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Benefits of High Power Impulse Magnetron Sputtering (HiPIMS) Method for Preparation of Transparent Indium Gallium Zinc Oxide (IGZO) Thin Films

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Abstract : Transparent semiconducting amorphous IGZO films have attracted great attention due to their excellent electrical properties and possible utilization in thin film transistors or in photovoltaic applications as they show 20-50 times higher mobility than that of amorphous silicon. It is also known that the properties of IGZO films are highly sensitive to process parameters, especially to oxygen partial pressure. In this study we have focused on the comparison of properties of transparent semiconducting amorphous indium gallium zinc oxide (IGZO) thin films prepared by conventional sputtering methods and those prepared by high power impulse magnetron sputtering (HiPIMS) method. Furthermore we tried to optimize electrical and optical properties of the IGZO thin films and to investigate possibility to apply these coatings on thermally sensitive flexible substrates. We employed dc, pulsed dc, mid frequency sine wave and HiPIMS power supplies for magnetron deposition. Magnetrons were equipped with sintered ceramic InGaZnO targets. As oxygen vacancies are considered to be the main source of the carriers in IGZO films, it is expected that with the increase of oxygen partial pressure number of oxygen vacancies decreases which results in the increase of film resistivity. Therefore in all experiments we focused on the effect of oxygen partial pressure, discharge power and pulsed power mode on the electrical, optical and mechanical properties of IGZO thin films and also on the thermal load deposited to the substrate. As expected, we have observed a very fast transition between low- and high-resistivity films depending on oxygen partial pressure when deposition using conventional sputtering methods/power supplies have been utilized. Therefore we established and utilized HiPIMS sputtering system for enlargement of operation window for better control of IGZO thin film properties. It is shown that with this system we are able to effectively eliminate steep transition between low and high resistivity films exhibited by DC mode of sputtering and the electrical resistivity can be effectively controlled in the wide resistivity range of 10^{-2} to 10^{5} Ω.cm. The highest mobility of charge carriers (up to 50 cm2/V.s) was obtained at very low oxygen partial pressures. Utilization of HiPIMS also led to significant decrease in thermal load deposited to the substrate which is beneficial for deposition on the thermally sensitive and flexible polymer substrates. Deposition rate as a function of discharge power and oxygen partial pressure was also systematically investigated and the results from optical, electrical and structure analysis will be discussed in detail. Most important result which we have obtained demonstrates almost linear control of IGZO thin films resistivity with increasing of oxygen partial pressure utilizing HiPIMS mode of sputtering and highly transparent films with low resistivity were prepared already at low pO2. It was also found that utilization of HiPIMS technique resulted in significant improvement of surface smoothness in reactive mode of sputtering (with increasing of oxygen partial pressure).

Keywords : charge carrier mobility, HiPIMS, IGZO, resistivity
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