

[T-19]

Flat-surface indium tin oxide (ITO) films prepared by ion beam sputtering

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Indium tin oxide (ITO) films with a smooth surface were made using a combination of deposition conditions in the ion beam sputtering method. R_{ms} roughness of the film was 0.40 nm and sheet resistance was 13.8 $\Omega/\text{sq.}$ for 150 nm thick film at the deposition temperature of 150°C. The film was grown in an oxygen environment up to 15 nm thickness and then the oxygen was off throughout the rest of the deposition. Typical single layer deposition was also used for comparing to the combination method. For ITO films grown at 150°C with no oxygen present, a rough surface (R_{ms} roughness = 2.06 nm) and a low sheet resistance of 14.4 $\Omega/\text{sq.}$ were observed. Whereas, a flat surface (R_{ms} roughness = 0.46 nm) with a high sheet resistance of 41 $\Omega/\text{sq.}$ were obtained in the films grown with ambient oxygen throughout the film growth. The addition of the ambient oxygen resulted in a flat surface but caused the electrical conductivity to decrease. The surface morphology and the microstructure of the films were determined by the deposition conditions at the beginning of the growth. The method of controlling the microstructure and surface morphology without sacrificing the electrical conductivity will be discussed.