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POTENTIAL OF SMART MATERIALS FOR SUSTAINABLE ARCHITECTURE

SÜRDÜRÜLEBİLİR MİMARLIK İÇİN AKILLI MALZEMELERİN POTANSİYELİ

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Abstract

In a world with growing concerns about global energy use and carbon emissions, energy efficient and sustainable building design becomes a necessity. The true material selection plays a key role for the sustainability. This study aims to understand the smart materials because for designing and building a sustainable future the impact of these materials are significant. Smart materials offer different and significant solutions for various architectural demands. They can be generally defined as the engineered materials that perform special tasks. These are the materials which have one or more properties that can be altered by external stimuli like temperature, moisture, electric field etc. Basic types of smart materials are normally used in conjunction with many other materials. With the conjunction of other materials; devices, components, assemblies and systems can be produced. Complex functions are needed for using these materials in design context and single materials cannot alone respond many demands. Their potential is already recognized by the architects and they will be inevitable elements for the future projects with enhanced properties. This study also aims to determine the potential of nanotechnology which has the potential to offer architecture an abundance of smart materials that will be precisely engineered to perform specific tasks and energy concious design.

Keywords: Smart Materials, Nanotechnology, Sustainable Architecture

Öz

Global enerji tüketimi ve karbon emisyonu gibi konulara ait duyarlılığın giderek arttığı günümüz dünyasında enerji etkin ve sürdürülebilir yapı tasarımı bir zorunluluk olmaktadır. Bu çalışma, sürdürülebilir gelecek tasarımı için etkisi çok güçlü ve önemli olan akıllı malzemeleri tanımlamayı amaçlamaktadır. Akıllı malzemeler çeşitli mimarlık ihtiyaçları için farklı ve önemli çözümler sunmaktadır. Akıllı malzemeler genel olarak özel görevleri yerine getiren mühendislik malzemeleri olarak tanımlanabilirler. Bu malzemelerin bir veya daha fazla özellikleri ısı, nem, elektrik v.b. dış uyaranlar tarafından değiştirilebilir. Akıllı malzemelerin temel türleri birçok diğer malzeme ile

birlikte kullanılır. Diğer malzemeler ile birlikte; cihazlar, bileşenler, montaj ve sistemler üretilebilir. Bir malzeme tek başına birçok talebe cevap vermediğinden yapı tasarımı bağlamında bu malzemeleri kullanabilmek için karmaşık fonksiyonlar gereklidir. Potansiyelleri mimarlar tarafından farkedilmiş olan bu malzemeler, geliştirilmiş özellikleri ile gelecekte de kaçınılmaz unsurlar olacaktır. Bu çalışma aynı zamanda mimarlık alanına zengin miktarda ve özel olarak belirli amaçlar için tasarlanmış enerji atkin akıllı malzeme sunma olasılığı olan nanoteknolojinin potansiyelini anlatmayı amaçlamaktadır.
Anahtar Kelimeler: Akıllı Malzemeler, Nanoteknoloji, Sürdürülebilir Mimarlık

1.INTRODUCTION

Architecture presents itself with different materials that made it. The technological development of architecture has been dependent on discoveries surrounding the best capacities of each material.

For the first time since the rise of modernism the real need to stop harming the natural systems, begins to shift architectural practice. It has been realized that overall energy use in buildings could be reduced with better design and improved technology. The true material selection plays a key role for the sustainability. In 1980, the World Conservation Union published the World Conservation Strategy, which first brought the concept of sustainability to a wide audience. It referred to the sustainable use of resources, the maintenance of ecological processes, and the maintenance of genetic diversity. Although not directly based on architecture, these have direct correlations to the built environment.

New materials are being discovered and developed every day and the selection of material can make a significant impact in the sustainability of buildings and smart materials play a key role on designing and building a sustainable future. Advances in material related technologies also have enhanced the creative possibilities of architectural design. Nano technology is one of the most promising technology of the twenty-first century and may provide more efficient solutions to avoid wasting of energy and it could be seriously useful for saving resources.

Research on nanotechnology will probably provide the basis for a sustainable development of industry. The construction sector needs research activities in this field to benefit from the great potential for energy savings and sustainable building designs [Hervé,P.,2004].

Future buildings will use more environmentall-friendly materials. "The big issue is sustainability," said Prof. Harry Kroto, "and we will need much more sustainable technologies in future, with nanotechnology making a big contribution."

This study investigates and aims to understand the concept of smart materials because for designing and building a sustainable future the impact of these materials are significant. Complex functions are needed for using these materials in design context and single materials cannot alone respond many demands. Their potential is already recognized by the architects and they will be inevitable elements for the future projects with enhanced properties. This study also aims to determine the potential of nanotechnology which has the potential to offer architecture an abundance of smart materials that will be precisely engineered to perform specific tasks.

2.SMART MATERIALS

Smart materials can be generally defined as the engineered materials that perform special tasks. These are the materials which have one or more properties that can be altered by external stimuli like temperature, moisture, electric field etc. NASA's definition of smart materials is 'materials that remember configurations and can conform to them when given a specific stimulus' [Addington M, Shodek D, 2005]. As a naturally occurring smart material, skin is a good example. It senses the sunlight, changes pigmentation in response, and the colour signals that tanning or burning is occurring [URL1]. Advances in smart materials are impacting various disciplines.

Basic types of smart materials are normally used in conjunction with many other materials. With the conjunction of other materials; devices, components, assemblies and systems can be produced. Complex functions are needed for using these materials in design context and single materials cannot alone respond many demands. Smart materials can be classified into two types.

2.1 Type I Materials

These types of materials change their properties in direct response to a change in the external stimuli which occurred in the material's environment. These changeable properties of the materials can be chemical, mechanical, electrical, magnetic or thermal. Changes occur directly and they are reversible. There is no need for an external control system to cause these changes to occur.

Thermochromic materials change reversibly color with changes in temperature. An input of thermal energy to the material alters its molecular structure and changes its color. The new molecular structure has a different spectral reflectivity than does the original structure. A thermochromic material could be used as a device for sensing a change in the temperature of an environment via its color response capabilities [Addington M, Shodek D, 2005].

A thermochromic furniture is designed by Juergen Mayer (in fig. 1). The furniture changes its color due to the heat released by its user.

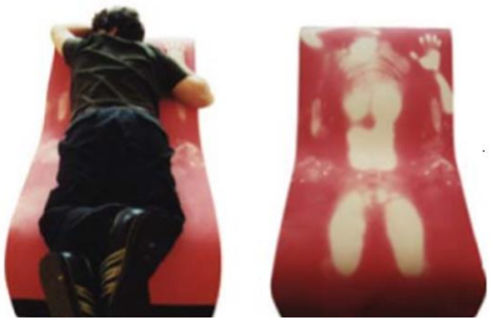

Fig. 1. Thermochromic furniture designed by Juergen Mayer

Magnetorheological –the application of a magnetic field causes a change in microstructural orientation. It results a change in viscosity of the fluid. Figure 2 shows a ferrofluid forms spikes along the magnetic field lines when the magnetic surface force exceeds the stabilizing effects of fluid weight and surface tension [Addington M, Shodek D, 2005].

Fig.2.Magnetorheological material

Thermotropic – an input of thermal energy to the material alters its microstructure through a phase change. In different phases, most materials demonstrate other properties, including conductivity, transmissivity, volumetric expansion, and solubility [Addington M, Shodek D, 2005].

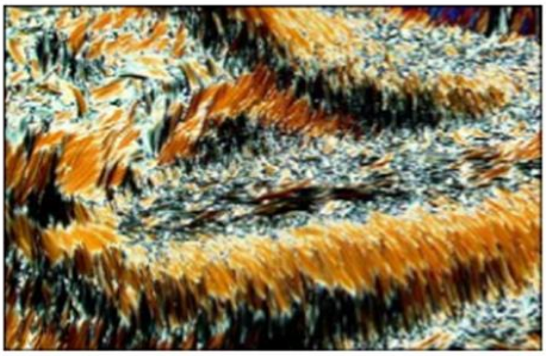

Fig.3. Thermotropic liquid crystal compound Shape Memory

Shape Memory - an input of thermal energy alters the microstructure through a crystalline phase change. This change enables multiple shapes in relationship to the environmental stimulus [Addington M, Shodek D, 2005].

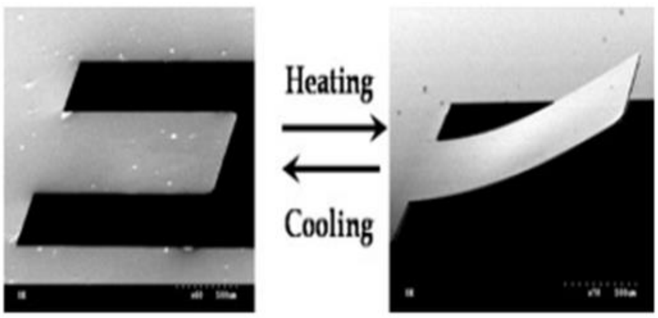

Fig.4. TiNi cantilever showing the actuation during heating and cooling

2.2. Type II Materials

These types of materials transform energy from one form to output energy in another form. They have the ability to do this again and again directly and reversibly. Therefore, an electro-restrictive material transforms electrical energy into electric (mechanical) energy [Addington M, Shodek D, 2005].

This process results with a physical shape change. These materials are constituted in a way to provide a particular type of function. In the use of type 2 materials as a sensor or actuator, there are also different kinds of electronic systems that are integral to the system to amplify, modify, transmit, or interpret generated signals.

Piezoelectric – these materials produce electrical charge when mechanically stressed. Most piezoelectrics are bi-directional in that the inputs can be switched and an applied electrical current will produce a deformation (strain) [Addington M, Shodek D, 2005].. Figure 5 is the piezoelectric material, developed at NASA's Langley Research Center (LaRC), can "feel" deformations such as bending or surface pressure, producing a small voltage in response that can act as a signal for a central computer [URL 2]. Piezoelectric crystals could be used as actuators by passing an electric current through the material to create a force [Addington M, Shodek D, 2005].

Fig.5. Piezoelectric material

Sensors: Many smart materials also act as sensors or actuators. As sensors, a smart material responds to a change in its environment by generating a perceptible response. Many common sensors and actuators are based on the use of smart materials [Addington M, Shodek D, 2005].

Sensors can model physical, chemical and biochemical parameters. They are detection devices that respond to different types of stimuli by returning a differential voltage output. Many types of sensors are commercially available; they are built into many consumer electronic devices, security and safety devices, and systems for monitoring pollution and environmental conditions. Sensor/computer/actuator technologies are used in buildings for several decades, such as the elevator and the thermostat [URL 3]. With the new technological developments sensors become a significant part of architecture. They work like a nerve system for a building. They can feel and determine the reaction to internal and external conditions. All type of data and information to systems are achieved through the sensors [Sherbini, K.- Krawczyk, R., 2004]. Their potential to create new ways of interaction between people and architectural space is starting to be explored. Sensors generally work in connection with a microcomputer that averages, calibrates, and processes the input of a potentially large number of sensors [Cardosa et.al.]. Sensors are classified into three groups: Security and Safety Sensors, Weather and Space Quality Sensors, System Monitoring Sensors

With smart materials, electronic computer systems, and other technologies, architecture is increasingly described as dynamic, responsive or interactive. Intelligent construction materials have the potential to incorporate display and data components. Developments in display technology and building materials led to new forms of hybrid architecture.

3.NANOTECHNOLOGY AND SMART MATERIALS

Nanotechnology is the ability to manipulate matter at the molecular scale for creating something new. It offers the possibility of significant advances over conventional technologies. It is a multidisciplinary field that includes materials science and engineering, mathematics, physics, biology, chemistry, computer science, and many other scientific areas. Therefore, it has attracted the attention of researchers, from physics to chemistry to biology and engineering. The prefix "nano" derives from the Greek word "nanos" for dwarf and expresses extreme smallness. In English nano refers to one-billionth represents one-billionth of a unit. For example, nanometer shows the length that is measured in billionths of a meter [URL 4]. In a broad manner, nanotechnology is the study, design, creation, characterisation, manipulation, and application of functional materials, devices, and systems through control of matter with a dimension or production tolerance of less than 100 nanometres [URL 5]. The reason for the widespread interest in this field is the ability to manipulate individual atoms and molecules to produce nano-structured materials. Once it becomes possible to control feature size, it will also become possible to enhance material properties and device functions. The properties of these materials actually become affected and they behave differently from the same materials produced on a larger scale. They exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes because of their nanoscale size.

Nanomaterials can be simply defined as "Novel materials whose molecular structure has been engineered at the nanometre scale." [AIRI 2006]. Nanostructured materials behave very differently compared to conventional materials. They differ from larger materials not only in size, but also in surface/interface-to-volume ratio and grain shapes [URL 6]. Their properties are different from other materials because of two principal factors: these are increased relative surface area, and quantum effects [URL 7]. These factors can change or enhance the rates and control of chemical reactions, electrical and thermal conductivity, magnetic properties, thermal conductivity, and strength and fire safety. Nanostructured materials can be highly conductive, highly insulating, or semiconducting and can have resistance to fracture or deformation. [NNI, 2000]

If the particle gets smaller then it has larger active surfaces per unit mass and greater chemical activity. It means that a given mass of material in the form of nanoparticles is more reactive than the same mass of material made up of larger particles. As the size of the particle decreases more proportion of atoms are found at the surface compared to those inside. For example, a particle with a size of 30 nm has 5% of its atoms on its surface, at 10 nm 20% of its atoms, and at 3 nm 50% of its atoms [URL 7].

To consider a material as a nanoscale material at least one dimension shall be 100 nanometres or less. Nanomaterials can be nanoscale in one dimension, two dimensions, or three dimensions. They can exist in various forms: single, fused, aggregated or agglomerated with spherical, tubular, and irregular shapes [URL 8]. Common types of nanomaterials are shown below: [Luther W.,2004].

Classification	**Examples**
Dimensions	
3 dimensions<100nm	Particles, quantum dots, buckyballs, etc
2 dimensions<100nm	Tubes
1 dimensions<100nm	Films, coatings, etc

Recently, nanoscientists have broadened the application of nanotechnology. Some examples are:

- Materials are much harder, stronger, more reliable, and safer. They can be applied to bridges, roads, road signs, and traffic control systems. They last many times longer than our current technology allows
- These smart materials will have condition-based maintenance and will provide new materials capabilities. For example, paints can change color with temperature
- white when hot (solar reflective) and black when cold (solar absorptive)
- and could provide home heating or cooling adjustments. Additionally, smart windows will create huge energy savings [NNI, 2000].
- Intelligent facades (multifunctional and switchable, e.g. photoelectrochromic coa-
-

tings, heat-regulating, light conductive, useable as lighting and display surfaces etc.)

- Dirt-repellent, or also antibacterial surfaces (e.g. kitchen furniture, sanitary goods,etc.)
- Transparent protective coatings for steel, copper, etc.
- Heating systems (ceramics as components, membranes for fuel cells) - Photovoltaics (TiO2 surfaces, Gratzel cells, ...)
- Lightweight construction materials with maximum heat insulation (aerogels, polymer composites, fire-protection walls, nanoencapsulated latent heat stores...)
- Cheap solar cells (dye-sensitised, possibly low efficiency, but high price/performance ratio)
- Efficient, compact energy stores (nanoparticle capacitors with fast chargedischarge characteristic) [BMBF, 2004].

Fig.6. Self-cleaning coated surfaces

New and smart materials can bring many significant advances and can be applied in various areas such as components used for batteries, sensors, packaging materials, pigments and artificial body parts. Construction industry also benefits from those materials for buildings, roads and bridges, through retrofitting and repair technologies to fire prevention.

Nanoscientists are creating revolutionary materials like coatings a single atom thick, carbon nanotubes which are stronger than steel and quantum dots that could enable us to change the color of almost any object instantaneously [Elvin, G.,2007].

The development of carbon nanotubes and other nano enhanced materials have potential to alter building design and performance radically. It can bring dramatic mprovements in building performance, energy efficiency and sustainability. These improvements include carbon nanotube structural panels, quantum-dot lighting, nanosensors, and more environmentally sensitive buildings [Elvin, G.,2007].

One of the most promising areas of nanotechnology is the usage of renewable energies. Nanostructured materials and nanotechnology are contributing to technology development especially in solar photovoltaic electricity production. Regarding to technological developments the efficiency of solar cells can be increased significantly and new designs for low cost solar cells can emerge. They can be made from nanoparticles and nanotubes. Some examples of those new emerging solar cells are nano-composite, quantum well cells, quantum dot cells, dye cells and organic cells.

5.CONCLUSION

Energy conscious design is one of the responsibilities of the architects requiring an understanding of the fundamental materials and devices. Nanotechnology has the potential to offer efficient solutions for the sustainable design. Beyond the rapid growth of new smart materials and products molecular manufacturing, nanorobotics, and nanobiotechnology might be revolutionize the design disciplines and the society

The construction sector needs research activities in this field to benefit from the great potential for energy savings and sustainable building designs [Péro,H., 2004]. To solve energy problems and environmental problems nanotechnology may provide more efficient solutions.

A common work between various disciplines will play a key role to achieve the maximum benefit from this new technology. The designers of future buildings must be aware of current trends to create more innovative and efficient solutions. It is ignificant understanding sthe fundamental principles of architecture-related disciplines. A dialogue is needed across the professionals to understand the nanotechnologies' full impact on architecture and built environment. Various products such as self cleaning materials, nano-sensors, nano-solar-cells and many others would be inevitable design elements at the near future.

The need to conserve global material and energy resources requires more energy-efficient buildings. The significance of improving the buildings' environmental sustainability considered as urgent and the use of renewable sources with advanced technological solutions predicted as a future design solution. Architecture should respond to technological and environmental concerns. Buildings of the 21st century should be responsive to environmental conditions to embrace sustainable development. Energy conscious design is one of the responsibilities of the architects requiring an understanding of the fundamental materials and devices. Nanotechnology has the potential to offer efficient solutions for the sustainable design.

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Fig.1:Thermochromic furniture designed by Juergen Mayer [http://www.klubswiatla.pl/archiechos/jmayerh.pdf]

Fig.2: Magnetorheological material, Photo: Felice Frankel, MIT [http://jcwinnie.biz/wordpress/?p=2528]

Fig.3: Thermotropic liquid crystal compound-by Brian Johnston-A gallery of liquid crystal photomicrographs. [http://www.microscopy-uk.org.uk/mag/artsep03/bjpolar3.html]

Fig.4: TiNi cantilever showing the actuation during heating and cooling [http://www-g.eng.cam.ac.uk/edm/research/mems/shape_memory_alloys.html]

Fig.5: Image courtesy NASA's Morphing Project at LaRC

Fig.6:Nanotec Surface treatment for concrete and stone surfaces, [www.nanotec.com.au/index.htm]