Development of switchable mirror sheet using gasochromic method: New technology for energy-saving window glass

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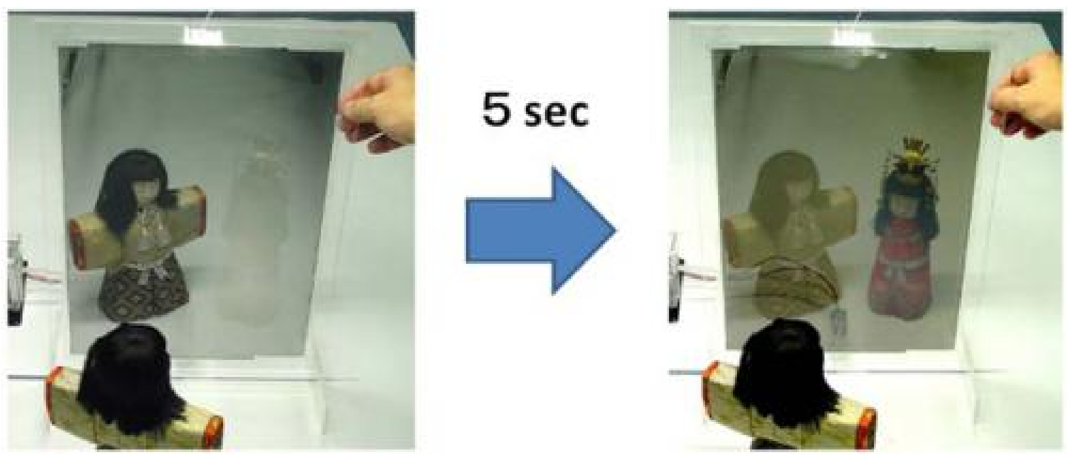

Switching of the switchable mirror using the new method (37 cm x 26 cm).

Kazuki Yoshimura, Energy Control Thin Film Group, the Materials Research Institute for Sustainable Development of the National Institute of Advanced Industrial Science and Technology, has developed a switchable mirror that uses a new switching method.

Switchable mirrors can be switched between a transparent state and a mirror state. Their use can yield energy-saving window glass that substantially reduces cooling loads by effectively blocking sunlight. The developed switchable mirror sheet uses new gasochromic switching that is completely different from conventional gasochromic switching methods. It can control the reflection of visible to near-infrared light at a switching speed about 20 times faster than that of conventional electrochromic switchable glass. The present development can solve the issues involved in bringing gasochromic switchable mirrors into practical use. Because the thickness of the thin film that controls light is about 1/10 that of conventional films, substantial reduction in production cost is expected.

Details of this technology were exhibited and presented at Nano tech 2013, the 12th International Nanotechnology Exhibition and Conference, held from January 30 to February 1 at Tokyo Big Site in Koto-ku, Tokyo.

Air conditioning accounts for about 30% of energy consumption at home and at work. A window is a building component that significantly affects energy consumption. Normal window glass transmits visible light as well as heat and reduces the effectiveness of insulation. Increasing the insulation value of windows is very effective in saving energy, and double-pane glass and low-e (low-emissivity) glass with high insulation values are becoming widely used. Switchable glass can control incoming and outgoing light and heat to increase energy-saving effects by insulating heat and blocking sunlight.

Electrically controllable electrochromic glass is a typical type of switchable glass. Recently, in the United States, electrochromic glass with a tungsten oxide thin film as the switchable layer has been commercialized for building applications. However, inexpensive switchable glass is required to promote the widespread use.

All conventional electrochromic glass absorbs light to control light and therefore has a drawback; the temperature of the thin film rises and the film re-radiate heat into the room. If light could be controlled by reflection, then sunlight could be blocked more efficiently. Therefore switchable mirrors that can be switched between the transparent state and the mirror state are awaited.

Since 2001, AIST has been conducting research and development of thin-film materials for switchable mirrors. It has installed actual-size window glass in a real building and has demonstrated that the glass can reduce the cooling load by more than 30% compared with conventional transparent double-pane window glass.

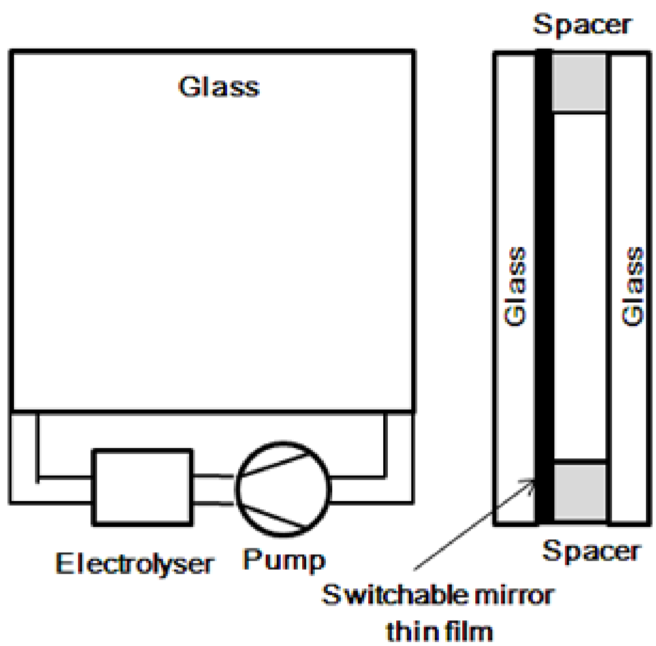

Figure 1: Conventional gasochromic switchable glass.

Electrochromic switchable glass has a complex structure and is therefore very expensive to produce. Gasochromic glass has a simple structure consisting of two thin films and has been expected to be low-cost switchable glass. The advantage of gasochromic switching is that the switching speed is size-independent. Therefore, the method is considered to be suitable for large switchable glass. However, its durability has been a problem.

AIST has developed a magnesium-yttrium alloy thin-film switchable mirror that can perform more than 10,000 cycles of switching (AIST press release on September 20, 2012). However, safety concerns have been raised about the hydrogen gas used for the switching. AIST has therefore been conducting the research and development of a safe gasochromic switchable mirror.

Conventional gasochromic switchable mirrors are made of two panes of glass bonded to a spacer. Switching is performed by the introduction of gas into the space between the panes (Fig. 1). When hydrogen produced by the electrolysis of water is introduced into the space, the switchable mirror thin film is switched from a mirror state to a transparent state by hydrogenation. When oxygen is introduced, the thin film is switched back from the transparent state to the mirror state by dehydrogenation.

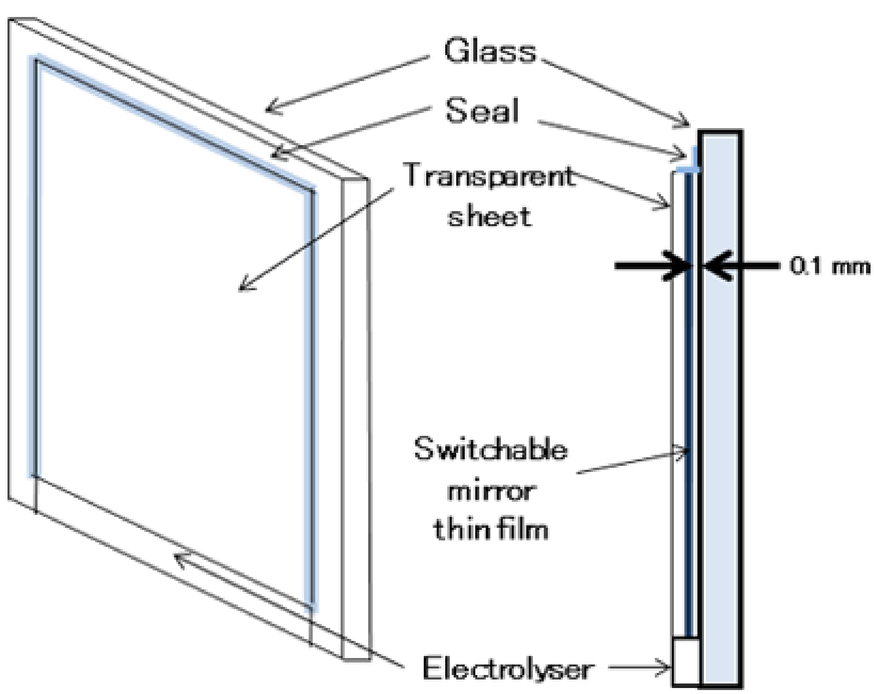

Figure 2: Gasochromic switchable mirror that uses the new switching method.

The researcher has found that when glass and a transparent sheet are bonded together without a spacer, an air gap with an average thickness of about 0.1 mm is formed, and gasochromic switching can be performed by introducing gases into the air gap. However, because the air gap is very small, switching cannot be performed satisfactorily by introducing hydrogen or oxygen in a conventional manner. The researcher investigated the mechanism of gasochromic switching and has developed a new method that can perform switching satisfactorily in this small air gap (Fig. 2). Switchable glass that uses this new switching method can switch as well as conventional gasochromic switchable glass, even though the sheet is locally in contact with the glass at many points.

Conventional gasochromic switchable glass must be double-paned and cannot be used in vehicles, where single-pane glass is used. Adopting the developed gasochromic method, a transparent sheet with sputter-deposited switchable thin film, whose rim is bonded to a single pane of glass, works as switchable glass and can be used in vehicles.

With the conventional switching method, if an air gap of 5 mm is provided between two panes of 1 x 1 m glass, the volume of the gap is 5 L and a large amount of gas is required for switching. With the new switching method, the volume of gas required to switch glass of the same area is only about 100 mL—1/50 of that required with conventional methods—allowing switching with a small amount of hydrogen. In addition, the small amount of hydrogen introduced into the gap is absorbed quickly by the switchable thin film, leaving little hydrogen in the gap and eliminating risks such as hydrogen leakage.

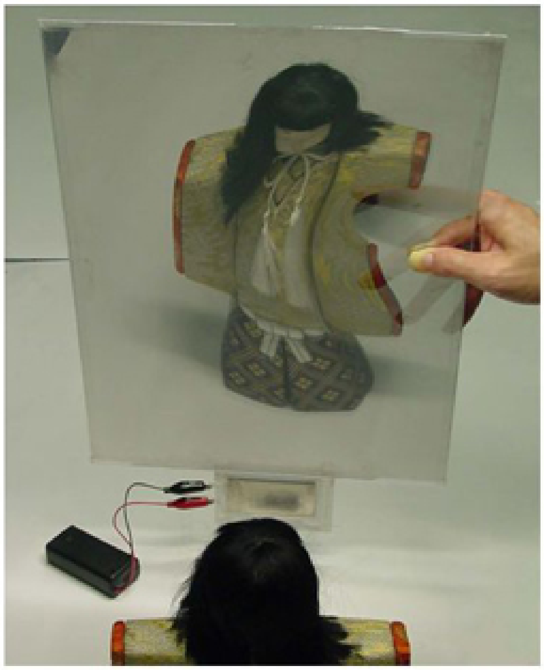

Figure 3: Switchable mirror sheet that can be operated simply by connection to a battery The sheet is flexible and can be bent to some degree.

The switching speed of conventional electrochromic switching glass depends on the current through the transparent conductive film and therefore decreases as the film size increases. It takes at least about 10 min to completely switch meter-size glass if the commonly used ITO (indium tin oxide) is used as the transparent conductive film. With the new gasochromic switching method, a meter-size switchable sheet can be completely switched to a transparent state in about 30 s—a switching speed about 20 times faster than that of conventional gasochromic films.

In addition, because the switching can be performed with a very small amount of hydrogen, the moisture (water vapor) in air can be used as the source of hydrogen. For example, the water vapor concentration in air is about 2% at a temperature of 30 °C and a humidity of 50% and the electrolysis of this water vapor can produce a small but enough amount of hydrogen for switching. It was previously necessary to supply water for electrolysis from a water tank, but with the new method this is not necessary: switching can be performed simply by applying a voltage of about 3 V to the polymer film for hydrogen production by electrolysis of water vapor. Because only a very low concentration of hydrogen is produced, there is no risk of explosion.

Figure 3 shows a switchable mirror sheet that uses water vapor in air. This gasochromic sheet requires no gas or added water. It can be switched simply by connecting a 3-V battery to the terminals and is as easy to handle as electrochromic switchable glass.

Switchable glass and films were produced by vapor deposition of thin films using the magnetron sputtering method. One of the major factors that determine the cost of production by this method is the thin-film deposition rate; increased deposition rate reduces the production cost. Commercialized electrochromic switchable glass typically has five thin films and an overall thickness of about 1 μm. The developed switchable mirror sheet has two thin films and an overall thickness of less than 100 nm—about 1/10 the thickness of electrochromic switchable glass. In addition, because the developed switchable mirror sheet consists only of metal thin films with a high deposition rate, the deposition time is much shorter than that of conventional electrochromic switchable glass and a marked reduction in production cost is expected.

The researcher will evaluate the durability of the sheet by performing cyclic switching. The developed technology will be applied to the areas in which conventional gasochromic switchable glass cannot be used, particularly in the small windows used in vehicles, trains, and airplanes. He aims to increase the visible light transmittance of the glass to more than 70% and to use the glass to effectively block sunlight from entering through vehicle windshields. He also intends to study thin-film deposition on large sheets in collaboration with the private sector aiming for the early use of this switchable mirror glass as large glass for buildings.

Provided by Advanced Industrial Science and Technology

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