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Impact of the Oxygen Content on the Optoelectronic Properties of the Indium-Tin-Oxide Based Transparent Electrodes for Silicon Heterojunction Solar Cells

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Abstract : Transparent conductive oxides (TCOs) used as front electrodes in solar cells must feature simultaneously high electrical conductivity, low contact resistance with the adjacent layers, and an appropriate refractive index for maximal light in-coupling into the device. However, these properties may conflict with each other, motivating thereby the search for TCOs with high performance. Additionally, due to the presence of temperature sensitive layers in many solar cell designs (for example, in thin-film silicon and silicon heterojunction (SHJ)), low-temperature deposition processes are more suitable. Several deposition techniques have been already explored to fabricate high-mobility TCOs at low temperatures, including sputter deposition, chemical vapor deposition, and atomic layer deposition. Among this variety of methods, to the best of our knowledge, magnetron sputtering deposition is the most established technique, despite the fact that it can lead to damage of underlying layers. The Sn doped In_2O_3 (ITO) is the most commonly used transparent electrode-contact in SHJ technology. In this work, we studied the properties of ITO thin films grown by RF sputtering. Using different oxygen fraction in the argon/oxygen plasma, we prepared ITO films deposited on glass substrates, on one hand, and on a-Si (p and n-types):H/intrinsic a-Si/glass substrates, on the other hand. Hall Effect measurements were systematically conducted together with total-transmittance (TT) and total-reflectance (TR) spectrometry. The electrical properties were drastically affected whereas the TT and TR were found to be slightly impacted by the oxygen variation. Furthermore, the time of flight-secondary ion mass spectrometry (TOF-SIMS) technique was used to determine the distribution of various species throughout the thickness of the ITO and at various interfaces. The depth profiling of indium, oxygen, tin, silicon, phosphorous, boron and hydrogen was investigated throughout the various thicknesses and interfaces, and obtained results are discussed accordingly. Finally, the extreme conditions were selected to fabricate rear emitter SHJ devices, and the photovoltaic performance was evaluated; the lower oxygen flow ratio was found to yield the best performance attributed to lower series resistance.

Keywords : solar cell, silicon heterojunction, oxygen content, optoelectronic properties
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