Unveiling the Potential of Transparent Conductive Materials by Atomic/Molecular Layer Deposition: From Process Synthesis to Functionalization

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From powering renewable energy systems to transforming lighting and data storage technologies, solar cells, electroluminescent displays (ELDs), organic light-emitting diodes (OLEDs), sensors, and printed electronics are driving the next wave of technological innovation. Transparent conductive materials (TCMs) play a key role in enabling and improving the performance of these devices by offering unique advantages for human–device interfaces and information processing. Today, transparent conducting indium tin oxide (ITO) remains the most widely used TCM, thanks to its excellent optical transparency (>90%) and low sheet resistance (<30 Ω/sq)[1,2]. It currently holds about 55% of the transparent conductive electrode (TCE) market in 2024[3]. However, ITO is brittle, which limits its use in flexible devices, and its dependence on indium, a critical and scarce resource, raises sustainability concerns. To address these limitations, several alternative TCMs are being actively explored, covering inorganic, metallic, and organic material families.

In this presentation, I will give an overview of our ongoing work on developing alternative TCMs using different vapor-phase deposition (VPD) methods. I will first focus on the growth of oxide films using atmospheric pressure spatial atomic layer deposition (AP-SALD), an innovative alternative to conventional ALD[4]. Unlike traditional ALD, AP-SALD relies on the spatial separation of precursors within a 3D manifold head rather than sequential gas injection. This approach enables faster deposition over large areas, making it well suited for scalable manufacturing. I will present some recent results on p-type oxides obtained by this method[5–7]. I will then show how oxide coatings can be used to improve the stability of transparent electrodes based on silver nanowire networks[8,9]. Finally, I will discuss the development of conjugated conductive polymers using oxidative VPD, with examples of their integration into real devices[10]. Overall, this work illustrates a comprehensive approach, from process synthesis to device functionalization, aimed at advancing the next generation of transparent conductive materials.

References

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