Plasma Science
Room: C-105 - Session PS2-MoA

Plasma Processing for Large Area Substrates
Moderator: D. Leonhardt, US Naval Research Laboratory

2:00pm **PS2-MoA1 Ion Flux Uniformity in Large Area High Frequency Capacitive Discharges**, ***A. Perret****, *P. Chabert, J. Jolly, J.P. Booth, J. Guillon*, Ecole Polytechnique, France

Etching and thin film deposition using capacitive RF discharges at 13.56 MHz are routinely used for Flat Panel Display fabrication. The current trend in FPD technology is to increase the substrate size (> 1m2) while keeping high throughput (> 50 glass/hour). Very High Frequency (VHF) plasma excitation promises to provide faster processes whilst avoiding damage due to high energy ion bombardment. However, the reactor size may no longer be negligible with respect to the wavelength of the RF electromagnetic wave, causing non-uniformity in the plasma density across the reactor. The physical origin of this phenomenon is the beginning of a spatial standing wave within the reactor. The standing wave effect will become more important as the frequency is increased. Other phenomena causing non-uniformity will appear if the skin depth become small compared to the reactor size. We will present an experimental study of the ion flux uniformity of a plasma created in a large area capacitive discharge driven at frequencies of 13.56 to 60 MHz. The discharge was produced between two square plates (40cm x 40cm) separated by a distance of 8 cm. The ion flux variation across the reactor is measured by a system composed of 64 electrostatic probes inserted in the grounded upper electrode and biased negatively. The probes are regularly spaced and the time to read all probes is less than 2 seconds. The experimental results will be compared with a recently proposed model (Lieberman et al. Plasma Sources Science and Technology, accepted 2002).

2:20pm **PS2-MoA2 Electrical Characterization of Linearly Extended Inductively Coupled Plasma Sources for Large Area Processing**, ***Y.J. Lee***, *K.N. Kim*, Sunkyunkwan University, South Korea, *S.E. Park, J.K. Lee*, Pohang University of Sci. and Tech., South Korea, *G.Y. Yeom*, Sunkyunkwan University, South Korea

In order to achieve the performance required for high resolution flat panel display (FPD) devices, especially for TFT-LCD of next generation, improved dry etch processes currently indispensable technology for semiconductor industry are required for volume manufacturing and superior critical dimension control. The plasma sources developed to date for the production of high-density and large-area plasmas mainly focused on the spiral-type planar external ICP sources. However, due to its large inductance with the scale-up to larger areas and the cost and the thickness of its dielectric material, the conventional ICP source using an external spiral antenna may have reached its limit in extending the process area. Therefore, in this study, a plasma source utilizing inductive coupling of linear extended internal antennas has been used as a candidate for the efficient large area high-density plasma source. To minimize the inherent electrostatic coupling effect in the internal inductive linear antenna configurations, various internal-type linear antenna designs have been used in a square shaped (830mm*1,020mm) plasma chamber. Characterization of the system impedance for the various internal-type antenna schemes were achieved by measuring the current, the voltage, and the phase angle difference at 13.56MHz using a V/I probe (ENI). It was found that there was a significant change in inductance depending on the type of linear antenna designs. A simple modeling and simulation with a 2-D fluid code were also used to analyze the optimum arrangement and the distance of the each line source. In this presentation, the effects of various arrangements of the linear antennas and process conditions on the plasma characteristics were investigated using a quadrupole masss spectrometer (QMS: Hidern Analytical Inc., PSM 500) and a Langmuir probe (Hiden Analytical Inc., ESP) located on the sidewall of the chamber and the results were compared with the simulation data.

2:40pm **PS2-MoA3 Optimization of Source Modules in ICP-Helicon Multi-Element Arrays for Large Area Plasma Processing**, ***J.D. Evans***, *F.F. Chen*, University of California, Los Angeles

Optimization studies of compact inductive rf-source modules for use as individual elements of a multi-element ICP-helicon source array, with sufficient density N and spatial N(R) profile uniformity for plasma processing of arbitrarily large substrates, is described. Attention is restricted to a low-magnetic-field (low-B) regime (B < 250G), within which a local maximum (low-B peak) in N vs B is routinely observed and exploited for optimum plasma production efficiency. Proof of principle experiments that exploit this low-B peak have been successfully performed [PSST 10, 236 (2001)] in Ar and Cl. Arrays consisted of 7 cylindrical Pyrex tubes (o.d. = 5cm) plus antennas, with center-to-center spacing = 2d, mounted in a honeycomb pattern on top of a magnetic bucket. Optimization of individual modules of various aspect ratios and sizes are the focus of the present work. Static Bo is provided by a combination of coils and ring-shaped permanent magnets in close proximity to each module, designed such that they can fit in a usable multi-element source of arbitrarily large area. Measurements of N(R) vs B, at RF powers Prf < 1.6kW and neutral pressures Po = 1-25 mTorr, as well as radial N(R) profiles obtained from Langmuir probes vs axial distance are obtained. Anomalous enhancement of N(R) uniformity is observed when the low-field peak condition is met, with "flat" density profiles extending 5 tube radii, at axial distances < 2 tube diameters below the mouth. The implications for large area plasma processing applications are discussed.

3:00pm **PS2-MoA4 Scaling up of a Magnetic Pole Enhanced Inductively Coupled Plasma Source (MAPE-ICP)**, *P. Colpo*, ***T. Meziani***, *F. Rossi*, European Commission, Joint Research Centre, Italy

The principles of a Magnetic Pole Enhanced Inductively Coupled Plasma are presented. Plasma characterisation made on a 200mm source show that the electrical coupling efficiency is increased by a factor 4 as compared to a conventional flat coil configuration. Scaling up of the reactor to the dimension of 800x800mm poses several technological problems that have been solved and are presented. Characterisation of the large scale source show that a plasma density of 2 to 4 E11cm-3 with an Ar plasma at 2MHz is obtained and an homogeneity of the ion current density better than 20% over 800mm. Application of the source to the etching of SiO2 layers is presented. Etching rates of the order of 100nm/mn are obtained over the whole area. Results of plasma characterisation and chemistry are presented.

3:20pm **PS2-MoA5 Plasma Processing for Large Area Substrates**, ***V. Cassagne***, *M. Elyaakoubi*, UNAXIS France **INVITED**

In the liquid crystal flat panel display industry, the large area has another meaning than in semiconductor business. First, in size , the starting generation in the early 90's was in the range of 300x400mm glass substrate, now (5^{th} generation) the average size is 1100x1250 mm (higher productivity, higher flexibility). Second is the generation cycles : in 12 years, the market generated 6 size generations without real sizes standards. Now with more than 1.4m^2 substrates, in parallel of economic and production pressure, we have to face Physics challenges in addition to standard engineering issues. Both for PECVD, PVD and dry etching processes, we have to deal with new phenomenon linked to the dimensions. There are first mechanical (loading 0.5mm thick substrate, thermal expansion, atmospheric pressure stress), then thermal (temperature process uniformity, heating/cooling power and time), gas flow (as diffusion length is smaller than reactor size local defaults are exhibited), RF electric field uniformity (now electrode dimensions start to be not negligible compare to RF wavelength, local field disturbances affect the process uniformity due to diffusion limitation). In addition, production trends require higher throughput (higher deposition rate, faster plasma cleaning), higher yield (low particles, lower defaults), higher up-time (higher reliability, easier maintenance), smaller footprint (compact solution, parallelism). It leads to R&D programs like plasma uniformity (gas flow, RF field, plasma chemistry), arcing-free plasma, up-scalable concepts and target utilization optimization for PVD and PECVD and high density source for Dry Etching. All these topics are evaluated by numerical modeling and experimental set-up. Advanced materials, laboratory tests and prototyping are used in order to prepare new plasma system generations.

4:00pm **PS2-MoA7 High-rate Large-area Plasma Deposition using Multiple Expanding Thermal Plasmas**, ***M. Schaepkens***, *C.D. Iacovangelo*, General Electric Global Research Center

A unique, high rate, large area plasma deposition process has been developed to generate various functional coatings on polymeric substrates. The process relies on the integration of a plurality of individual expanding thermal plasma sources into a multi-source setup. In this work we will discuss the effects of various hardware (e.g. reagent injection configuration) and process (e.g. pressure, reagent flow, preheat) parameters on the performance of a dual-source system that has been used to apply abrasion resistant coatings to polycarbonate substrates. It will be shown that a properly engineered dual-source system can generate transparent,

* PSTD Coburn-Winters Student Award Finalist

organosilicon-based coatings that provide uniform, glass-like abrasion resistance across substrates up to 30 cm x 30 cm. Multi-source systems comprising more than two plasma sources hold promise for generating even larger area uniform coatings.

4:20pm **PS2-MoA8 Reflective Enhancement of Distributed Helicon Sources**, ***F.F. Chen***, University of California, Los Angeles

In Ref. 1 it was shown that large-area substrates can be covered uniformly with dense plasma by using a plurality of short helicon sources.[1] In this source use was made of the "low-field peak" (LFP), a density peak occurring near B = 50G which had been observed in several helicon devices.[2] A very quiet, stable discharge could be obtained in the neighborhood of this peak.[3] This feature was not predicted by standard helicon theory and was unexplained. In the latest version of the code HELIC developed by Arnush,[4] it is possible to model a short helicon source bounded at one end. The LFP is produced by constructive interference by the reflected wave from an end plate near the antenna and not, for instance, by a resonance of the Trivelpiece-Gould mode. This mechanism can also explain previous observations[5] of density enhancement by flaring magnetic fields or inserted blocks. This knowledge permits design of more compact helicon reactors.

[1] F.F. Chen, J.D. Evans, and G.R. Tynan, Plasma Sources Sci. Technol. 10, 236 (2001).
[2] F.F. Chen, X. Jiang, J.D. Evans, G. Tynan, and D. Arnush, Plasma Phys. Control. Fusion 39, A411 (1997).
[3] F.F. Chen, J. Vac. Sci. Technol. A 10, 1389 (1992).
[4] D. Arnush, Phys. Plasmas 7, 3042 (2000).
[5] G. Chevalier and F.F. Chen, J. Vac. Sci. Technol. A 11, 1165 (1993).

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