Development of a magnetron sputtering deposition process for In_2O_3:H transparent back contact for $Cu(In,Ga)Se_2$-based solar cells

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Abstract

Semi-transparent photovoltaic technologies combine the benefits of visible light transparency and light-to-electricity conversion [1], which can be integrated into windows to be used in buildings. Thin-film $Cu(In,Ga)Se_2$ (CIGS) solar cells have high conversion efficiency (23.35% ([2])), direct bandgap, high absorption coefficient, low temperature coefficient and less material waste [3], [4], becoming an interesting candidate for this type of application. CIGS solar cells commonly use Mo as back contact. Therefore, to use a transparent conductive oxide, such as In_2O_3:H (IOH), some requirements are needed, such as (1) create an ohmic contact to the absorber, (2) be highly transparent and, (3) exhibit a low sheet resistance [5]. In this work, a deposition process where oxygen was pulsed during the entire deposition process was investigated. To optimize the optoelectronic properties, the sputtering conditions were varied including RF power, O_2 pulse and flow, Ar/H_2 flow and duration. The pulse variation consisted in providing oxygen for one minute in intervals varying from 2, 3 to 4 minutes. After deposition, the films were post-annealed in vacuum at 200 °C for 1 hour. The IOH film electrical properties were characterized by 4-point probe, and the optical properties by transmittance measurements. The oxygen plays an important role in optoelectronic properties, where a high content of oxygen allows higher transparency but also increases the sheet resistance. The best balance between electrical and optical properties of IOH was obtained for a RF power of 30 W, total gas pressure of $6.4*10^{-3}$ mbar, duration of 180 minutes, with pulses of two minutes without oxygen and one minute with oxygen, resulting in an IOH film with a thickness of approximately 420 nm, average visible transparency over 80% and sheet resistance before and after annealing of 23 and 17 ohms/sq, respectively.

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FIGURES

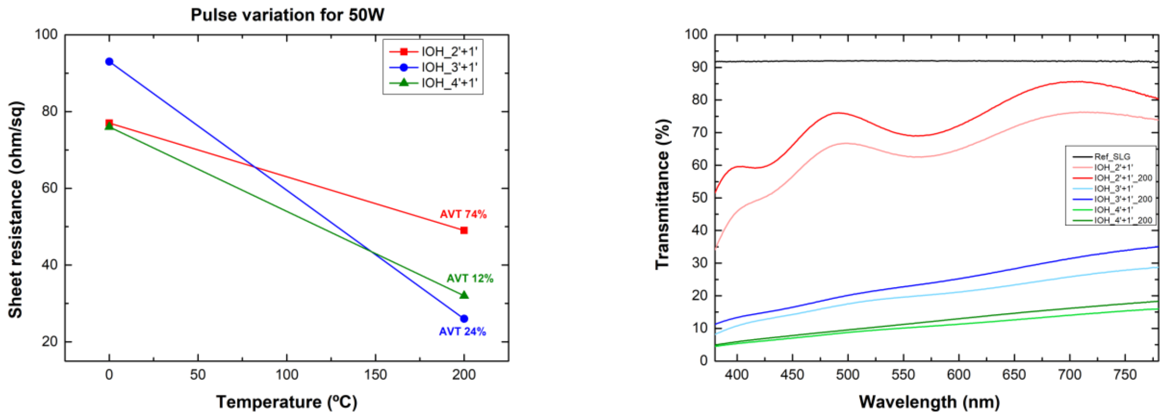

Figure 1: Sheet resistance and transmittance of samples deposited with different pulses at 50W, with an O_2 and Ar/H_2 flow of 1.5 sccm and 2 sccm, respectively. Thickness of the film ~345 nm.