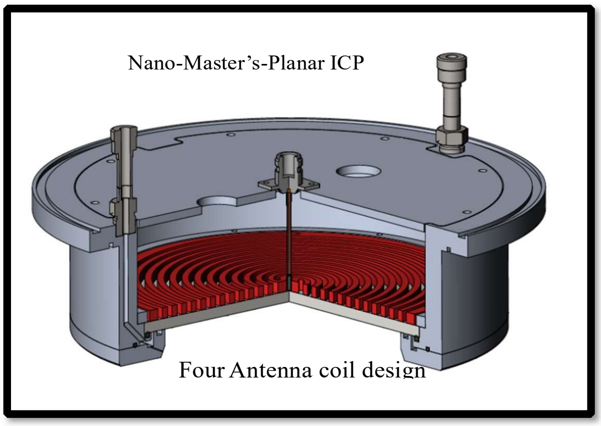
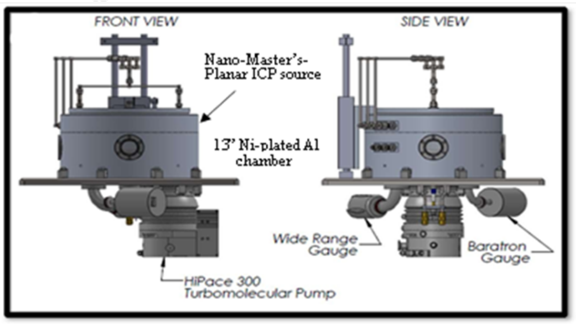
NANO-MASTER, Inc

Nano-Master's Inductively Coupled Planar Plasma Source for PECVD, ICP-RIE, PE-ALD Applications



Upscaling of the cylindrical plasma source using one multi-turn spiral coil has limitations due to the increase in the inductance with antenna diameter. The large inductance causes a large voltage drop between the end of the antenna and unstable impedance matching.

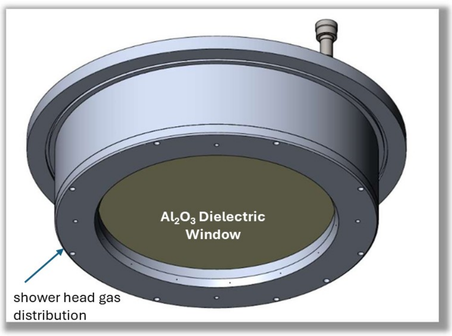
Additionally, the large voltage increases the capacitive coupling of the antenna to the plasma causing a low-efficiency non-uniform plasma production. Also, the cylindrical plasma source occupies a larger volume in the system, more power volume, and needs a higher power to operate, competitors use a 3kW RF power supply to produce the same ion density say 10^{11} ions/cm^3 as 1KW applied in the Planar ICP source. For more information, please see the supplement material at the bottom of the page about the ion density curve obtained at different powers. The Nano-Master's planar ICP source volume is 10x smaller than the cylindrical ICP source volume which is 1.6 liters only and occupies the small chamber volume, requires only a 260l/sec corrosive turbo molecular pump to pump down the chamber and reaches a base pressure of $5x10^{-7}$ torr in a clean system in 13" Al chamber.



Nano-Master's proprietary four-antenna coil design is designed to overcome the large inductance problem. First, a novel four antenna, low inductance (0.22μH) spiral coil is used that allows operation at lower rf voltage, since the coils are electrically parallel to each other. Secondly, the antenna housing consists of an

Aluminum cylinder which acts as an eddy current shielding and an Alumina (Al_2O_3) dielectric window, resistant to fluorine and chlorine chemistry thus reducing the resistive losses of the system. A uniform plasma at high density is produced without relying upon external magnetic coils.

Solving the ion bombardment problem on the dielectric window: Because of the low antenna impedance, the capacitive coupling between the dim capacitive discharge mode (so-called E mode) and the bright inductive mode (so-called H mode) occurs already at very low coil input powers even without the faraday shield (Ref 2). The cylindrical or other planar ICP sources in the market - do not have the means of avoiding the ion bombardment on the dielectric window. For example, the ions generated close to the proximity of the plasma source will bombard the dielectric window (say quartz or Al_2O_3) and etch the material leading to cross-contamination and oxygen contamination will deposit on the pattern wafer leads to an isotropic profile on the samples.



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Cylindrical antenna configurations have a discontinuity at the point where RF power is fed to the ICP coil antenna. The RF electric field in this area resembles the field of a dipole occupying the gap between the two antenna terminals. Such a field protrudes via the dielectric window into the plasma below it and produces an RF component perpendicular to the dielectric wall and sustains a high self-bias voltage. However, the high self-bias voltage of this sheath is very much unwanted, and it is uncontrollable in the cylindrical or other planar plasma sources: it gets higher with higher antenna currents and limits the plasma density that can be sustained. (Ref 2)

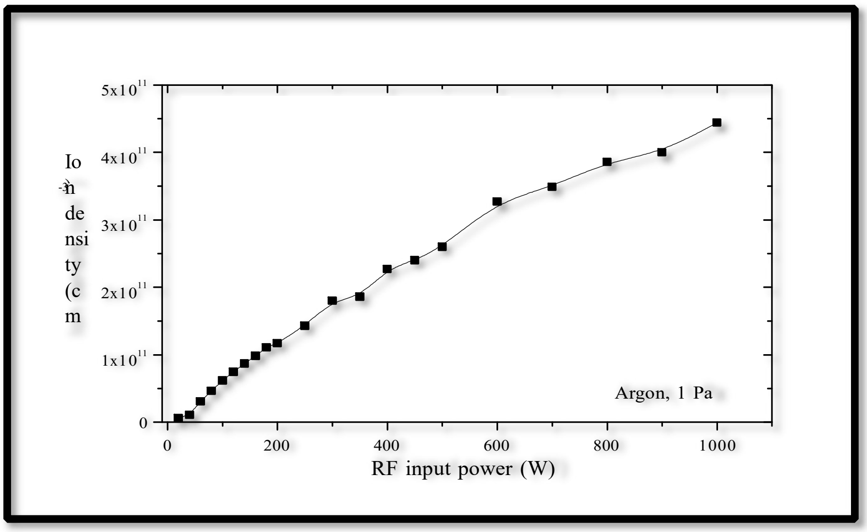
Dielectric window sputtering causes contamination and shortens the dielectric window's lifetime. The RF power is wasted to undesired ion acceleration, so that less power is left for the plasma chemistry. As a result there are fewer active species (ions, radicals and excited atoms/molecules) and the process rates are slower.

To mitigate the problems competitors, use Faraday Shield in their plasma source which leads to contamination and maintenance issues every six months to change faraday shield liners and we avoided this issue by having a low inductance design.

References :

1) "Inductively Coupled Plasma Sources and Applications" – Tomohiro Okumura, Panasonic, Japan.
2) "Faraday Shielding of One-turn Planar ICP Antennas" – P. Ganachev, MN. Moriyama, D. Ogawa and K. Nakamura, Shibaura Mechatronics, Japan and Chubu University, Japan.

Supplement Material ion density curve for Argon



Source: Plasma Consult, Germany