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Deposition of Oxide Semiconductor Films via ICP-Enhanced Reactive Sputtering for Development of Advanced Flexible Devices

次世代フレキシブルデバイス創成に向けた誘導結合プラズマ支援反応性スパッタリングによる酸化物半導体薄膜堆積

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ICP-enhanced reactive sputter deposition system has been developed for low-temperature formation of oxide semiconductor films. This advantage of fine control of reactivity during the deposition process is of great significance for film deposition of the transparent amorphous oxide semiconductor, amorphous indium gallium zinc oxide (a-IGZO), whose electrical properties are significantly sensitive to the reactivity during the film deposition. The electrical properties of IGZO thin film transistors (TFT) shows feasibility of low-temperature formation of IGZO TFTs with mobility as high as 18.5 $cm^2(Vs)^{-1}$ at substrate temperature as low as or less than 150 °C. Optical transmittance of the a-IGZO film for visible region was about 85%.

1. Introduction

Recently, oxide semiconductors have attracted much attention as a channel material for transparent thin-film transistors (TFTs), due to their superior electrical properties that include wide band gap, high field effect mobility, and high uniformity over large areas compared with that of conventional Si TFTs [1,2].

In particular, amorphous indium gallium zinc oxide (a-IGZO) has been recognized as an ideal TFT channel material for the devices requiring high mobility, high on/off ratio, and process availability at room temperature. The a-IGZO TFTs can gain a high field effect mobility of 10 $cm^2/(V \cdot s)$, even in the amorphous phase[2].

In the conventional fabrication of the IGZO TFTs, post annealing processes at elevated temperature as high as 400 °C is required for the IGZO TFTs to work as transistor. However, in application of the flexible electronics including IGZO-TFT fabrication on polymer substrates, development of a-IGZO film low-temperature deposition is desired.

For low-temperature formation of the IGZO TFTs, novel plasma-enhanced reactive sputter-deposition process has been developed by installation with an inner type of low-inductance antenna (LIA) which allow high-density plasma production with active control of power deposition profiles over large area and low sheath-edge potential [3-6].

In this presentation, electrical properties of IGZO thin film transistors (TFT) are reported to show feasibility of low-temperature formation of IGZO.

2. Experimental

Schematic illustration of plasma-enhanced magnetron sputter deposition system with inner-type LIA is shown in Fig. 1. Four inner-type LIA units were mounted around a magnetron target

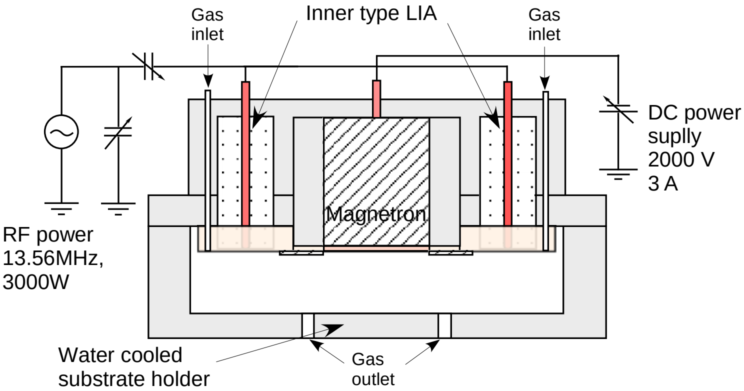

Fig. 1. ICP-enhanced reactive sputter deposition system with inner-type LIAs.

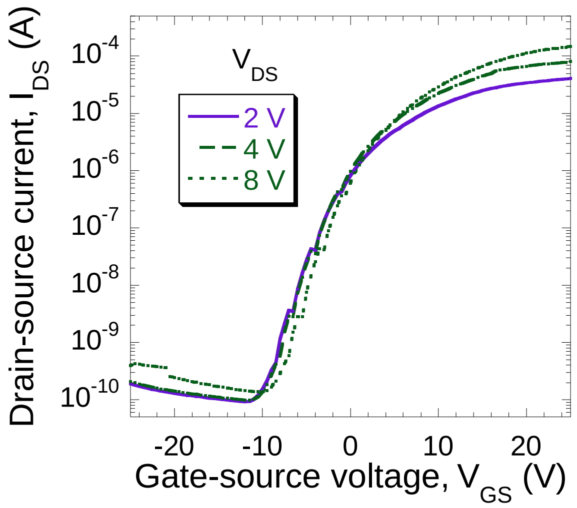

Fig. 2. I_{DS}-V_{GS} characteristics of TFT fabricated using a-IGZO films with plasma-enhanced magnetron sputter deposition system.

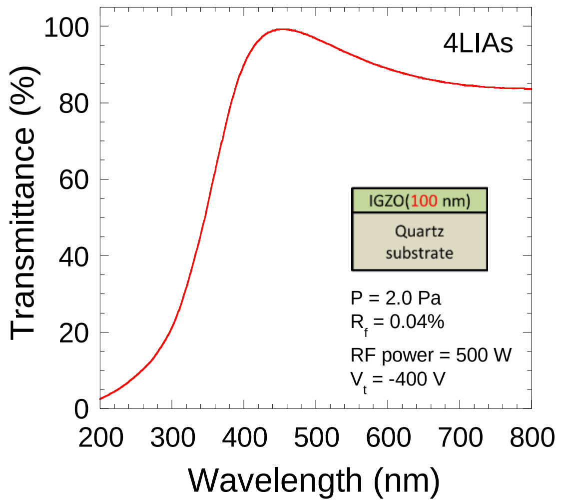

Fig. 3. Optical transmittance of a-IGZO film deposited by ICP-enhanced reactive sputter deposition system.

and coupled to an RF power generator at 13.56 MHz via a matching network. Indium-gallium-zinc-oxide target was used for amorphous oxide semiconductor film deposition. The magnetron sputter target was biased with DC high-voltage source for sputter discharge of the target. In this investigation, a-IGZO films were deposited on glass and Si substrate mounted on a water-cooled substrate holder. The I_{DS}-V_{GS} characteristics of TFT fabricated with IGZO film was measured with a Keithley 4200-SCS semiconductor characterization system. The optical transmittance of zinc oxide films was measured by ultraviolet-visible spectrophotometer.

3. Results

Figure 2 shows I_{DS}-V_{GS} characteristics of TFT fabricated using a-IGZO films with plasma-enhanced magnetron sputter deposition system. Field effect mobility evaluated from the I_{DS}-V_{GS} characteristics is as high as μ_{FE} = 18.5 cm^2(Vs)$^{-1}$. The measured substrate temperature during deposition is overestimated in this regard, however, the substrate temperature during deposition time (2 min) was evidently less than 150 °C. The results exhibit the IGZO TFT with mobility as high as or higher than 15 cm^2(Vs)$^{-1}$ have been successfully formed at the substrate temperature as low as or less than 150 °C.

The optical transparency of the a-IGZO film deposited with plasma-enhanced magnetron sputter deposition system has been investigated via UV-Vis spectroscopy. Figure 3 shows optical-transmission characteristics of the a-IGZO film. Optical transmittance of the a-IGZO film for visible region was about 85%.

4. Summary

Plasma-enhanced sputter deposition system has been developed via enhancement of target sputter discharge with ICP driven by multiple inner-type LIAs. The low-temperature formation of IGZO films using ICP-enhanced reactive sputter deposition was performed. The electrical properties of IGZO thin film transistors (TFT) shows feasibility of low-temperature formation of IGZO TFTs with mobility as high as 18.5 cm^2(Vs)$^{-1}$ at substrate temperature as low as or less than 150 °C. Optical transmittance of the a-IGZO film for visible region was about 85%.

Acknowledgements

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