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SOL-GEL DEPOSITED ELECTROCHROMIC FILMS FOR ELECTROCHROMIC SMART WINDOW GLASS

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Abstract

Electrochromic windows offer the ability to dynamically change the transmittance of a glazing. With the appropriate sensor and controls, this smart window can be used for energy regulation and glare control for a variety of glazing applications. The most promising are building and automotive applications. This work covers the use of sol-gel deposition processes to make active films for these windows. The sol-gel process offers a low-capital investment for the deposition of these active films. Sol-gel serves as an alternative to more expensive vacuum deposition processes. The sol-gel process utilizes solution coating followed by a hydrolysis and condensation. In this investigation we report on tungsten oxide and nickel oxide films made by the sol-gel process for electrochromic windows. The properties of the sol-gel films compare favorably to those of films made by other techniques. A typical laminated electrochromic window consists of two glass sheets coated with transparent conductors, which are coated with the active films. The two sheets are laminated together with an ionically conductive polymer. The range of visible transmission modulation of the tungsten oxide was 60% and for the nickel oxide was 20%. We used the device configuration of glass/ SnO_2:F/ WO_3/polymer/$Li_zNiO_xH_y$/SnO_2:F glass to test the films. The nickel oxide layer had a low level of lithiation and possibly contained a small amount of water. Lithiated oxymethylene-linked poly(ethylene oxide) was used as the laminating polymer. Commercially available SnO_2:F / glass (LOF-Tec glass) was used as the transparent conducting glass. We found reasonable device switching characteristics which could be used for devices.

1. INTRODUCTION

Electrochromism (EC) can be broadly defined as a persistent and reversible color change as a function of injected/extracted charge and their coloration can be controlled via the number of coulombs passed during electrochromic reaction. Electrochromic materials are attractive candidates for smart window applications (1). Electrochromic devices consist of thin films that provide optical modulation, ion conduction and transparent electrical conduction.

Electrochromic smart windows can be constructed in several different ways (2). One design these windows consist of oxide layers that are deposited on two conductive glass

The electrochromic system was made by joining the pre-lithiated $LiNiO_xH_y$ / α-PEO / $F:SnO_2$ coated glass with the WO_3 /$F:SnO_2$ coated glass. The polymeric solid electrolyte was laminated between the two electrodes. The windows were hot- pressed at 80°C the dry box and sealed with a low vapor pressure adhesive (Varian Torr-seal). The optical performance of the windows was measured with a Perkin and Elmer Lambda 2 UV / VIS spectrophotometer.

3. RESULTS AND DISCUSSION

We have successfully fabricated prototype small area (2 cm x 3 cm) five layer smart window devices. Figure 1 shows the schematic of the laminated smart window. This is a five-layer device that has been deposited on a transparent conducting substrate. WO_3 is used as cathodicaly coloring electrode and lithiated NiO_xH_y is used as anodically coloring electrode.

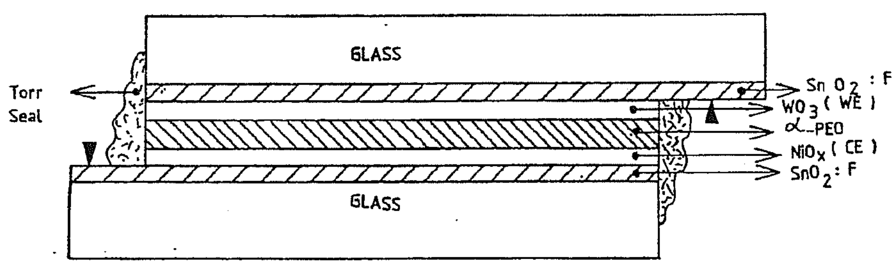

Fig. 1. Schematic diagram of a sol-gel deposited, laminated smart window.

The following reaction takes place as a lithium is transported from the NiO_xH_y layer to WO_3 via ion conductor.

$Li_zNiO_xH_y \leftrightarrow NiO_xH_y + 2\ Li^+ + 2\ e^-$
$WO_3 + z\ Li^+ + 2\ e^- \leftrightarrow Li_xWO_3$
(Bleached) (colored)

WO_3 goes through a large optical modulation from transparent to a deep blue tungsten bronze color when lithianated (14). NiO_xH_y changes from colorless state to a brown colored state with lithium extraction. This device exhibits good spectrally selective transmissivity in the visible range. Such a device has been switched between ± 1.4 V for more than 1200 cycles.

The cyclic voltammetry of the WO_3 /α-PEO-$LiClO_4$ / $LizNiO_xH_y$ window is shown in Figure 2. The window shows a reproducible electrochromic behavior for many cycles. During the cathodic scan the window becomes dark while during the anodic scan the window becomes transparent. Both coloration and bleaching took place in within 15 seconds as judged from visual observation.

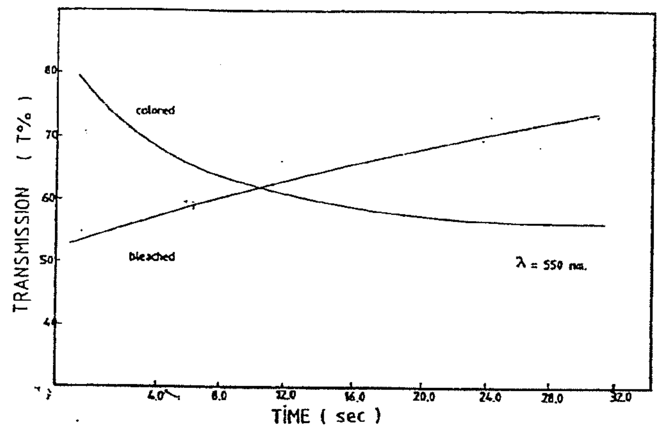

Fig. 4. Charge reversibly exchanged during the coloring - bleaching process of the window.

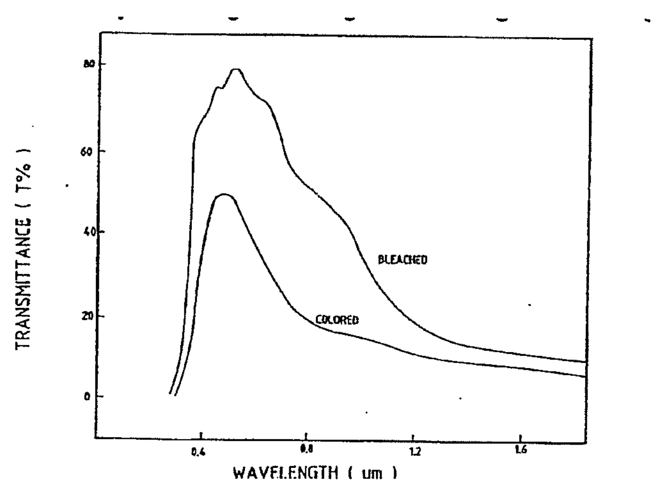

Fig. 5. Optical transmittance of sol-gel deposited smart window having the configuration: glass - F: SnO_2 - $LiNiO_xH_y$ / α PEO - $LiClO_4$ / WO_3 -F: SnO_2 - glass.

4. CONCLUSION

Sol-gel deposited electrochromic layers can be used for the fabrication of electrochromic smart windows. A prototype of smart window glass employing sol-gel deposited layers has been successfully fabricated. In the prototype device, a WO_3 film was used as a working electrochromic layer, and a $Li_zNiO_xH_y$ film as the counter electrode, and amorphous oxymethylene linked poly (oxyethylene) - $LiClO_4$ as an ion conducting layer .The polymeric ion conducting layer was transparent and showed a high ionic conductivity of the order of 10^{-5} Scm^{-1} at room temperature. Potentiostatic cycling (± 1.4 V) was performed on the elecrochromic window and reversible transmittance variance from 50 % to 80 % was observed at 550 nm. The device cycled unchanged for 1200 cycles.