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Development of Low-Damage Reactive Sputter Deposition Processes with Inner-Type Low Inductance Antenna
埋込型低インダクタンスアンテナによる低ダメージ反応性スパッタ製膜プロセスの開発

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Discharge properties have been investigated for inductively coupled RF plasmas (ICP) sustained with inner-type low-inductance antennas (LIAs). The inner-type LIA has been developed as a new-type of LIA, in which an RF antenna conductor with a length much shorter than the RF wavelength is embedded in a hall region dug in the chamber wall and the dielectric window plate is installed at the same height of the chamber-wall inner surface as an insulator for shielding the antenna conductor from the plasma. The discharge technology with the inner-type LIA has been applied to ICP-assisted magnetron sputtering with an attempt to attain low-damage reactive sputtering process for advanced deposition of functional films to develop flexible electronics.

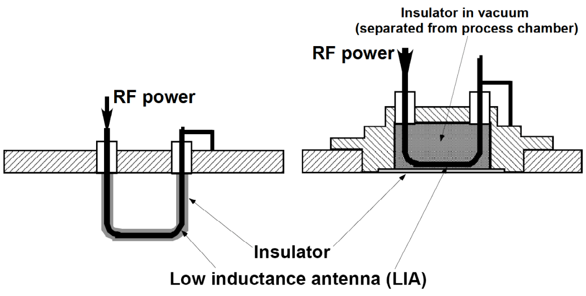
1. Introduction

High-quality device fabrications with inorganic/organic hybrid structures are desired for advanced applications including flexible electronics. For successful development of these processes in large-area processes, it is of key importance to employ plasma production and control technologies with capabilities of low-damage process and excellent uniformity over large area. In our previous investigations for large-area plasma processes, inductivity-coupled plasma (ICP) sources have been developed with multiple low-inductance antenna (LIA) modules [1-3]. The LIA module consisted of an internal RF antenna with dielectric isolation, which allowed low-voltage and high-density plasma production.

For application to ICP-assisted magnetron sputtering process [4,5], an inner-type LIA [6] has been developed as a new-type of LIA, in which an RF antenna conductor with a length much shorter than the RF wavelength is embedded in a hall region dug in the chamber wall and the dielectric window plate is installed at the same height of the chamber-wall inner surface as an insulator for shielding the antenna conductor from the plasma, as shown in Fig. 1 with conventional LIA for comparison.

Since the conventional LIA has the shape that is salient toward the plasma region from the chamber-wall inner surface, this new type of the LIA shown in Fig. 1 is called as "inner-type LIA". Special feature of the ICP-assisted magnetron with the inner-type LIA is that the ICP antenna is located at the same height or beneath the target surface of the magnetron.

In the conventional designs of the plasma-assisted magnetrons [7], additional plasma sources are located in the region between the target and the substrate, thus the target-substrate distance is elongated due to the installation of the additional



(a) conventional LIA　　(b) Inner-type LIA

Fig.1 Schematic illustrations of (a) conventional and (b) inner-type LIA.

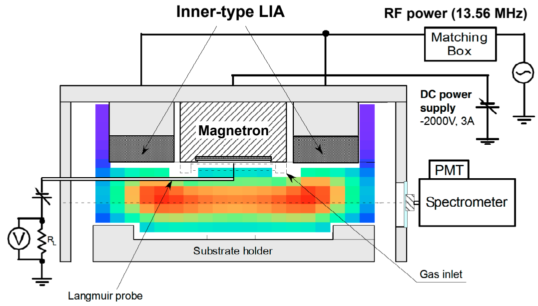


Fig.2 Schematic illustrations of ICP-assisted magnetron sputtering deposition system with inner-type LIA.

plasma source. As a result, the conventional configuration of the plasma-assisted magnetron suffers loss of deposition rate

In this presentation, basic performance of the plasmas sustained with LIAs will be reported together with applications to plasma-enhanced sputter deposition for formation of microcrystalline silicon films and oxide semiconductor films.

2. Experiment

Discharge properties of ICPs sustained with the inner-type LIA were examined by installing one set of the inner-type LIA with an RF conductor length of 100 mm in a vacuum chamber with a diameter of 500 mm. Ion saturation current and floating potential were measured in an Ar plasma sustained at pressures of 1.3-6.5 Pa. For ICP-assisted magnetron sputtering, two sets of the inner-type LIA with an RF conductor length of 150 mm were installed beside a magnetron sputtering source, as schematically shown in Fig. 2. In the ICP-assisted magnetron sputtering, an un-doped Si target with a high electrical resistivity was employed as the sputtering target for deposition of intrinsic silicon layer.

3. Results and discussion

Fig. 3 shows the ion saturation current and the floating potential (DC and oscillation components) for argon plasmas sustained with the inner-type LIA. The ion saturation current increased almost linearly with increasing RF, and the achieved plasma density is as high as on the order of 10^{11} cm^{-3}. Furthermore, the floating potential measurements show that the plasma generation with significantly suppressed potential fluctuation has been attained, as in the conventional LIAs [1-3].

In the ICP-assisted magnetron sputtering experiments, it has been shown that the flux of the deposited atoms can be controlled independently via target voltage, while the flux of the reactive species (in this case oxygen radicals and ions) can be kept almost constant in the ICP sustained with the constant RF power. Especially, this feature of the independent and fine control capability of the flux ratio is very much significant for high-quality film deposition to control flux ratio of the excited species (radicals and ions) to the deposited atoms

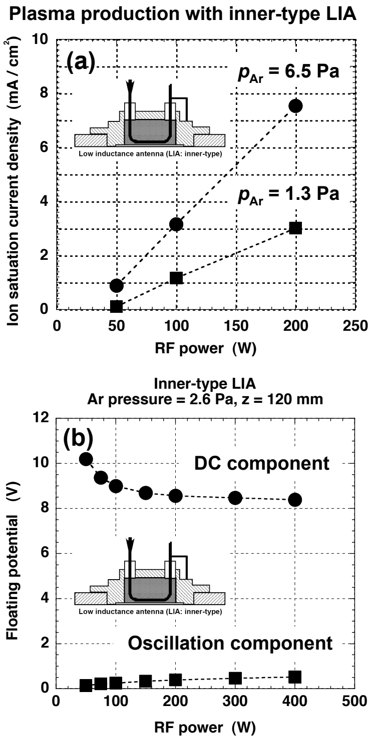


Fig.3 Ion saturation current and floating potential measured for Ar plasmas sustained with inner-type LIA.

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