*2011 International Conference on Intelligent Building and Management*
*Proc .of CSIT vol.5 (2011) © (2011) IACSIT Press, Singapore*

# The status of energy efficient usage of smart materials in sustainable built environment in hot and dry climates (case study: Middle Eastern countries)

Mohammad Mehdi Moulaii [1], Mohammadjavad Mahdavinejad[2] , Mohammad Gheisar[3]
[1] Corresponding Author ,M.A student, Department of Architecture, Faculty of Art, University of Tarbiat Modares(Jalal Ale Ahmad St, Tehran, Iran)
[2] Assistant Professor, Department of Architecture, Faculty of Art, University of Tarbiat Modares(Jalal Ale Ahmad St, Tehran, Iran)
[3] Postgraduate, Department of Architecture, Faculty of Art, Islamic Azad University, Tehran Central Branch

**Abstract.** The employment of renewable forms of energy is important all over the world, not just in countries where there are concerns over the accessibility of fossil fuels. With the aim of developing and encouraging appropriate energy policies for the future, it is required to gain an understanding of professional views in all countries, as well as those with extensive fossil fuel reserves. The volume of construction work in the countries with hot and dry climates (like Middle Eastern countries) has recently been at exceptional levels, with an enormous environmental impact from construction and also from potential of future energy demands. The purpose of this paper is to evaluate the potential usage of a particular, but precious, renewable energy options: Smart Materials in those climates. Such exploitation could alleviate, at least in some part, the future environmental burdens. A large-scale assessment, followed by a number of in-depth interviews, has been undertaken with the aim of examining the application of Smart Materials in connection with sustainability and energy efficiency and assesses the optimization of proposed Smart Materials and their products in favor of this region. Experimental research findings are presented, and then analyzed with the purpose of determining the present capability of a significant development of Smart Materials in the hot and dry climatic regions. Suggestions are then provided to help the improvement of appropriate application and the wider introduction of viable Smart Materials in these regions.

**Keywords:** Smart Materials, renewable energy, sustainability, environment

## 1. Introduction

It can be observed that over the last 30 years, this Region has experienced an unparalleled construction boom; more particularly in the last 10 years. This has led to a swift expansion in the size of cities as well as in a growth in energy consumption per capita that currently exceeds most parts of the world [1, 2]. Simultaneously, the exploit of renewable energy technologies has increased all through many regions of the world with the aim of increasing more sustainable sources of energy. Given the fact that this area receives some of the most extreme sunlight in the world, Smart Materials seem to be a fascinating sustainable alternative. Smart Materials are a particular type of materials that have recently received considerable attention in the international construction industry because they suggest the feasibility of preparing clean energy sources for buildings in aesthetically and architecturally fascinating ways. The goal of this paper is to inspect the possible usage of Smart materials in the buildings of Middle Eastern countries through surveying a number of relevant professionals in the region. Firstly, however, the present status of Smart Materials and the need to consider these materials in these countries are highlighted. The paper then outlines the design of the initial research that was carried out to evaluate the probability of the widespread use of Smart Materials. Next, experimental research findings, acquired from surveys and interviews, are analyzed and discussed. At last, the paper suggests a 'diffusion strategy' that, if put into action, could improve the feasibility and image of Smart Materials in this region.

## 2. An overview of Smart Materials and their characteristics

The innovative use of newly developed materials and technologies has historically been a driving force behind the development of new architectural ideas and forms. In our modern era, architects are fortunate to have access to a wide variety of materials that exhibit many interesting properties or characteristics that can be potentially utilized in the creation of new forms. These include "smart materials" that exhibit transient behaviors when their environments vary, or have properties that can otherwise be made responsive to changing needs. Photochromic materials, for example, change their color when exposed to varying light intensities, while a change in temperature causes a change in color in thermochromic materials. Many smart materials exhibit electroluminescent behaviors when the source of excitation is an applied voltage or electric field. Shape memory alloys exhibit a remarkable ability - these materials can shaped into one configuration at a high temperature, deformed dramatically while at a lower temperature, and then revert back to their original configuration upon the application of heat in any form, including an electrical current. Shape memory polymers exhibit similar capabilities. Other newly developed materials include a whole range of different types of materials whose transparencies can be varied to suit different architectural needs, e.g., suspended particle displays. These and other materials exhibit so-called "smart" behaviors. So perhaps the most unique aspects of these materials and technologies are the underlying concepts that can be gleaned from their behavior. These newly developed materials and technologies offer an architect exciting new possibilities for making new forms of buildings that are responsive to their surrounding environments and user needs. Many of these materials and technologies are already in widespread use in the product design sector, e.g., photochromics and thermochromics, and are rapidly finding their way into architecture. Others, however, remain in the early stage of development and their applicability to architectural needs is either unclear or problematic. Shape memory alloys, for example, are exciting but currently exist only in very small dimensions suitable more for products rather than buildings. With many smart materials, actual applications in an architectural setting remain largely unexplored. Perhaps this is one reason why the field is so exciting at the moment. Whether a molecule, a material, a composite, an assembly, or a system, 'smart materials and technologies' will exhibit the following characteristics [3]:

- Immediacy – they respond in real-time.
- Transiency – they respond to more than one environmental state.
- Self-actuation – intelligence is internal to rather than external to the 'material'.
- Selectivity – their response is discrete and predictable.
- Directness – the response is local to the 'activating' event.

Smart materials and systems are divided in two classes, according to their behaviors until energy stimulus from surrounding environment:

- Type 1 materials are those that have capability to change their properties - chemical, mechanical, electrical, magnetic or thermal, including thermochromic, magnetorheological, thermotropic, shape memory alloys. The energy input to a material affects the internal energy of the material by altering the material's microstructure and the input results in a property change of the material.
- Type 2 materials are those that have capability to transform the energy from one form to another, including photovoltaic, thermoelectric, piezoelectric, photoluminescent and electrostrictive. The energy input to a material changes the energy state of the material composition, but does not alter the material, it stays the same, but the energy undergoes a change [3].

## 3. The need to consider Smart materials in Middle Eastern countries

It appears that the energy consumption of buildings in the Middle East region is amongst the highest in the world. For instance, a study in the United Arab Emirates concluded that energy use per area in domestic buildings is high when compared with typical examples in Europe [4]. Looking into the case of Bahrain, a recent study maintained that the vast majority of Bahraini buildings currently lack sustainability measures [5]. Other studies (e.g. [6, 7]) have called for the formulation of strategic policies on both the use of renewable energies and the rational use of energy in order to ensure the sustainability of future buildings and architecture. However, it should be noticed that the idea of sustainable architecture involves a various range of sustainable characteristics (e.g. passive solar design, construction and materials, etc.) in addition to the only use of renewable energies. Despite current restricted application of renewable energies in buildings, it comes into view that there are some promising projects emerging in the Middle Eastern countries. For instance, a $211 m Green City Project is to be built at the Euro University in Bahrain that aims to use PV to power 10–20% of the campus [8]. Given the fact that the Middle Eastern countries at this time lag behind the international movement towards alternative energy choices, it is of interest to evaluate the potential to increase the application of Smart Materials. As part of such an attempt, it is also of pertinence to inspect levels of awareness among possible professionals in connection with current energy and environmental issues. With this in mind, the next part discusses the methodology that was adopted with the purpose of achieving this aim.

## 4. Research design

This research takes the form of an extended case study and survey of opinion (case studies have been cited as a suitable research method when the researcher has no control over events and is not able to manipulate the relevant behavior [9, 10]). The use of online questionnaires was also selected as the most appropriate record collection technique as it prepared a cost- and time-effective approach to obtain information from a vast and geographically separated population of respondents (i.e. professionals). The survey was planned with the inclusive aim of assessing the level of professionals' awareness pertaining to current energy and environmental issues, and distinguishing attitudes towards acceptance of Smart Materials in the Middle Eastern countries. Three target groups (academics, building developers and architects) were selected as the most pertinent professional groups. Keeping in mind the scope of this research, the survey sample was chosen to represent as fairly as possible the prearranged target groups and the Middle Eastern countries. The survey was distributed via e-mail to a total of numerous professionals in the Middle Eastern countries in July 2010. Of the three target groups, academics were most likely to complete their surveys.

## 5. Experimental findings

This section is dedicated to analyzing and discussing the responses gathered together from each of the three survey groups, as well as feedback from the follow-up interviews.

### 5.1. Academics

Ninety three responses were gathered from academics in this area. As one might expect, survey participators holding academic posts in this region were informed about and concerned in order to energy and environmental aspects. Comprehensive discussions in subsequent follow-up interviews pointed out that there is a pervading belief in this region that a lot can be done to help the environment apart from the use of Smart Materials. For instance, some interviewees emphasized the need for promoting effective measures in connection with energy efficiency and conversion. In other words, Smart Materials should be seen as only one choice among other things that could be done to address energy and environmental concerns. The current building projects, despite being low in number, confirm that almost all obstacles could be overcome if there was a satisfactory support regarding the need for sustainable energy. There is evidence that in some Middle Eastern countries, governments have shown interest in exploring sustainable energy choices.

### 5.2. Building developers

Thirty-three responses were gathered from building and property developers in this region. Disappointingly, the survey pointed out that this group of professionals appeared to be indifferent about the environment, and most actually opposed the extensive use of Smart Materials in their countries. Many of these participants' remarks, particularly from building developers in Kuwait and Qatar, recommended that the sooner Smart Materials would be available at affordable prices, the sooner Smart Materials would become commercially viable. In general terms, however, feedback regarding the level of knowledge of these respondents in connection with Smart Materials revealed a lack of up-to-date knowledge.

### 5.3. Architects

Fifty-six responses were gathered from architects in the Middle East region. Compared with the previous professionals' groups, the architect's survey showed a vast interest in Smart Materials and declared concern over energy and environmental issues. Similar to the other professionals' groups, the architects proposed that, given the apparently abundant natural resources, Smart Materials are the most appropriate form of renewable energy for use in building applications within the Middle East region. The architects surveyed also scored highly in their obvious level of knowledge of the present efficiency of Smart Materials. The architects surveyed were better notified than the building developers with regard to the likelihood of the use of Smart Materials in applications. Surprisingly, when asked whether they thought that using Smart Materials could unfavorably affect the quality of their designs, the architects' most prevailing answer was ''never thought of it.''

## 6. Rating of Optimization of energy efficient Smart Materials to Architectural Needs in hot and dry climates

| Architectural Need | Smart Material Application | Products proposed in Architecture in hot and dry climates | Rating of Optimization in hot and dry climates |
|---|---|---|---|
| Control of solar radiation transmitting through the building envelope | Electrochromics | Electrochromic Glass systems incorporating Metal Oxides | 330% |
| | Photochromics | Photochromic Pigments | 270% |
| | | Photochromic Glass | 380% |
| | | Photochromic Plastics | 310% |
| | Liquid crystal displays | LCDs | 170% |
| | Louver control systems<br>_ exterior radiation sensors (photovoltaics)<br>_ interior daylight sensors (photoelectrics)<br>_ controls (shape-memory alloys) | Organic Photovoltaic Cells (OPV) | 430% |
| Control of conductive heat transfer through the building envelope | Thermotropics | Thermotropic Glass | 230% |
| | Phase change materials | Microencapsulated PCM (e.g. Micronal, Technology by Dasf) | 180% |
| | | Plaster with PCM (e.g. Technology by Dasf) | 150% |
| | | Gypsum Plasterboard with PCM (e.g. Technology by Dasf) | 125% |
| | | Aluminium foil bags with PCM (e.g. Technology by Dasf) | 170% |
| Control of interior heat generation | Fiber-optic systems | Fiber-optic systems | 220% |
| | Thermoelectrics | Thermoelectric Generators (TEG) | 340% |
| | Photoluminescents | Daylight-Luminous Dispersion-Based Paints | 270% |
| | | Daylight-Luminous Paints Based on Two-Component Acrylate-Based Paint | 260% |
| | Light-emitting diodes | Light-emitting diodes | 210% |
| Secondary energy | Photovoltaics | Organic Photovoltaic Cells | 410% |

| | | | |
|---|---|---|---|
| supply systems | | (OPV) | |
| Optimization of lighting systems | Electroluminescents | Injection Electroluminescence | 150% |
| | | Powder Electroluminescence | 160% |
| | | Thin Film Electroluminescence | 175% |
| | | Thick Film Electroluminescence | 170% |
| | | Polymer-/Small Molecule Electroluminescence | 120% |
| Optimization of HVAC systems | Pyroelectrics | Pyroelectrics | 80% |
| | Hygrometers | Hygrometers | 70% |
| | Photoelectrics | Dye Solar Cells (DSC) | 165% |
| | Biosensors | Biosensors | 55% |
| | Thermoelectrics | Thermoelectric Generators (TEG) | 210% |

## 7. Conclusion

Smart technologies are being exploited in many countries currently. The more successful countries have adopted appropriate policies, rules and encouragement to support the improvement of industries and diffusion of the technologies into the broader marketplace. In this paper the particular case of Smart Materials have been examined where the worldwide commerce is developing as part of the wider endeavor to accomplish the pledge of green and sustainable architecture. This paper has examined the possible use of Smart Materials in the Middle East region. The outcomes of a research questionnaire and interviews have been discussed and prominent features extracted. The obstacles and encouraging characteristics for the viability of Smart Materials in this region have been investigated and a diffusion strategy to introduce viable Smart Materials to the Middle East markets recommended. In order to ensure the broader use of Smart Materials in buildings in the Middle East region three objectives should be followed:

- Firstly, energy and environmental awareness need to be raised in the Middle Eastern countries in order to improve the rightfulness of Smart Materials in the eyes of the different possible professionals.
- Secondly, Middle Eastern governments need to support the application of Smart Materials as a part of achieving sustainable buildings and helping to address growing demands for energy in buildings.
- Thirdly, financial stimuli need to be established so that the costs associated with the use of Smart Materials become both affordable to consumers and competitive regarding the costs associated with conventional sources of energy.

## 8. References

[1] Al-Hathloul S. Planning in the Middle East: moving toward the future. Habitat International 2004;28(4):641–3.
[2] Castle EN, Price KA. United States interests and global natural resources: energy, minerals and food. Baltimore: John Hopkins University Press; 1983.
[3] Addington, D. Michelle and Daniel L. Schodek. 2005, Smart materials and new technologies: for the architecture and design professions, Boston: Architectural Press
[4] AboulNaga MM, Elsheshtawy YH. Environmental sustainability assessment of buildings in hot climates: the case of the UAE. Renewable Energy 2001; 24(3–4):553–63.
[5] Alnaser NW, Flanagan R. The need of sustainable building construction in the Kingdom of Bahrain. Building and Environment 2007; 42(1):495–506.
[6] Doukas H, Patlitzianas KD, Kagiannas AG, Psarras J. Renewable energy sources and rationale use of energy development in the countries of GCC: myth or reality? Renewable Energy 2006; 31(6):755–70.
[7] Patlitzianas KD, Doukas H, Psarras J. Enhancing renewable energy in the Arab States of the Gulf: constraints and efforts. Research Policy 2006;34(18):3719–26.

[8] Egbert C. Bahrain set to build multi million dollar Green City. Construction Week Magazine. Available from: <http://www.itp.net/business/news/details. php?id¼16056&srh¼green%20city&tbl¼itp_news> 11 June 2010.
[9] Huberman AM, Miles MB. The qualitative researcher's companion. London: Sage Publications Ltd; 2002.
[10] Yin RK. Applications of case study research. 2nd ed. London: Sage Publications Ltd; 2003.