

Electronic Supplementary Information

A surfactant-free co-assembly route to fabricate 2D TiO₂-WO₃ composite inverse opal for the photochromic application

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Materials and Characterization

Polystyrene latex microsphere with the diameter of 900 nm aqueous suspensions (PS particles, 2.5 % w/v) was purchased from Alfa Aesar. Before using, they were diluted into 1.0 % w/v with equal volume of ethanol and water. ITO coated glass substrates were ultrasonically treated in warm water, acetone, ethanol and deionized water for 15 min, successively. Tungsten powder (99.9 %), hydrogen peroxide (H₂O₂) (30 %) and H₂SO₄ (98 %) were reagent grade and purchased from Aldrich. All the aqueous solutions were prepared with Millipore water (resistance = 18.2 MΩ cm⁻¹). The glass substrates were cleaned in a piranha solution (H₂O₂: H₂SO₄ = 3:7 v/v) at 100 °C for 15 min, and then washed with Millipore water.

Synthesis of WO₃ solution

WO₃ solution was made by dissolving 1.85 g tungsten powder in 10 ml H₂O₂ (30 %). After the initial reaction, the mixture stirred at room temperature for 20 h to get a clear solution, and then refluxed at 100-110 °C for 20 min to get a clear yellowish solution. After getting rid of the excess H₂O₂ by stirring with a Pt wire, the solution was mixed with ethanol at the final volume ratio of water: ethanol = 7:3.

Synthesis of TiO₂ solution

1.35 ml of Titanium tetrachloride (TiCl₄) was slowly added to deionized water (DI). After 1 hour stirring, the crude product was rinsed four times with DI water. The wet cake was slowly added to an ice-cooled solvent consisting of 10 ml H₂O₂ (30 %) and 2 ml NH₃·H₂O (25%). After stir for 90 min, a homogeneous pale yellow-green solution was obtained. Then, the solution was mixed with ethanol, and the final volume ratio of water: ethanol is 7:3.

Characterization

Morphologies of the films were characterized using a Zeiss ULTRA 55 scanning electron microscope (SEM). The optical transmittance spectra of the films and of the

devices in their colored states were obtained using UV-vis spectrometer (Perkin-Elmer Lambda 18) with quartz cuvettes. Raman spectrometer (514 nm laser, Renishaw microprobe RM 1000) was used for Raman test. Wide angle X-ray diffraction (XRD) measurements were conducted using a Scitag diffractometer with a $\text{CuK}\alpha$ x-ray emitter (Rigaku, D/max-Ra). Photochromic tests were made under 100 mW/cm^2 illumination from a 450W Oriel solar 3A simulator with an AM 1.5G filter.

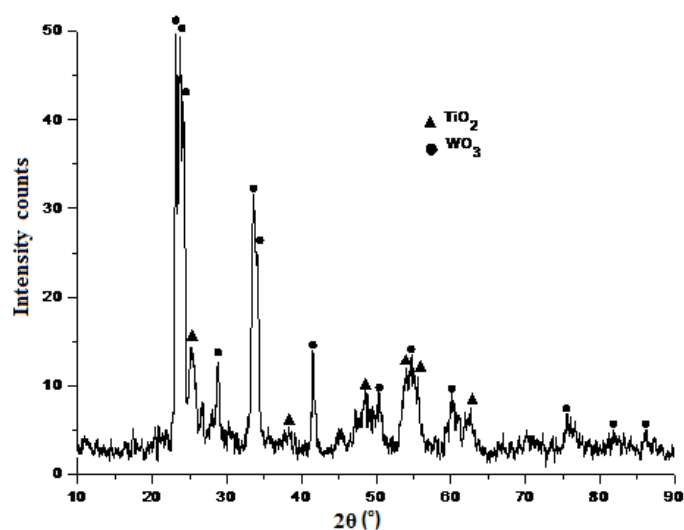


Figure S1. XRD pattern of a TiO_2 - WO_3 composite IO film. Which shows monoclinic WO_3 (PDF #43-1035 and # 75-2072) and anatase TiO_2 (PDF #21-1272).

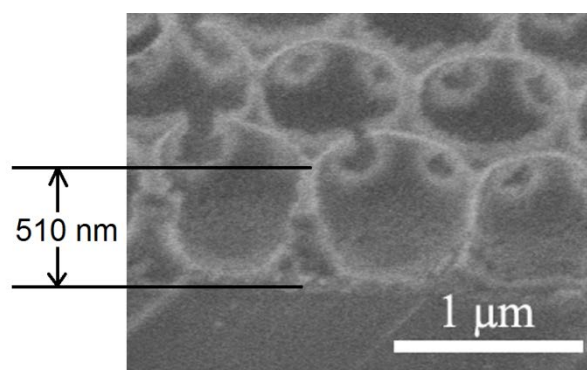


Figure S2. Cross-sectional SEM image of a TiO_2 - WO_3 composite IO film templated by PS spheres with the diameter of 900 nm. (Sample tilted at 49°)