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Smart Materials in Architecture

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Abstract. The project activity presides over the choice of materials and technical capacity within two dimensions of action: the previous knowledge and the tension about the future. That allowed us to identify the succession of the "technological and material" paradigms that have come and gone, featuring the project with the arrival of new materials and production processes. The advent of composite smart materials has challenged all the materials overturning the features.

Introduction

All materials are evolving with the development of technology. Intelligent materials, or smart materials, are the ultimate expression of the "paradigm of engineered materials", as a model of technical and scientific capacity to intervene in the matter at molecular level (Fig. 1). The technological and material paradigm is that of designed materials. The materials within these categories are often called "advanced" if they combine the properties of high (axial, longitudinal) strength values and high (axial, longitudinal) stiffness values, with low weight, corrosion resistance, and in some cases special electrical properties. Generated by micro and nanotechnologies, these materials are implementing the potential of artificial intelligence [1]. They interact and respond to external stimulation by modifying their properties; to detect and communicate the environmental parameters and the human body; to meet and interact on a predetermined basis with human beings and the environment, developing the real physical behavior. For various aspects present similarities with biological organisms and natural systems.

During the past decade, intelligent materials have received increasing attention from scientists because of their technological potential. The class of smart materials with the greatest number of potential applications to the field of architecture is the property-changing class. These materials undergo a change in a property or properties - chemical, thermal, mechanical, magnetic, optical or electrical - in response to a change in the conditions of the environment of the material. The conditions of the environment may be ambient or may be produced via a direct energy input such as a field of forces, with stimuli in their environment or the simple human presence; materials capable of emitting light, budge and communicate interactively, allowing extraordinary performance [2].

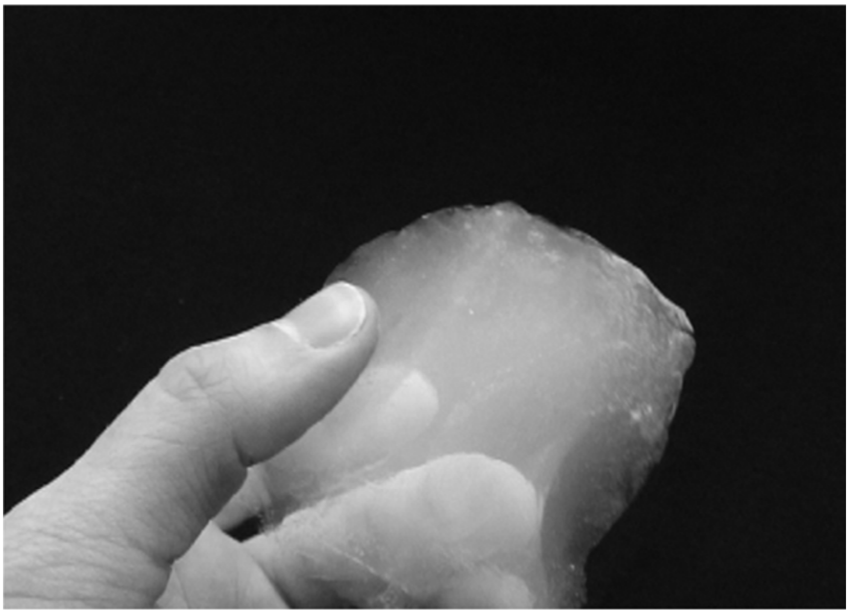

Figure 1. Insulating transparent aerogel.

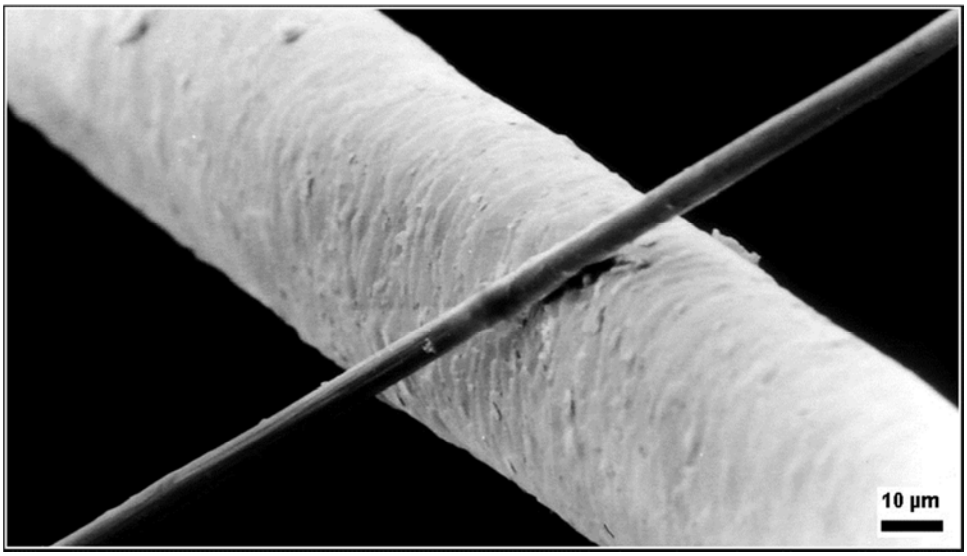

Figure 2. A 6 μm diameter carbon filament (running from bottom left to top right) siting atop the much larger human hair.

Methodology

Sensitivity, interactivity and communication skills feature "thinking objects", connecting surfaces and interactive microenvironments, setting a world more concerned about our needs and desires. In fact, materials, devices and intelligent systems are a universe that extends well beyond our expectations on the matter, which may be able to self-repair and self-generate an increasingly behavior more similar to that of living beings. The ability to edit and create new materials, designing the specific functions they have to perform, is an important opportunity for the built environment. Technically, the potential value is enormous, but it implies a radical transformation of the design process and, with it, a new design philosophy. The design of the object of design moves from the "artifact to performance". Priority is given to the point of view of design, in which issues relating to "are identified as" and "why" of the systems performance that integrate smart materials. The examples provide a broad overview of smartness solutions in various application areas and in some cases it is possible to note that the same benefits are achieved through the application of different materials and technologies [3]. The correspondence between material, shape and function in its consolidated significance now lost its importance, and create a new concept of form as essence a concept that coincides with the behavior and the very meaning of the material. In addition to assessing the benefits of new materials, the risks that they imply to understand how best to tackle the deliberate abuse of the technologies are also considered. Taking possession of the new instruments and the ability to go "back and forth" between the micro and the macro, between the old and the new, technologists and designers will be able to make use of smart materials to create a sense of well-being and comfort, expression of our needs and desires.

The materials are classified by functional typologies and defined for what they are "capable of making". This information encourages the creation of interactive and sensitive relational configurations that, through "design of the performance", are transformed into objects and services, systems and structures, spaces and surfaces, according to new behavior patterns [4].

Experimental and results

Sustainability and nanotechnology - Nanotechnology develops methods of manipulation of materials and systems at the atomic and molecular level. In the nineties the growing interest in nanotechnology is born with the ability to control matter at the structural level for which each molecule can be positioned in an orderly way. In smart materials the feature is implicit in the same characteristics of the atomic or molecular structure, according to the principle that every induced stimulus (input) follows an active response and reversibile which generates variable behaviors and changeable performance (output) that are adapted to the environmental context. The composite materials with nanoparticles, such as carbon nanotubes, nano rings, nanocrystals, nanowires of silicon, considerably improve the macroscopic properties of traditional materials. The main feature of smart materials thus consists in the ability to perceive external stimuli and react by adapting to changes in environmental conditions in a reversible way. The objects, the surfaces, the environments relate to the senses and with the human body, improving performance and the subjective experience of use in the report and in the ratio of human-machine interaction. The project becomes interactive, sensitive, communicative, conscious, adaptive, accountable, in one word "smartness".

An intelligence ambient can be a room (house, office, hospital, home for the elderly…) crammed with sensors, actuators and computers that are interconnected and connected to the internet. The separate parts are controlled and activated by an 'intelligent agent' software that is familiar with the preferences of the occupants and able to adapt the environment according to their wishes. The occupants may communicate with this ambient intelligence by means of speech, movements or other actions. The new concept has, in essence, the objective of improve the quality of life of users in daily activities and protect the environment to achieve sustainable development.

Advanced materials for architecture: coatings - We said that the smart materials are advanced materials insofar as they possess intrinsic mechanical properties, thermal and chemical, and thermal performance standards, acoustic and structural significantly higher than traditional materials. Often they consist customized, designed and produced according to the different specificities, which can be of climatic or structural nature. It is not uncommon to see a coating system designed to meet certain requirements and a set of advanced materials used for that purpose. As for the materials, technology innovation has found growth opportunities both through scientific research, or because of the contamination between different fields of application of already known materials. An example is the use of titanium in architecture, as a covering element, a new application field for this material, previously used for its high cost only in areas where it is not possible to come to terms with the economy, in particular in the shipbuilding, automotive and aerospace industries [5]. The opportunity for innovation was presented at the design for the Guggenheim Museum in Bilbao (Fig. 2) where Frank Gehry has used titanium for the outer casing in a highly innovative way, either for using a material until then never used to "coat the architecture" that to have exploited an IBM software technology, 3D Catia program, which had only applied until then in the aerospace field [6]. Therefore the outer casing, the "skin" of the building has become one of the first revelatory elements of this material.

The attractive look, the possibility to get it in different finishes and colours its light weight its mechanical characteristics and above all, its weather resistance, making it pretty eternal even in the toughest environments even when it is used very thin they have projected its use in architecture. The first applications of titanium in this area date back to the seventies. Japanese are the most important achievements until the mid-nineties: among these are the covers of the Tokyo Electric Power building, designed to stop the leakage of radiation from the reactors at the Fukushima nuclear power plant damaged after the disaster of 2011; and covers of the Fukuoka Dome, the largest baseball stadium in Japan (1994).

Today, titanium is used for exterior and interior cladding, for coverage of prestigious buildings, for artworks such as sculptures and monuments, decorative details of buildings or urban furniture. Generally it is possible the use of titanium in its natural silvery coloration which, moreover, presents different aspects to, of the lamination type, blasting, pickling or passivation endured. In particular, the processing of the material is critical because, depending on how it is carried out, can lead to obtain matt surfaces, or, as opposed, to finishes able to give coloured reflections with tones that change in relation to the variation of the light. Therefore, there are yellow or gray tones in the morning if it is not sunny, to an intense, bright white around noon, pink at sunset , blue at night or with iridescent and multicoloured flashes when illuminated with artificial light. This change is clearly visible in the masterpiece of Gehry in Bilbao, which has been defined by Buckart as a sort of giant metal band that forms a landscape that, for the multitude of angled and rounded planes, carries the light, making it at every point of a different colour, up to form a large effect monochromatic ranging from gold to blue and from pink to white [7].

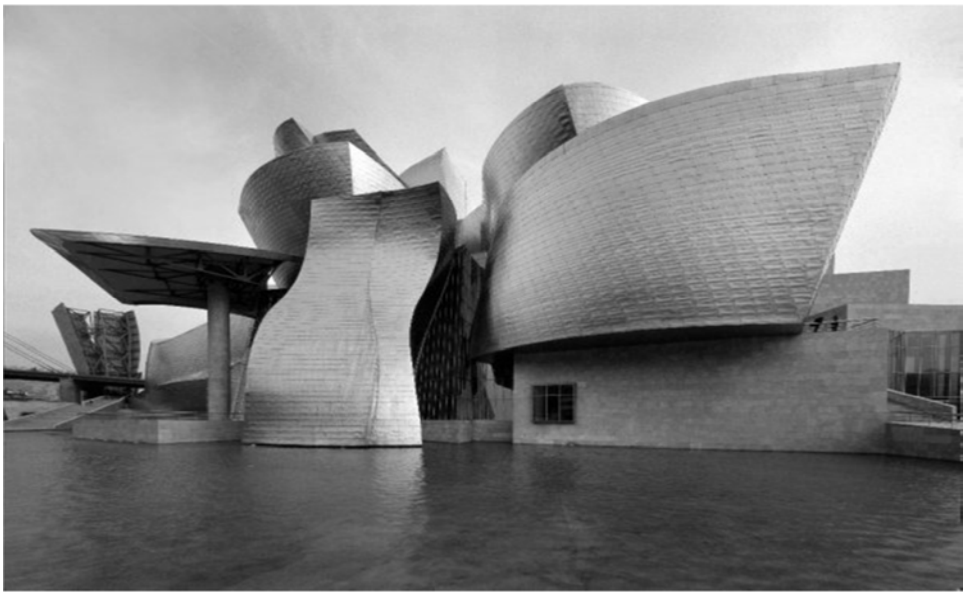

Figure 3. Guggenheim Museum, Bilbao.

The interactive facade Windswept - Nowadays a coating is not enough to make a building look like a more elegant building. There is the need that this skin make truly innovative and justified its application. Another extremely attractive example of this new concept of skin / facade, it is given by the so-called “Windswept facade”, ie an interactive facade designed to move around depending on the air currents, revealing the exact wind direction and also putting on the scene the artistic potential of natural ventilation. Designed by American designer Charles Sowers, the installation of this facade is currently been integrated on the exterior of the Randall Museum in San Francisco (Fig. 3, 4) and is a kinetic experiment that connects art and science. In fact, the installation combines not only an original design, it is able to make visible something that usually is not visible to the naked eye: create an architectural scale instrument for observing the complex interaction between wind and the building. Wind gusts, rippling and swirling through the sculpture, visually reveal the complex and ever-changing ways the wind interacts with the building and the environment. To realize this wind-driven kinetic façade Sowers took over a year, during which he worked to assemble 612 freely-rotating directional arrows in anodized aluminum on the exterior of the Museum. Each of these arrows has been installed on a special rear bracket, so as to allow the arrows to move in one direction at the first breath of wind. Windswept is 20′ high x 35′ long. It is installed on an 40′s era board-formed concrete building. I attach an image of that wall before the sculpture was installed. The whole piece sits off the wall to allow an equal volume of air to enter a ventilation intake mounted in the middle of the existing wall.The wind arrows are made of brake-formed anodized aluminum. The arrow axles are mounted to a standard metal architectural panel wall system consisting of 25 panels. The panels had holes punched in a 12″ x 12″ grid pattern into which the installation contractor secured rivet nuts to accept the stainless steel axles. Once the panels were installed the arrow assemblies were threaded into the rivet nuts. The mechanism is able to make the same facade as an artwork of looking changeable. Not surprisingly, the project was commissioned to Sowers from the San Francisco Arts Commission, with the specific purpose to create an interactive installation [8].

Figure 4. Charles Sowers' installation at Randall Museum in San Francisco.

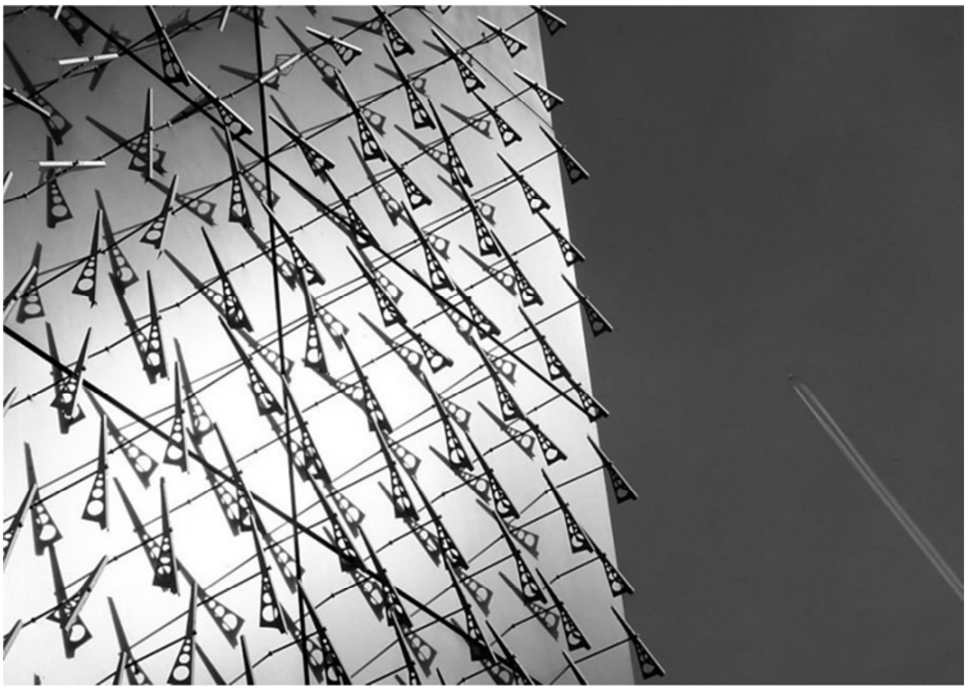

Figure 5. Charles Sowers' installation at Randall Museum in San Francisco.

Classification of smart materials - Intelligent materials are classified on the base on the type of stimulus (input) or the type of reversible reaction resulting (output). The materials are sensitive to external stimulation induced by the electric force, magnetic, mechanical and thermal. Additionally, smart materials react to small changes in environmental parameters such as temperature, pH, moisture, brightness, noise and the presence of harmful substances. Generally, they are distinguished according to the type of response that provide and which often coincides with the function they perform. The reaction generates a behavior of adaptation to the stimulus that causes the transformation of the intrinsic properties of the material, such as viscosity, dielectric constant, electrical resistance, etc.. Depending on the type of reaction to external stimulation, smart materials can be classified into seven functional groups: materials that change colour, shape, temperature, convert light, emit light, carrying light and move.

The new glass for smart "window" - At Lawrence Berkeley National Laboratory in Berkeley, California, a team of researchers led by Delia Milliron, has developed a new technology that allows to obtain a particular type of glass that can work dynamically controlling the flow of heat and light which passes through it, modulating it according to different weather conditions, through the transparency. The new glass of this type of smart window exploits the interaction of two highly conductive materials: the nanocrystals of indium oxide and tin, and a glassy matrix of niobium oxide; the interaction between the two conductors allows a selective control of visible light and heat, so as to obtain natural lighting inside without increase of heat, typical of the hottest months. Compared to current technologies, in which the control of the radiation also leads to a darkening of the glass surface, carrying some drawbacks about quality of the lighting of the environments, the conformation in three layers of the smart window allows the user a personalized and optimal control of heat, of light and transparency. In a perspective of energy saving this new approach would allow a considerable saving of resources and optimal management of costs, especially for cooling and lighting in residential buildings and in particular of the commercial ones, where the use of large glass is widespread [9].

From the point of view of the study of materials what is most important is that they were able to demonstrate that it is possible to combine very different materials to achieve new properties that can not be achieved with single-phase materials. The interaction of the two materials makes it possible to block approximately 50% of the heat and 70% of visible light compared to the use of the individual materials. Since 2013, the researchers are working with a start-up based in Oakland, California, to lower production costs, still too high. One possibility would be to use the crystals in the zinc base in place of expensive indium oxide and tin, experimentation that is giving good laboratory results (Fig. 5). A simple window can also perform functions of energy supply, as a solar panel. This is shown by the research on "Large-area luminescent solar concentrators", made by a research team from the University Milano-Bicocca in collaboration with the Los Alamos National Laboratory (U.S.A.). The team has developed solar concentrators: these are simple slabs of plexiglass "doped" with special fluorescent nanoparticles that capture and concentrate sunlighttransforming the windows of buildings in clean energy generators, without giving up the transparency of the material.

New technological solutions to illuminate the monuments - The lighting of facades and monumental buildings also requires special attention to uniform functional and aesthetic criteria, with the utmost respect of their formal and environmental features. Technological solutions for lighting facades and monuments are various: the lighting technology allows, in fact, effective solutions to illuminate monumental facades, with projectors that create grazing illumination of the wall structure so as to reduce light pollution. It is possible to use equipment collected to the ground or wall, from small spotlights to LED source, the projector which uses several watts, to fluorescent lamps. It is desirable, furthermore, to employ devices for the illumination that ensure a good control of the luminous flux directed to the outside of the area to be illuminated, for example headlamps with small lamps. In the lighting of the exterior is very widespread the use of small spotlights and between these the tendency is to use punctiform sources such as LEDs or xenon lamps, both characterized by a long duration in time. In particular, the solutions with the LEDs offer more and more high levels of performance and an extreme precision in the addressing of the flow, as they allow the possibility to edit the light intensity and chromatic effects, essential for dynamic lighting for both interiors and exteriors.

The monument lighting systems usually consist of lighting fixtures with high output sources, with particular regard to the resolution of issues associated with light pollution. To prevent light from coming out from the façade to be illuminated displays or asymmetric reflector headlamps can be installed. It is good to choose products that enhance, through the light they emit, the architectural space in which they are installed. For this reason, often it is favored a warm light rather than fluorescent lamps. To help reduce environmental pollution and promote energy savings, they are starting to be used also working devices with photovoltaic modules that fit harmoniously in historic buildings, monuments and buildings of historical interest [10]. Photovoltaic technology offers evident economic and environmental benefits, however until now the aesthetic and visual impact of the modules were the obstacles to its spread, also with the high costs of sale and installation and it is likely that in the future greater care in design and a wide range of photovoltaic products will allow further expansion of the the entire PV industry making it competitive [11] (Fig. 6).

Conclusions

Experience has shown that technological innovation occurs when a change process reaches a critical mass sufficient to overcome the inertia of the “classic” system, and only by supproting innovative processes it is possibile to implement much more ambitious plans compared to current practices. Therefore, it requires dialogue and confrontation with even distant skills that can be inspiring but at the same time require awareness of their specific knowledge and the goals that we intend to pursue. Through the results obtained by recent experimental projects, also implemented, there have been substantial changes in the way of seeing and living the built environment: the user becomes from spectator to protagonist. The projects considered here show the interest and ideas that are droning on research regarding innovative and reliable systems technology, to ensure the enhancement and enjoyment of the built landscape and a smart use of buildable space.

In this historical moment characterized by the use of high technology, the continual technological research may represent an opportunity for further renewed debate on innovation and sustainability concepts. We refer to technologies that can be used successfully in order to preserve the built environment, setting the stage for an “intelligent building”, thinking consciously about the same time formal and construction problems, the functional and technical issues and system implications, favoring a consideration on the multiple dimensions that underlie the conscious use of new materials.

Figure 6. Smart window.

Figure 7. PV panels.

Sources of photos

Fig.1 - source from a document online: repubblica.it/scienza_e_tecnologia/aerogel.
Fig.2 - document online: niilmuniversity.in/coursepack/humanities/Industrial_Development.pdf
Fig.3 - by the Author
Fig.4 - photo by Archdaily
Fig.5 - photo by Archdaily
Fig.6 - document online: rinnovabili.it/innovazione/finestra-intelligente.
Fig.7 - by the Author

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