

Evaluation of transition metal oxides as carrier selective contacts for silicon heterojunction solar cells

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Reducing light absorption in the non-active solar cell layers, while enabling the extraction of the photogenerated minority carriers at quasi-Fermi levels are two key factors to improve current generation and voltage, and therefore efficiency of silicon heterojunction solar devices. To address these two critical aspects, transition metal oxide materials have been proposed as alternative to the n- and p-type amorphous silicon used as electron and hole selective contacts, respectively. Indeed, transition metal oxides such as molybdenum oxide, titanium oxide, nickel oxide or tungsten oxide combine a wide band gap typically over 3 eV with a band structure and theoretical band alignment with silicon that results in high transparency to the solar spectrum and in selectivity for the transport of only one carrier type.

Improving carrier extraction or injection using transition metal oxide has been a topic of investigation in the field of organic solar cells and organic LEDs; from these pioneering works a lot of knowledge has been gained on materials properties, ways to control these during synthesis and deposition, and their impact on device performance. Recently, the transfer of some of this knowledge to silicon solar cells and the successful application of some metal oxide to contact heterojunction devices have gained much attention.

In this contribution, we investigate the suitability of various transition metal oxide films (molybdenum oxide, titanium oxide, and tungsten oxide) deposited either by thermal evaporation or sputtering as transparent hole or electron selective transport layer for silicon solar cells. In addition to systematically characterize their optical and structural properties, we use photoemission spectroscopy to relate compound stoichiometry to band structure and characterize band alignment to silicon. The direct silicon/metal oxide interface is further analyzed by quasi-steady state photoconductance decay method to assess the quality of surface passivation. In complement, we construct full device structures incorporating in some cases surface passivation schemes, with measured initial conversion efficiency over 15% and evaluate the carrier transport properties using temperature-dependent current-voltage and capacitance-voltage measurements. With this detailed characterization study, we aim at providing the framework to assess the potential of a material as a carrier selective contact and the understanding of how each of the aforementioned parameters on the metal oxide films influence the full solar cell operating performances..