiency Definition	**Examples**	**Definition of Examples**
Energy efficiency of materials means reducing the amount of energy required to do a job. It is a measure that expresses the degree of consumption, combining, or wasting of raw materials. There is something more energy efficient if it lasts longer or works better than the traditional version of the same device but uses the same amount. of energy	**High-strength and light aluminum alloy**	When advanced high-strength, lightweight aluminum alloys replace steel, cars can maintain or increase their size and still reduce weight. The less a car or truck weighs, the less fuel or battery power is needed to move it, extending range, reducing exhaust carbon emissions and reducing the energy used in its

or even if it provides the same performance as the traditional version but uses less energy.		operation. Automotive manufacturing.

Applications

Type	Applications in The Form of Products with Explanations	
High-strength and light aluminum alloy	An air-cooling device has been designed to help keep the roofs of homes cool and dry and remove heat and humidity, which helps the heating, cooling and air conditioning device improve its performance and thus reduce the user's electricity bill and save the consumption of Unclean energy. It runs on solar energy, there is no need to connect, Electricity for a solar-powered attic fan.  Fig.12. a solar-powered attic fan.	Some of the most fuel-efficient cars in the world rely on aluminum used in their designs. With the help of aluminum, the Ford F-150 has the highest EPA fuel economy ratings among full-size gas trucks thanks to its partially aluminum body. As more hybrids and all-electric vehicles hit the roads, the need for heavy battery power in a vehicle can be reduced. Aluminum dense because less weight requires less battery power. When aluminum is used to reduce the weight of commercial vehicles, transportation trucks can save fuel costs and be able to carry more payload efficiently.  Fig.13. Ford F-150 vehicles

Advanced Materials

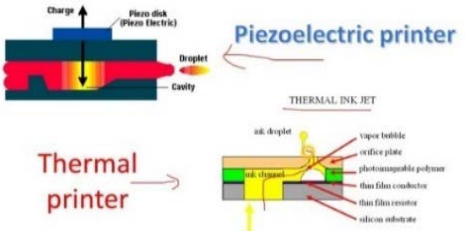
Advanced Materials Definition	Classifications	Applications
-Advanced materials are basically multifunctional materials, they are those that can perform at least two functions. One of the requirements for multifunctional material technology is to reduce weight and volume. - are those materials used in high-tech applications and by high-tech we mean a device or product that works or operates using relatively complex and sophisticated principles.	- classified into: - Smart materials. - Nanomaterials. - Self-healing materials. - Self-diagnosis materials. - Optical materials.	-CD Player. -Electronic Equipment. -Computers. -Spacecraft. -Military Aircraft and Missiles.

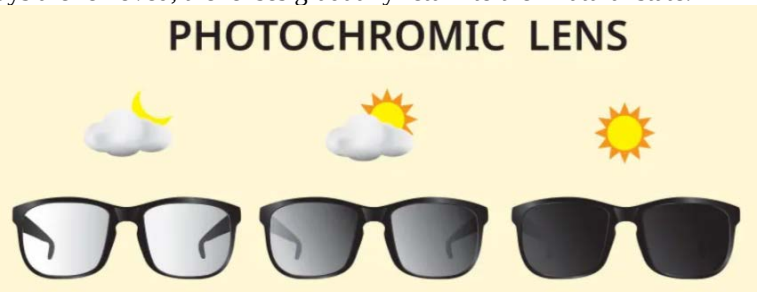
Smart Materials

Smart Materials		Classification	Advantages of Each Type
Smart Materials Definition	- as Eddington and Skodak defined, they are materials with special properties and concepts that distinguish them from traditional materials. These properties are (transmissibility, instantaneous, and direct operation).	**Piezoelectric materials**	It is a natural physical phenomenon that some materials exhibit, especially crystals and some types of ceramics. These materials have the ability to generate an electrical potential difference when exposed to mechanical stress. If the surface of the material is pressed forcefully, a separation of electrical charges occurs across the crystalline lattice of the material as a result of the separation of the charges. An electric potential difference is produced on both sides of the material.
Smart Material	- Self-deduction. - Self-diagnosis.	**Shape Memory Alloys**	They are metal alloys that can be deformed at one temperature, but when heated or cooled, they return to

Advantage	- Debugging and self-operation. - Self-control. - Self-healing. - Immediacy, flexibility and transition.		their original shape.
		Photochromic Materials	Materials are sensitive to exposure to light, which makes them undergo a reversible change in color when exposed to a certain amount of light.
		Sensitive Materials That Change with Temperature	These materials and their colors change depending on the change in temperature, and they have a set of responses to heat and cold.
		Thermoelectric Materials	A material that can be used to convert thermal energy into electrical energy.

Applications

Smart Materials	**Applications on It in The Form of Products with Explanations**	
Thermoelectric Materials **Materials Examples** Lead Telluride	Designing Thermoelectric Portable Automotive Car Beverage Cooler and Warmer, as one of its properties is to provide cooling directly from electrical energy.  Fig.14. Thermoelectric Portable Cooler	Design of Three Types of Wearable Sensor Nodes Powered by Thermal Energy Harvesters Thermoelectric generators data is sent via a short-distance wireless communication protocol such as Bluetooth to a server Portable personal such as a cell phone.  Fig.15. Wearable Sensor Nodes
Piezoelectric Materials **Materials Examples** **Quartz. Lead Titanate. Phosphate Minerals.**	Design for a portable device made of crystal placed under the keyboard and for each key a pressed vibration is generated. This vibration can be used for charging purposes.  Fig.16. Piezoelectric Materials application	Design of a piezoelectric dot matrix printer Piezoelectric motors in the printer head move needle-like pins that pierce through a strip of ink ribbon (similar to a typewriter) against a piece of paper.  Fig.17. piezoelectric dot matrix printer
Sensitive Materials That Change Temperature **Materials Examples** Liquid crystal. Thermoplastic	A design for a cup made of temperature-sensitive materials that changes color with the change in temperature from cold to hot.	A design for a children's spoon made of temperature-sensitive materials to indicate whether the food is hot or palatable to the child by changing its color with each temperature.

polymer.	 Fig.18. a cup made of temperature-sensitive materials.	 Fig.19. temperature-sensitive materials spoon
Shape Memory Alloys **Materials Examples** Nitinol	Flexible nitinol wires, which are used in designing robot muscles and have the ability to bend robotic muscles according to the electrical pulse that is sent through the wire.  Fig.20. Flexible nitinol wires in robotic muscles	Design of eyeglasses Frames from Nitinol are very versatile and will return to their original shape if distorted due to accidental damage.  Fig.21. eyeglasses Frames from Nitinol
Photochromic Materials **Materials Examples** Silver Chloride	Glasses are designed to darken photochromic lenses when exposed to ultraviolet rays, and when the rays are removed, the lenses gradually return to their natural state.  Fig.22. eyeglasses Frames from photochromic lenses	

Nano Materials

Nano Materials			**Features**	**Advantage**
Nano Definition -Nano means something very small or precise in size (things that are extremely small). The word nano appeared at the beginning of the Greek era, as it is derived from the word nanos	**Nanoscience Definition** -It is the science that studies and is interested in dealing with materials at the atomic and molecular level at a scale not exceeding 100 nanometres and is interested in classifying molecules and atoms and studying their distinctive properties of nanomaterials and studying the phenomena associated with reducing	**Nanotechnology Definition** -It is the technology that gives us the ability to directly control materials, and its concept also depends on particles that are less than a hundred nanometres in size, which give the material new properties and behaviours, and this is because these particles (are smaller than the characteristic lengths associated with some phenomena) by manufacturing, monitoring, measuring, and studying their properties, and dealing with	-They have very high magnetic resistance. -Low temperature and high self-diffusion coefficient, they have high catalytic activity and lower electrostatic phase transition temperature	-Using nano materials, we can innovate and create unique products, the advantages of which are that they are stronger, lighter, cheaper, more durable, and more precise.

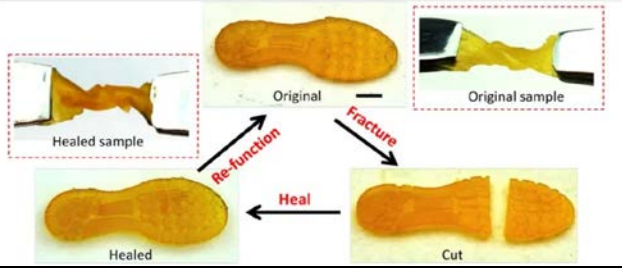
in the ancient Greek language.	their size in -order to interpret them.	Atomic clusters range from five to a thousand atoms.		

Self-Healing Materials

Self-Healing Materials Definition	**Self-Healing Materials Classification**		
Self-healing is the ability to repair damage in an automatic and specific manner without manual intervention. The ability of a material to be able to heal damage automatically and independently is called the self-healing property. Self-healing materials can seal the damage within its structure by restoring its original mechanical properties. Self-healing materials are synthetic or artificially created materials that have the built-in ability to automatically repair damage to themselves without any external diagnosis of the problem or human intervention. Cracks and other types of damage at the microscopic level have been shown to alter the thermal, electrical and acoustic properties of materials. The propagation of cracks can lead to failure of the material. Ultimately, in general, cracks are difficult to detect at an early stage and manual intervention is required to carry out periodic inspections and repairs. In contrast, self-healing materials counteract deterioration by initiating a repair mechanism that responds to small damage. Self-healing materials (SHM) are materials that can recover themselves from damage due to mechanical exposure or stimulation from the outside. This means that the material can recover on its own but can be recovered by adding heat.	**Non-Self-Healing Polymer**	**Light**	Light can be used to induce chemical healing processes. The advantage of this mechanism is that light reactions are usually very rapid and can be initiated selectively by applying light at a different wavelength (visible light or ultraviolet light). Light also allows greater control of the healing process as it can be localized to specific locations.
		Heat	Heat is used in most of the self-healing polymers already developed and compared to other non-autonomous self-healing systems these mechanisms are more applicable in the design of soft robots due to their relatively easy thermal control based on their chemistry.
	Self-Healing Polymer	**Encapsulation**	A subclass of autonomic systems are self-healing mechanisms using encapsulation in which case reactive chemical reagents (so-called healing agents) are stored through partitioning usually in the form of small capsules within the material and when damage occurs the capsules break and the chemicals are released and react in such a way that the voids are filled Through chemical reaction, the surfaces bond together.
		Chemical Mechanical System	mechanochemical systems, these mechanisms rely on weak, reversible interactions (Which forms a reversible network by cross-linking) in conjunction with a polymeric structure designed to withstand pressure and its subsequent release. These weak, reversible interactions (which form a network reversible by cross-linking) will break under sufficient mechanical stress but in the absence of stress at ambient temperature the bonds will be rebuilt again due to the reversible behaviour of the reaction and renew the chemical bonds without the need for an external catalyst.

Applications

Advantages	**Applications on It in The Form of Products with Explanations**
- Providing continuous recovery throughout life.	Researchers at the University of Southern California School of Engineering have exactly created 3D-printed rubber materials that can literally repair themselves

- Merge the material surface without any edges. - The shelf life of the product can be increased.	without human intervention. The 3D printing method used to create these self-healing objects is based on photopolymerization, which is a technology that uses light (visible or ultraviolet) to initiate the polymerization reaction, Figure "23". 

3. Research Results, Recommendations, Discussion and Conclusion*:*

3.1. Research Results:

The research concluded with a set of results:

- Establishing of a classification of eco-friendly materials, which are divided into several categories, including (recycled materials "whether directly or indirectly, renewable materials" - natural materials "whether new natural materials or natural materials from agricultural waste" - materials for energy efficiency - advanced materials including "smart materials, nano materials, and self-healing materials" then emphasizing their importance and integrating them into existing knowledge of product design.
- Applying the concepts of sustainability, sustainable design, new eco-friendly materials and technological development to overcoming the problem of depletion of natural resources and non-renewable materials, reducing the rate of damage to the environment, increasing economic development, preserving the environment, society and achieving the sustainability of industrial products in product design.
- The use of eco-friendly materials provided the opportunity to get rid of agricultural waste and factory waste, which had a negative impact on the surrounding environment, by taking advantage of these wastes and recycling them in innovative practical and technological ways, as they are used in various fields, especially product design.
- The manufacture of wood panels from eco-friendly materials has provided the opportunity to get rid of agricultural waste and factory waste that negatively affected the surrounding environment, by benefiting from these wastes by recycling them in an innovative scientific and technological way in producing wooden panels that can be used in various design fields, especially the field of Products design.
- The product designer has an effective role in linking his own philosophy of product design with respect for the environment and preservation of its resources, by searching for design solutions that have the functional, aesthetic, and environmental dimension.

3.2. Research Recommendations:

The research concluded with a set of recommendations:

- Urging stakeholders to modern and eco-friendly materials to reduce the risks resulting from the use of materials that are harmful to the environment.
- Expanding the recycling of various materials such as paper, glass, plastic, etc. to be used in producing modern eco-friendly materials used in protecting the environment.
- Colleges of applied arts and research centers must study and follow up on developments in the field of advanced materials, nanotechnology, smart materials, and eco-friendly materials in general, and determine the extent of their effectiveness in improving and developing product design.
- The industry and investment sector and major scientific bodies must raise the awareness of investors and society as a whole that investing in modern, eco-friendly science, technology and materials may have a rewarding financial return and not just support the country's future in the field of scientific research and development.

- Moving towards environmental sustainability for all stages of the product design process to preserve the environment.
- Working on rationalization and awareness through the media, advertisements, schools and universities to raise awareness of sustainability concept and eco-friendly materials.
- Researchers in product design field must pay attention and focus on eco-friendly materials field, discover what is new in them, and apply them in multiple ways in designing products to contribute to leaving a healthier planet, a vibrant and sustainable economy, and a brighter future for all.

4. Conclusion

The journey towards sustainable product development is a necessity and an opportunity that tempts the modern designer and manufacturers. By adopting life cycle assessments, we lay the foundation for understanding the environmental impacts of products from cradle to grave. This foundational step is critical, not only to identify areas for improvement but also to create a baseline against which future innovations can be measured. The choice of materials then depends on this basis, requiring a careful balance between function and sustainability. In this area, the challenge is not only to meet the basic requirements of the product, but to do so in a way that minimizes harm and maximizes positive environmental outcomes.

The consideration of end-of-life recyclability brings the journey full circle, emphasising the importance of designing products that leave a positive legacy. This aspect of product development serves as a reminder of our responsibility to the planet and future generations, urging us to think beyond the immediate lifespan of our creations. By focusing on these three pillars - lifecycle assessments, material selection, and end-of-life recyclability - we pave the way for a future where products are not merely consumed and discarded but are integral parts of a circular economy.

Industrial design plays a crucial role in reducing the environmental impacts of products. Making informed decisions early on to plan the product life cycle is key to developing sustainable products. With this in mind, we must think about using environmentally friendly and sustainable materials, adopt circular design, and be more aware of the product's carbon footprint. By prioritizing sustainability during the design process, industrial designers can foster a more environmentally sustainable future.

Eco-friendly materials and their role in achieving sustainability in product design is not just a moral necessity, but rather an opportunity for inspiration, innovation and leadership in an era defined by environmental challenges. Our commitment to this cause will define the legacy we leave behind - a healthier planet, a vibrant economy, and a brighter future for all.

References

[1] Sim vn der ryn and stuart cowan, (1996), "ecological design book", Published by Island press, ISBN 9781597261418

[2] Ritter, Axel, (2006), "Smart Materials in Architecture, Interior Architecture and Design book", Published by Birkhauser, ISBN: 9783764373276.

[3] Michaud, kyle, (2018), "The significance of sustainability book", Published by Platform Publications, ISBN 1983749532.

[4] Addington, Michelle and Schodek, Daniel, (2004), "Smart materials and technologies for the architecture and design professions", Burlington: Architectural Press, Published by Birkhauser, ISBN 9780750662253.

[5] Ghareeb N, Farhat M., "Smart Materials and Structures: State of the Art and Applications", Nano Tech Appl, 2018; 1(2): 1-5, URL: https://doi.org/10.33425/2639-9466.1015.

[6] The Bohmerian, Ingenuity, "The Endless Chair | The Bohmerian", (2011, June 5), URL: http://www.thebohmerian.com/2011/06/the-endless-chair-made-of-recycled-refrigerator-plastic-designed-by-dutch-furniture-designer-dirk-van-der-kooij/

[7] Hikmahilhamsasongko, V.a.P.B, "Design Furniture From Recycled Materials Interior Design, Architecture and Furniture", (2010, December 17), URL:

https://tdeco.wordpress.com/2010/12/17/design-furniture-from-recycled-materials/
[8] Thukral, Chi , “This Sustainable Furniture is Made From 2000 Pounds of Recycled Cardboard”, (2020, April 23), URL: https://www.yankodesign.com/2020/04/23/this-sustainable-furniture-is-made-from-2000-pounds-of-recycled-cardboard/
[9] Tej, Daniel, “Former Mine Worker Artistically Recycles Old Tires into Furniture”, Homecrux, (Updated: 2019, April 16) (2016, DECEMBER 27), URL: https://www.homecrux.com/former-mineworker-artistically-recycles-old-tires-furniture/59426/
[10] Designboom. “shavings’ stool by yoav avinoam”, Designboom | Architecture & Design Magazine, (2009, August 25), URL: https://www.designboom.com/design/shavings-stool-by-yoav-avinoam/
[11] Dornob, “Classic Furniture Reimagined in Liquid Wood”, URL: https://dornob.com/liquid-wood-chairs-classic-material-flows-in-new-furniture/
[12] Hitti, Natashah, “Carlo Ratti's orange squeezer serves juice in bioplastic cups made from the peel”, (2019, September 10), URL: https://www.dezeen.com/2019/09/10/carlo-ratti-feel-the-peel-circular-orange-juice-bar-design/
[13] Manek, Jakub & Jozefiak, Maciej, “Bamboo Living International Bamboo Building Design Exhibits”, Bamboo Cell. Category 07: Temporary, Portable, Emergency Relief, (2007), URL: http://www.bamboocompetition.com/spages/1480-07.html
[14] Morgan, Helen, “DMFD’s Amazing Curved Chaise Lounge is Made From 100% Recycled Cork”, (2012, February21), URL: https://inhabitat.com/recycled-corks-arranged-into-amazing-curved-chaise-lounge-by-dmfd/
[15] Iannone, Michael , mebl transforming furniture, “Maker Portrait: Iannone Design”, (2021, January 1), URL: https://meblfurniture.com/blog/Iannone-Design
[16] Dinesh, Nikhil, “Coconut Shell Furniture”, Behance, (2020, August 16), URL: https://www.behance.net/gallery/102547329/Coconut-Shell-Furniture
[17] Ventilation, A. B.-. A. L. I. S. P, “Self-Flashing solar Attic fans Fans, Attic Breeze”, URL: https://www.atticbreeze.net/sfa.html
[18] Adams, Kathy, “2018 Ford F-150 tops ratings for fuel efficiency”, Mega Dealer News, (2017, December 6), URL: https://megadealernews.com/stories/511285222-2018-ford-f-150-tops-ratings-for-fuel-efficiency
[19] Industrywaala.com, “Black+Decker BDC24L-B1 24L Black & Orange Thermoelectric Portable Automotive Car Beverage Cooler & Warmer”, (2024, June 10), URL: https://industrywaala.com/product/blackdecker-bdc24l-b1-24l-black-orange-thermoelectric-portable-automotive-car-beverage-cooler-warmer/
[20] Froyo, “Color Changing Spoons Explained”, (2020, November 12), URL: https://froyogelatosupplies.com/color-changing-spoons-explained/
[21] Bahk, J., Fang, H., Yazawa, K., & Shakouri, A., “Flexible thermoelectric materials and device optimization for wearable energy harvesting”, Journal of Materials Chemistry, (2015, July 1), C,3(40),10362-10374,URL: https://pubs.rsc.org/en/content/articlelanding/2015/tc/c5tc01644d/unauth
[22] Blankenship, Tim, “Tactile feedback solutions using piezoelectric actuators (Part 1 of 2)”, (2010, November 17), URL: https://www.eetimes.com/tactile-feedback-solutions-using-piezoelectric-actuators-part-1-of-2/
[23] Teaching Guru, “printer and types of printer inkjet, laser,piezoelectric,dot matrix”, (2019, February 13), Video URL: https://youtu.be/b8pVrOokhoE?t=1
[24] Ashish, “Science Of Magic Mugs: How Does Heat-Sensitive Paint Work?”, ScienceABC, (Last Updated 2023, October 19), (Published On 2016, February 10), URL: https://www.scienceabc.com/pure-sciences/science-of-magic-mugs-how-does-heat-sensitive-paint-work-thermochromism.html
[25] George, Sajith, “Shape memory alloys”, [Slide show]. SlideShare, (2016, February 16), ppt URL: https://www.slideshare.net/slideshow/shape-memory-alloys-58329620/58329620
[26] Volkman, Jena, *(2023, September 1),* Are Titanium Eyeglass Frames Good? Exploring the Benefits, Titanium Optix, URL: https://titaniumoptix.com/2023/09/01/are-titanium-eyeglass-frames-good/

[27] Ali, Nabila, "Photochromic Lenses: Are They Right For You?", The Lenskart blog. Medium, (2022, June 13), URL:https://blog.lenskart.com/photochromic-lenses-are-they-right-for-you-ff9e5340481f

[28] Albright, Brian, "USC Prints Self-Healing Rubber", (2019, February 22), URL: https://www.robotics247.com/article/usc-prints-self-healing-rubber