**Adaptive Chromogenic Material for Smart Windows**

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The number of buildings featuring glass facades or large windows is steadily increasing, driven by rising living standards and evolving architectural trends. This shift highlights the growing need for energy-efficient building solutions. One promising approach involves the development of adaptive glass coatings with tailored optical properties to (1) reduce heat transfer through windows, and (2) block irritating visible (VIS) and ultraviolet (UV) light. Chromogenic thin films—such as electrochromic, thermochromic, and photochromic materials—are at the forefront of smart window technology.

Within the EU HORIZON project *Smart Windows for Zero Energy Buildings*, innovative single- and multi-layered transition metal oxide (TMO) thin films have been designed and fabricated. These include electrochromic (WO₃ and NiO) and photochromic rare-earth metal oxyhydrides (Y-O-H), utilizing advanced reactive magnetron sputtering and industrially scalable roll-to-roll (R2R) deposition techniques.

Building on pioneering work initiated in the 1980s [1], synchrotron radiation XAFS studies (accompanied by Raman, XRD, and electrochemistry) have been extensively applied to investigate electrochromic materials and devices developed at ISSP LU: cathodic electrochromic oxides such as WO₃, MoO₃, and NiO-WO₃, as well as anodic oxides including NiOx, IrOx, and NiO-IrOx [2,3].

The discovery in the 2010s of photochromic yttrium oxohydrates (YOH) [4] and the family of rare-earth oxohydrates (REOH) represent a groundbreaking class of inorganic mixed-anion compounds with exceptional photochromic properties. We have extended these investigations to multilayer photochromic Y-O-H and electrochromic MoO₃ systems [5], as well as antibacterial TCO coatings such as WO₃/Cu/WO₃ [6], highlighting their potential for multifunctional applications. Additionally, large-area roll-to-roll deposition of YHO and WO₃/Cu/WO₃ has been explored to enable scalable production for smart windows and other optoelectronic devices. This work underscores the potential of advanced chromogenic materials to transform energy-efficient building technologies, offering a significant contribution toward achieving zero-energy goals.

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