Reversible Electrochemical Mirror (REM) Smart Window

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Smart windows are designed to reduce the amount of energy consumed for climate control of buildings and transportation vehicles by controlling the amount of transmitted solar radiation. However, conventional electrochromic devices have narrow dynamic ranges and involve light absorption in operation, resulting in heat being generated and transferred into the interior space by conduction, convection and infrared radiation. A smart window based on light reflection would be much more efficient at preventing interior heating.

Reversible metal electrodeposition has previously been investigated for display devices[1-3] but the electrodeposits obtained on indium tin oxide (ITO) transparent conductor electrodes have generally exhibited a dark appearance (indicative of poor nucleation). Such display devices have also generally employed continuous counter electrode and reactions other than metal deposition, which are unsuitable for smart windows.

This paper describes a reversible electrochemical mirror (REM) smart window device that utilizes a thin Pt nucleation layer (15Å) to provide Ag mirror electrodeposits on a transparent ITO front electrode. The device also employs a grid or dot matrix counter electrode, enabling use of reversible Ag electrodeposition as the counter electrode reaction. A typical electrolyte contains 1.5 M AgI + 2.0 M LiBr in a gamma-butyrolactone (GBL) solvent, which can be thixotropically gelled with highly dispersed silica (HDS).

Figures 1 and 2 show a REM device (7 x 8 cm window) in the reflective and transmissive states. The counter electrode is a fine Cr/Pt grid (on a glass substrate) with 7 µm lines and 144 µm spaces (varied randomly $\pm$10 µm to mitigate light interference patterns). Reflectance of the device is increased by electrodepositing a mirror layer of Ag on the transparent electrode and dissolving Ag from the counter electrode. Device transmission is increased by reversing the process so that Ag is removed from the mirror electrode and deposited onto the localized counter electrode so as to be substantially removed from the light path. The transmission and reflectance of the device can be varied continuously over a wide range with low voltage and power input, and no voltage is required to maintain a given mirror state. The device is highly efficient at preventing interior heating since most of the blocked light is reflected. Less than 500Å of deposited silver is needed to provide high reflectance. High cycle life has been demonstrated.

Figure 3 illustrates that it should be possible to produce low-cost REM counter electrodes by preferential electrodeposition of Pt at defect sites on an ITO substrate, which then serves as the current collector for a Pt dot matrix electrode. During REM operation, Ag deposition is confined to the Pt nuclei by the high overvoltage associated with deposition on the bulk ITO material (which also enables preferential deposition of Pt nuclei).

References:

1. S. Zaromb, J. Electrochem. Soc. 109 (10), 903 (1962)
2. H. J. Stocker, L. G. VanUitert, T. C. Loomis and F. B. Koch, J. Electrochem. Soc. 123(4), 746 (1981)
3. B. M. Howard and J. P. Ziegler, Solar Energ. Mat. & Solar Cells 39, 309 (1995)

Fig. 1 REM smart window device reflecting logo on white paper.

Fig. 2 REM device in transmissive state showing logo on white paper.

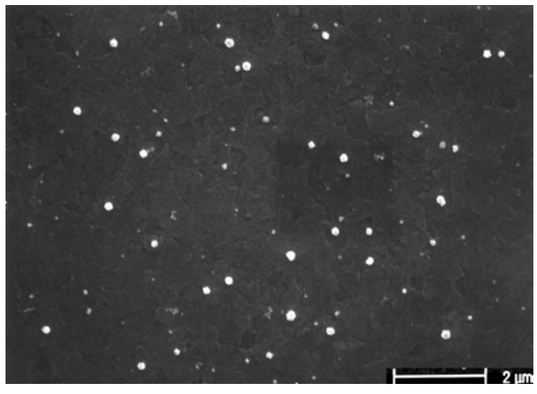

Fig. 3 SEM micrograph of Pt nuclei electrodeposited on ITO defects at –0.4 mA/cm^2 from pH 8 Pt plating solution operated at 70°C and containing 10 g/L chloroplatinic acid and 60 g/L ammonium dihydrogen phosphate.