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THE TECHNOLOGY FOR PRODUCTION SMART WINDOWS

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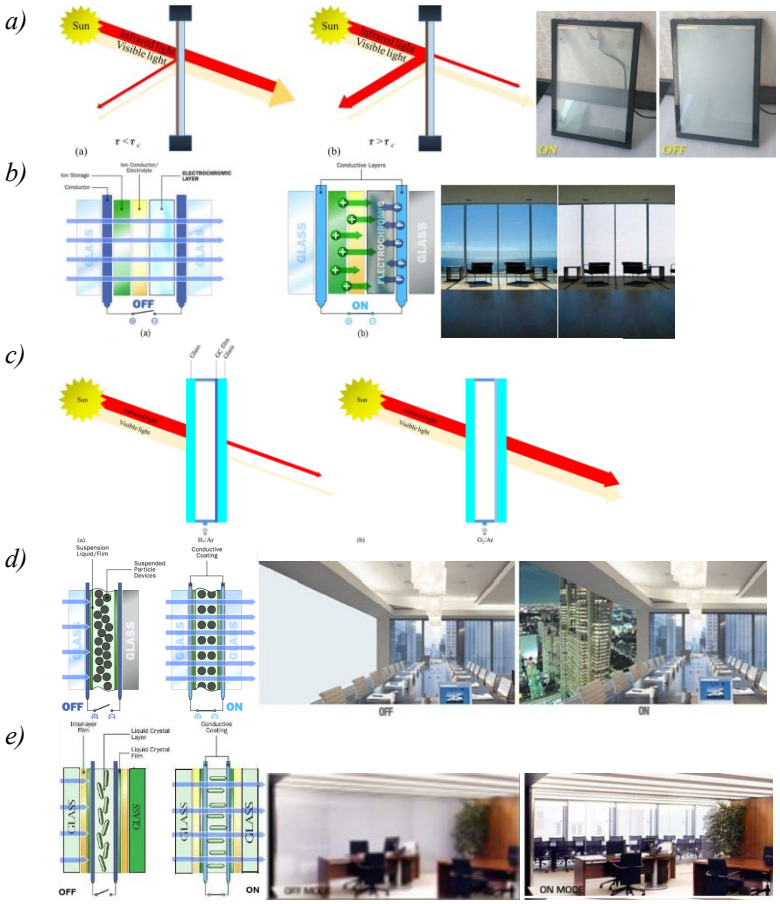
ABSTRACT
Raising awareness on sustainable, energy-efficient building construction affects the need to improve the characteristics of the window. More and more smart homes build. Windows and doors built into these homes must meet certain requirements to ensure that the quality of stay in these homes is at the desired level. For this reason, significant research and improvement of window characteristics has been carried out in recent years and decade. Solutions include the use of sensors, control units and sophisticated equipment to provide improved window characteristics.
This paper will present some of the solutions improving the characteristics of the windows so that are rightly call smart windows.
Keywords: smart window, technology, window characteristic control

1. INTRODUCTION
In order to improve the thermal characteristics of windows, significant improvements are made in the construction of window components (frames, glazing) as well as the application of new materials and techniques (different types of glass, coating on a particular surface (inner or outer)of glass or glazing, application of insulation materials etc.) [1,2]. The commonly used energy-related properties of windows are: insulating value (U-factor), ability to control heat gain from solar radiation (SHGC and SC), and visible light transmittance (VT). Various coatings, tints, and other glass surface treatments can affect the energy properties of windows.
All done improvements are not aimed only improve the energy performance of windows, but also the elimination of certain problems or disadvantages of using a window as for example the need for maintenance of wooden windows. Significant advances in the construction of smart homes have been made in recent years. Windows that are built into these homes should be able to recognize and adapt to the outdoor and indoor temperature, intensity and angle of the input light, wind intensity, as well as the amount of humidity in the air or the content of CO2. Smart windows may be part of a heating, ventilation and air conditioning (HVAC), which may include control of the temperature and humidity, fresh air heating and cooling naturally), or may function as an independent autonomous systems.

2. IMPROVEMENT OF THERMAL CHARACTERISTICS OF WINDOWS
Improving the thermal performance of the windows should be to influence the reduction of heat loss in winter and reduce heating of rooms in summer. This is achieved by certain glazing and shading solutions. The first improvement the glazing was usage more conventional glazing glass and coating including tinted glass, reflective glass, low- emissivity (low-E) coatings and different construction of the glazing (multiple-pane glazing with two or three glass certain characteristics with the use of gas or air between the glass and the corresponding spacers between the panels). Several ways to improve shading have been developed. The shading system (blinds and other equipment) can be embedded inside the glazing and only the shading is controlled manually or electrically or the shading system (blinds, shutters and other equipment) is installed on the outside of the window. Shading control can be performed manually or electrically. [1, 4]

The trend of research and advancement of window characteristics in recent years goes in the direction of making switchable windows, i.e. windows that react depending on the environment conditions (intensity and angle of sunlight, rain, wind and so on) and adapt their characteristic to specific conditions of environment. Smart glass film is intended to have the ability to control the amount of light, and heat, passing through. With a switch of a button on a wall or smart phone app, the glass can change from transparent to completely opaque. Unlike blinds, smart windows are capable of partially blocking light while maintaining a clear view of what lies behind the window. An external stimulus such as electrical current, voltage, heat, and light can alter the optical properties of some materials. Smart glazing can be primarily categorized into two types referred as passive and active glazing. Materials that change properties when exposed to heat are used for passive glazing, although they can not be directly modulated. In active glazing, an external stimulus such as an electric field, heat or ion diffusion is used to adjust optical properties. This modulation can be in various forms such as absorption, reflection or scattering. Various techniques are known to derive switchable windows or dynamic windows.Presently, three different technologies with external triggering signal are commonly known for this purpose and start to be available on the market: chromic materials, liquid crystals and electrophoretic or suspended-particle devices. Here, the chromic devices may be divided in four categories, i.e. electrochromic, gasochromic, photochromic and thermochromic devices, where the last two possibilities will respond automatically to, respectively, changes in light and temperature.



TC window (a) below transition temperature (b) above transition temperature

Schematic illustration of an electrochromic window (a) off-state (bleached) (b) on- state (colored).

GC windows exposed to (a) diluted H2 (b) diluted O2.

Schematic of a suspended particle device (SPD) window (a) upon the applied voltage (b) in the absence of voltage

Schematic illustration of LC window mechanism

Figure 1. Smart glazing windows technology

The thermochromic glass simply uses heat from direct sunlight to tint the windows when necessary. The more direct and intense the sunlight is on the glass the darker it will become. This allows the windows to drastically reduce the heat load coming into the building and because the glass transmission adapts continuously over a range of temperatures, a natural balance and maximum use of daylighting is achieved. Electrochromic windows allow the window to be darkened depending on the user's wishes or in accordance with ambient light conditions. They function in a way that changes in the electric field change the thermal and optical properties of the window. The electrochromic thin film stack is deposited on a glass substrate and is typically about one micron thick. The stack consists of ceramic metal oxide coatings with three electrochomic layers sandwiched between two transparent

electrical conductors. When a voltage is applied between the transparent electrical conductors, a distributed electrical field is set up. This field moves various coloration ions (most commonly lithium or hydrogen) reversibly between the ion storage film through the ion conductor (electrolyte) and into the electrochromic film. The effect is that the glazing switches between a clear and transparent blue-gray tinted state with no degradation in view, similar in appearance to photochromic sunglasses. A gasochromic (GC) layer is incorporated into the gasochromic window when exposed to diluted hydrogen gas (mixed with Ar gas), the layer colors and its transparency changes. The transparency level depends on the volume of hydrogen. To restore the transparency, diluted oxygen gas is inserted. The archetypal gasochromic material is tungsten oxide coated with a thin layer of catalyst (usually Pd or Pt) which breaks H2 into H + ions. Transparency ranges from 0.77 to 0.06 are achieved in the laboratory. The structure of the layers in this window is simpler than the electrochromic windows, however the gas chrome windows need more control equipment. Windows with suspended particles (SP) and liquid crystal (LC) windows are electro active windows. When SP and LC windows apply AC voltage, randomly scattered and orientated particles are aligned and the window becomes transparent. In the absence of electronic field, SP windows absorb light and reduce light transmission while most LC windows scatter light and appear white and translucent. Smart windows with liquid crystals are usually designed to ensure space discretion. Windows - solar panels represent a new step in the technology used for window constructions. The Norwegian company EnSol AS has created and patented a new special solar transparent film that can be placed on window's glass, and by using metal nanoparticles the sunlight is transformed into energy used for heating and home lighting. Photovoltaics (PV) are solid-state, semiconductor type devices that produce electricity when exposed to light. Electrons in the photovoltaic material are knocked free by light to flow out of the device as an electric current. The more intense the sunlight, the stronger the electric current. Photovoltaic vision glass integrates a thin-film, semitransparent photovoltaic panel with an exterior glass panel in an otherwise traditional double-pane window or skylight. All the PV types can be integrated and/or laminated in glass, but only thin-film photovoltaics will be translucent. Electric wires extend from the sides of each glass unit and are connected to wires from other windows, linking up the entire system. For buildings with low-performance glass (e.g., single-pane clear), automated (and manual) shades can also increase thermal comfort by raising or lowering the effective surface temperature of the window wall during the winter or summer, respectively. The shade material and location of the shade in the window wall dictates the degree of daylight transmission and solar heat gain rejection. Exterior shades reject more heat than interior shades. Between-pane shades perform somewhere between exterior and interior shades depending on the size of the glazing cavity and whether it is ventilated. Automated systems often have wall switches or hand-held remote controllers so that individual shades can be controlled. Automated controls feature scheduling, direct sun control or depth of sun penetration, solar heating, glare control, daylighting, occupancy, response to HVAC operations, and limits on exterior shade operations, in the case of high winds, snow, or ice.

3. IMPROVEMENT OF THE VENTILATION, SAFETY AND CONTROL SYSTEM

If the room is incorrectly ventilated, it will retain moisture, CO2 and other contaminated air particles that can cause great damage. The structure of the building can be damaged by the influence of fat and moisture. Mold, flower powder or home dust can also adversely affect human health, classical ventilation, and precious heat goes out.

Ventilation is carried out for the purpose of providing natural ventilation or ventilation due to smoke and fire. The manual ventilation mode does not produce the desired results and therefore natural ventilation systems are increasingly applied, which are connected to various climate sensors (rain sensors, wind sensors, indoor and outdoor temperature sensors, CO2 sensors). These sensors are connected to the control unit and, based on the readings, a signal is sent to a particular component of the room ventilation equipment. Conveniently, several ways to ventilate the room are practiced. The simplest way is to use a window opening / closing system (manual control) using certain actuators, another decentralized ventilator installation in a window frame that constantly provides fresh air - automatically or invisibly for each area (automatic ventilation control). Automatic control system allows the building to automatically react to ambient conditions, but the end user is enabled to have control over the override function.ly for each area (automatic ventilation control). For example,Germany firm Rehau,has been using its innovative solution in recent years, whereby the window alternately lets air out , and fresh air enters the room and warms it or cools it depending on

the difference ambient temperature and room temperature. Thanks to integrated sensors that measure moisture and carbon dioxide content in the air, this window decides independently when and with what intensity it will apply its ventilation system. Another intelligent addition is an alarm system window designed to alert the burglar and before the potential use of force by automatic shutter rolling or by calling for help.

Figure 2. Schematic representation of the ventilation system

The smart home system monitors and manages all systems, devices and home installations in real-time, in a way that is consistent with users' requirements, needs and habits, saving energy, while enhancing the comfort of life and security. This home automation system can include centralized control of lighting, heating, ventilation, air conditioning, various appliances, security door locks and other systems.

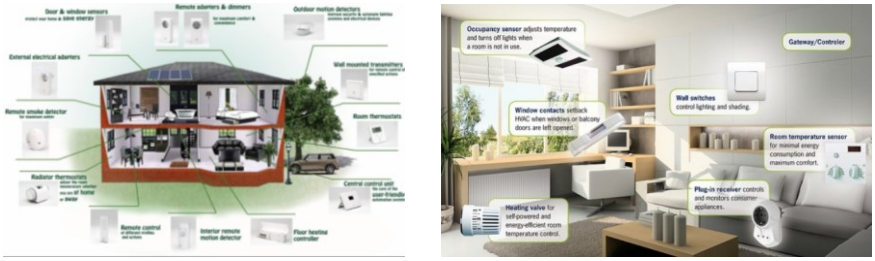


Figure 3. Smart home

This home automation system can now be managed intuitively and easily with a touch screen, internet, remote control or phone. In this system of automation is increasingly involved the system of smart windows. The currently proposed innovative window control feature includes control of lighting, shading, ventilation, and burglary safety. Integration of individual systems into a comprehensive control system (Rehau Corporation) enables integration of this control system into a control system for managing smart home features using tablet computers or mobile phones.

4. CONCLUSION

This paper presents conventional, advanced and smart glazing technologies in terms of solar control, ventilation control and security of windows currently being considered for their application in the window market.

The mentioned improvements significantly improve the energy efficiency of buildings and the comfort and quality of people living in buildings. The current cost of buying such windows is still quite high, especially for the population of Bosnia and Herzegovina, but we are hoping that the development of materials, technology, technological equipment for production of component or entire windows, and the use of innovative, smart solutions will affect the cost of window. This will enable their wider application, better energy performance of buildings, environmental protection and energy savings.

5. LITERATURE

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