Title	Development of a Meters-Scale Large Area Plasma Reactor Using Multiple Low-Inductance Antenna Modules for Giant Electronics Processing
Author(s)	Setsuhara, Yuichi; Ono, Kouichi; Ebe, Akinori
Citation	Transactions of JWRI. 2007, 36(2), p. 95-97
Version Type	VoR
URL	https://doi.org/10.18910/4138
rights	
Note	

Development of a Meters-Scale Large Area Plasma Reactor Using Multiple Low-Inductance Antenna Modules for Giant Electronics Processing †

SETSUHARA Yuichi*, ONO Kouichi** and EBE Akinori***

KEY WORDS: (Large-Area Plasma) (High-Density Plasma) (Plasma-Fluid Simulation)

1. Introduction

Fabrication of giant electronics devices, especially flat panel displays (FPDs) and thin-film solar-cell batteries, is tending toward enlargement of substrate size to greater than a meter and high throughput, primarily due to enhancement of production efficiency and/or cost reduction. These trends urgently require development of meters-scale/ultra-large-area uniform plasma reactors. Major specifications required for the plasma sources in such processing include a) controllability of plasma profile to ensure uniformity over large-areas, b) high-density plasma production for high throughput and production-efficiency enhancement, c) low plasma potential for high quality processing with suppressed plasma damage. Among these, the specifications b) and c) are mainly dependent on the scheme of discharge (method of power coupling for plasma production) and/or the plasma excitation frequency, which are to be selected according to the processing requirements. Therefore many efforts have been focused on the issues to scale up the conventional sources, which are well developed in silicon device technology, toward meters size via enlargement of power coupling elements (inductive antennas, capacitive electrodes, microwave transmission line for surface wave excitation and so on).

The plasma sources developed so far for production of large-area plasmas include capacitively-coupled plasmas (CCP), inductively-coupled RF plasmas (ICP) and surface wave plasmas (SWP). However, considering design issues to satisfy the requirements for enlargement of source size exceeding a meter, power deposition profiles and hence the plasma distributions become inherently non-uniform especially due to standing wave effects, which can not be avoided with increasing source size when the source employs power coupling elements with a scale length equivalent to or as long as the 1/4 wavelength of the high-frequency power transmission [1].

This work is aimed at developing meters-scale ultra-large-area RF plasma reactors by inductive coupling with multiple low-inductance antenna (LIA) modules [2], which can essentially solve the problems associated with the standing wave effects by employing an antenna size substantially shorter than the wavelength of the high-frequency power. Our proposal of the unique source configuration is based on the principle of multiple operation and integrated control of LIA modules, which allow low-voltage high-density plasma production with active control of power deposition profiles. In this article

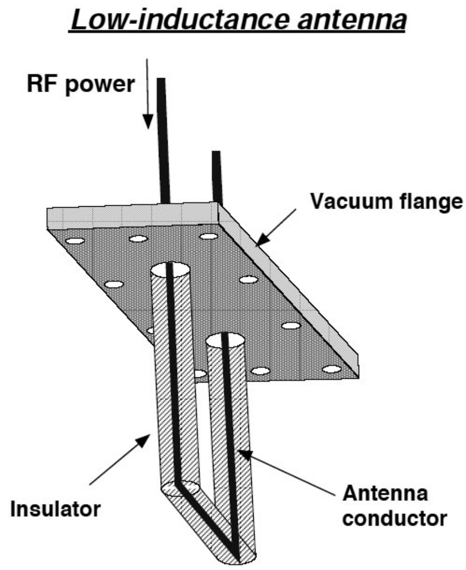

Fig. 1 Schematic illustration of low-inductance antenna (LIA) module.

† Received on December 14, 2007
* Professor
** Professor, Kyoto University
*** President, EMD Corporation

Transactions of JWRI is published by Joining and Welding Research Institute of Osaka University, Ibaraki, Osaka 567-0047, Japan.

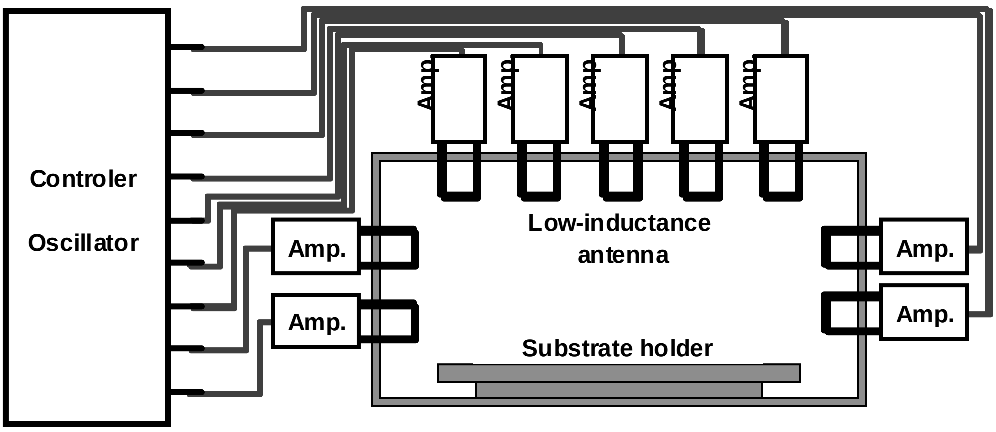

Fig. 2 Plasma profile control with multiple LIA modules which are independently and actively controlled by integrated module.

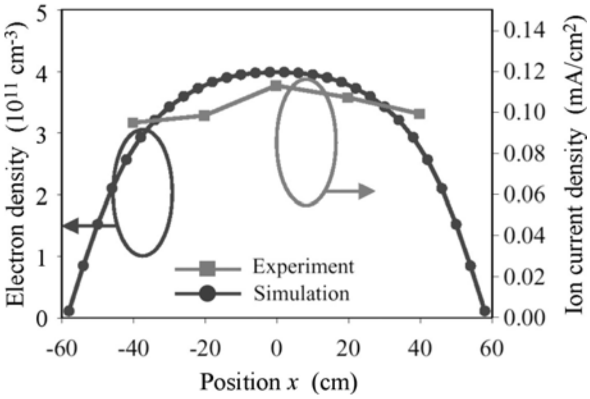

Fig. 3 Comparison of plasma profiles: fluid code (circles) and experiment (squares).

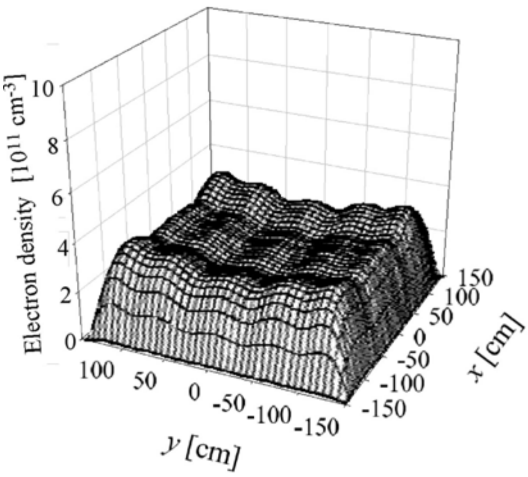

Fig. 4 Plasma density distribution numerically simulated for 3 m x 3 m plasma source.

we report the feasibility of uniform meter-scale high-density plasma productions based on three-dimensional plasma simulation. Furthermore, plasma control methods are described for understanding and designing the meters-size/ultra-large-area and high-density RF plasma sources driven by inductive coupling with LIA modules.

2. Production and Control of Large-Area Plasmas with LIA Modules

The ICP sources used in the present study employed the low-inductance antenna (LIA) module, schematically illustrated in **Fig. 1** [2)]. The LIA module consisted of a U-shaped antenna conductor, which was separately mounted on a vacuum flange. The antenna conductor was made of copper, which was fully covered with ceramics material for complete dielectric isolation from the plasma.

For active control of power deposition profiles and hence the plasma uniformity, we have developed plasma control technology as schematically shown in **Fig. 2**. With this configuration and integrated control of each module, the RF power supplied to each of the LIA modules can be controlled actively. Our proposal of the unique source configuration and profile control method is a straightforward solution and can provide breakthroughs to solve the problems associated with the standing-wave effects.

3. Simulation aided Reactor Designing

For designing meters-scale plasma reactors, we have developed a plasma-fluid simulation code, in which argon plasmas sustained with 13.56 MHz RF power are simulated. Electron density, effective electron temperature and neutral density are simulated with the fluid code, which solves the continuity equation and the electron energy conservation equation under the drift-diffusion approximation.

Justification of the simulation results was confirmed by comparing the results with experimental measurements using a Langmuir probe. One example shown in **Fig. 3** demonstrates consistency of the prediction of our simulation code with the experimental observation in a large-scale chamber (rectangular, 1230 x 1030 x 430 mm). These results show that uniform large-scale plasma can be designed in a further large-scale chamber by optimization of antenna configuration and power deposition profile. One example of designing ultra-large-area source with 3000 x 3000 mm area is shown in **Fig. 4**. In this example, uniform plasma profile with 2560 x 2600 mm was obtained with a non-uniformity of 10 %.

4. Summary

Feasibility of uniform meters-scale high-density plasma production using LIA modules has been demonstrated on the basis of three-dimensional plasma simulation. Furthermore, plasma control methods are described for understanding and designing the meters-size/ultra-large-area and high-density RF plasma sources driven by inductive coupling with LIA modules. The results show that these type of ICP driven by the internal LIA unit are quite attractive as plasma sources for a variety of giant electronics processing.

References

1) J. Perrin, J. Schmitt, C. Hollenstein, A. Howling and L. Sansonnens, Plasma Phys. Control. Fusion Vol. 42 (2000), p. B353
2) Y. Setsuhara, T. Shoji, A. Ebe, S. Baba, N. Yamamoto, K. Takahashi, K. Ono and S. Miyake, Surf. Coatings. Tehcnol.Vol. 174-175 (2003), p. 33