Plasma-assisted reactive processes for low-temperature formation of functional materials

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Functional thin films including oxides and nitrides are expected as key materials for next-generation electronic devices. In particular, the application of functional thin films to flexible devices have attracted much attention for next-generation FPDs and flexible solar cells. For low-temperature formation of functional thin films, a plasma-assisted reactive processes using inductivity-coupled plasma (ICP) has been developed. In our previous study, a plasma-assisted reactive sputtering deposition system with low-inductance antenna (LIA) modules has been developed to enhance reactivity of sputtering deposition[1]. The plasmas sustained with LIA modules allow high-density plasma production with active control of power deposition profiles over large area and low sheath-edge potential[2]. The sputtering deposition system makes it possible to enhance the sputter discharge and control of the reactivity during film deposition by superimposing ICP on sputter discharge. The results of functional thin film deposition using the system revealed the possibility of controlling the film properties due to the independent flux control of sputtered atoms and reactive species [2-4]. In this presentation, low-temperature formation of functional thin films at using these advanced plasma-assisted reactive processes is reported.

The plasma properties of a plasma-enhanced reactive sputter deposition system indicated the feasibility for the independent control of the sputtering flux and reactivity via the control of target voltage and plasma density. The deposition of a-IGZO films with this system and the fabrication of IGZO TFTs using the a-IGZO films as channel layers have been demonstrated. The discharge characteristics with an a-IGZO target and the resulting electrical properties of an IGZO TFT with as-deposited a-IGZO films deposited using this system confirm the feasibility of IGZO TFT formation with mobility higher than 42 $cm^2 V^{-1} s^{-1}$ at temperatures lower than 150 °C. [5,6]

In the conventional fabrication of IGZO TFTs, post annealing processes at elevated temperature as high as 400 °C is required for the IGZO TFTs to work as transistor. As an alternative process to thermal annealing, low-temperature post processes with plasma irradiation have been developed for controlling precise oxidation of a-IGZO films because of the extreme sensitivity of their electrical characteristics of IGZO TFTs. The effects of plasma irradiation to preparation of a-IGZO films by plasma-assisted reactive sputtering and annealing temperature of the post-processing on the performance of IGZO TFTs using a-IGZO films was evaluated. The IGZO TFTs fabricated using thermally annealed a-IGZO films showed the TFT operation over annealing temperature over 300 °C, while the IGZO TFTs fabricated using plasma-treated a-IGZO films at process temperature of 200 °C have been operated. Moreover, a plasma-treated IGZO TFT processed at low-temperature exhibited transfer characteristics with a ultra-high field-effect mobility as high as 40 cm^2/Vs. [4-6]

For precise control of the plasma-assisted reactive sputtering process, the formation of functional thin films was demonstrated by plasma-assisted reactive pulsed-DC magnetron sputtering at low substrate temperature. The formation of c-axis-oriented aluminum nitride thin films was demonstrated by plasma-assisted reactive pulsed-DC magnetron sputtering at low substrate temperature. The effects of the duty cycle at the pulsed-DC voltage applied to the Al target on the properties of AlN films formed via inductively coupled plasma (ICP)-enhanced pulsed-DC magnetron sputtering deposition were investigated. With decreasing duty cycle of target voltage, deposition rate decreased linearly because of the decrease in sputtering time. In contrast, the peak intensity of XRD AlN(0002) increased linearly. The improvement of crystallinity of AlN films is caused by the difference between the relative fluxes of ions and sputtered atoms. [3]

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