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Fundamental Issues with TCO on Plastic Substrates

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Tin doped indium oxide, ITO, is the most widely used of transparent conductive oxides (TCO). In most applications, e.g., displays, the ITO is deposited on a heated glass substrate, or it is post-deposition treated at high temperature (> 200 ºC). The electrical and optical properties of these ITO thin films have been extensively studied and reported ($\rho \sim 1 \times 10^{-4}$ Ω–cm, T ≥ 85%). However, there is considerable interest in flexible plastic displays and other applications involving temperature sensitive substrates. Comparatively little work has been reported on the properties of ITO thin films on plastic substrates even though roll-to-roll vacuum deposited ITO films are commercially available. Process temperatures with common plastic substrates are < 100 ºC, typically near room temperature (RT), which results in significantly degraded ITO properties. The electrical conductive characteristics are particularly affected compared with those obtained at high temperature. Typically, the volume resistivity, ρ, for ITO thin films made with a RT deposition processes is $\sim 6 \times 10^{-4}$ Ω–cm or higher. This high resistivity (low conductivity) is not suitable for many applications such as a transparent electrode for Organic Light Emitting Diode (OLED) displays deposited on flexible plastic film substrates. For several reasons, including performance, cost and availability, finding a TCO replacement for ITO is currently an area of very active research. However, replacement candidate TCO, e.g., AZO and GZO, exhibit similar degraded electrical performance when deposited near RT. This presentation focuses on the fundamental issues of achieving good electrical performance and corresponding high transparency, with ITO films deposited on temperature sensitive plastic substrates. However, many of these issues are also common to other TCO. Additionally, mechanical issues with TCO thin films on plastic substrates also are of key importance. For example, the critical strain for ITO is ~ 1.5%, which limits the useful film thickness and other processing and application parameters. Measured electrical and optical properties of ITO for high and low temperature depositions are compared, and the origins of these differences in properties are discussed. The effect of the deposition method selected, and the choice of process conditions, on the ITO resistivity is examined. The efficacy of various choices in improving the electrical performance of RT deposited ITO (TCO) is discussed.