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Effect of Al Concentration on Al-doped ZnO Thin Films deposited by Magnetron Co-Sputtering Technique

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Al-doped ZnO (AZO) thin films were deposited on glass and silicon substrates by magnetron co-sputtering of two targets, a ZnO ceramic target and an Al metallic target. During the samples fabrication, ZnO was prepared by RF magnetron sputtering while Al pulses were added by DC magnetron sputtering with various shutter opening conditions. During the ZnO sputtering, the Al shutter was opened periodically with a fix duration time of 3 seconds. The amount of Al in the thin film was modulated by varying the number of Al pulses. In order to achieve the same film thickness for all samples, the total deposition time was then fixed. The properties of the AZO thin films were characterized by several techniques. From UV-Vis spectroscopy, all samples show more than 85% transmission in the visible range but reveal absorptions in the ultraviolet region, corresponding to the energy gap of ZnO. The results suggest an increase in the energy gap with higher Al concentration in the ZnO films. In addition, electrical properties of thin films were characterized by the Hall measurement. The film resistivity changes with Al pulsing. With increasing number of Al pulses, the film resistivity reduces and reaches the minimum at 105 pulses before bouncing up. The Al atomic concentrations in the films were also investigated by Auger electron spectroscopy. It was found that the Al atomic concentration at the minimum resistivity corresponds to 5.6%. Corresponding to the XRD results, they express the highest peak intensity of the 002 plane at the same Al pulsing condition. Such agreement of both techniques suggests a relationship between the electrical resistivity and the film crystallinity and grain size. Furthermore, the results suggest that the Al doping and oxide formation might be occurred at every pulsing condition. At Al pulsing below 105 times, the Al doping is more effective, however for Al pulsing above 105 times, the amount of Al in this region could be over the solubility limit of Al in ZnO. The aluminum oxide cluster which is the electrical insulator might form and take the dominant role for blocking the charge transport in thin film. The formation of insulating cluster might be confirmed by the slightly shifting of signal peaks from the X-ray photoelectron spectroscopy technique. This study could lead to the growth mechanism realization of transparent conductive oxide thin film to obtain the desired properties for optoelectronic devices application.

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