# Synthesis of tungsten oxide thin film and nanowires for highly improved electrochromic smart windows

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ABSTRACT<br>
Tungsten oxide, has many interesting optical, electrical, structural, and chemical properties, are an ideal choice material for electrochromic smart windows devices. In this study, tungsten oxide thin films were prepared by the thermal oxidization on Tungsten/ITO/glass substrates at different heat-treatment temperatures. The optimum heat-treatment temperature, corresponding to the maximum electrochromic performance, was achieved by 550 oC. X-ray diffraction (XRD) analysis indicates that a tetragonal WO3 phase formed at temperatures below 550 oC and the phase transformed to monoclinic W18O49 after the temperature was raised to 650 oC. The electrical properties analysis confirmed that the highest electrical conductivity show the superior electrochromic performance, with the maximum coloration efficiency value of 60.4 cm2/C. The tetragonal WO3 films, with heat-treatment temperature 550 oC and 450 oC, exhibit good electrochromic properties such as a high diffusion coefficient (1.7x10-11 cm2/s), fast electrochromic response time (coloration time 1.6 s, bleaching time 1.2 s), and high coloration efficiency (60.4 cm2/C).
Furthermore, tungsten oxide nanowires were prepared on a tungsten film (W)/ITO-glass substrate at 500 oC for electrochromic devices using the heat-treatment technique. The electrical properties analysis confirmed that the highest electrical conductivity achieve the superior electrochromic performance with the maximum coloration efficiency value. The tungsten oxide nanowires shows excellent electrochromic properties such as a higher diffusion coefficient (2x10-9 cm2/s), faster electrochromic response time (coloration time 1.7 s, bleaching time 1.1 s), and higher coloration efficiency (67.41 cm2/C) than other tungsten oxide films without nanowires. Therefore, the tungsten oxides nanowire prepared by heat-treatment technique, corresponding to the maximum electrochromic performance, would be further adopted in the commercial application of smart windows.