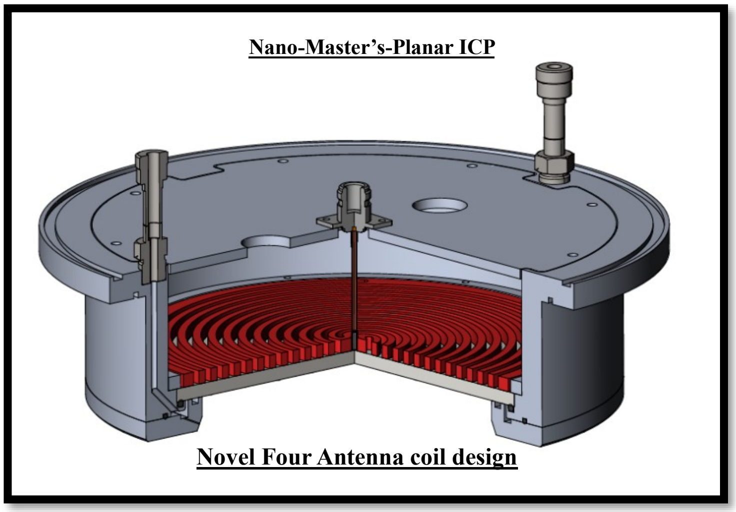
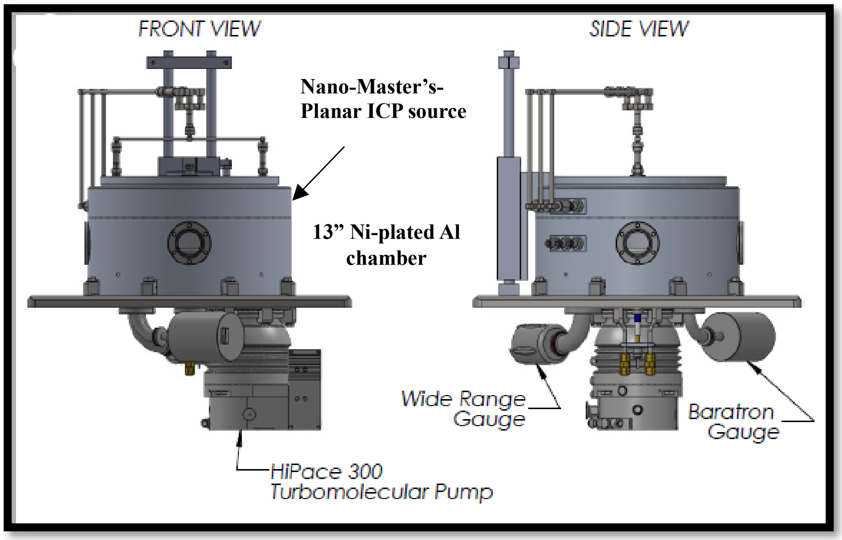
NANO-MASTER, Inc.

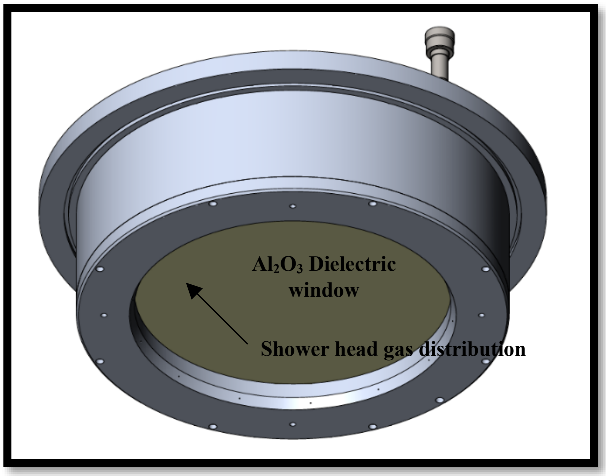
Novel Four Antenna Coil Design for Planar Inductively Coupled Plasma Source for DRIE, ICP-RIE Applications



The upscaling of a single multi-turn spiral coil cylindrical plasma source is limited as inductance increases with antenna diameter. An increased inductance results in a voltage drop between the antenna end and unstable impedance matching. In addition, a large voltage increases the capacitive coupling of the antenna to the plasma, which leads to a low-efficiency, non-uniform plasma. Also, a cylindrical plasma source occupies a larger volume within a system and requires more power to operate. A 3kW RF supply in a cylindrical power supply produces the same ion density (~10^{11} ions/cm^3) as a 1kW RF supply in Nano-Master's planar ICP source. For more information, please refer to the ion density curve figure shown below. Nano-Master's planar ICP source volume is 1.6L, which is 10x smaller than a cylindrical ICP source. In addition, in a clean system, the planar ICP source only requires a 260l/sec corrosive turbo molecular pump to reach a base pressure of 5x10^{-7} torr in a 13" Al chamber.



<u>Nano-Master's proprietary four-antenna coil design</u> is designed to mitigate issues caused by large inductance. The four-antenna coil design possesses a low inductance (0.22µH). The electrically parallel coils, coupled with the low inductance, allow for plasma generation at lower RF voltages. In addition, the antenna housing is composed of an aluminum cylinder, which shields eddy currents, and an alumina (Al_2O_3) dielectric window. The alumina is resistant to fluorine and chlorine chemistry, which reduces the resistive losses of the system. The coil



design, coupled with the coil housing, results in the production of uniform, high-density plasma without requiring external magnetic coils.

Solving the ion bombardment problem on the dielectric window: Due to the low antenna impedance, the capacitive coupling between the dim capacitive discharge mode (so-called E mode) and bright inductive mode (so-called H mode) occurs at very low coil input powers even without the faraday shield (Ref 2).

The cylindrical or other planar ICP sources on the market do not have the means of avoiding the ion bombardment on the dielectric window. For example, ions generated in close proximity to the plasma source will bombard the dielectric window (quartz or Al_2O_3) and etch the material. This leads to cross-contamination and oxygen contamination, which will deposit on the pattern wafer leads and result in an isotropic profile.

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)

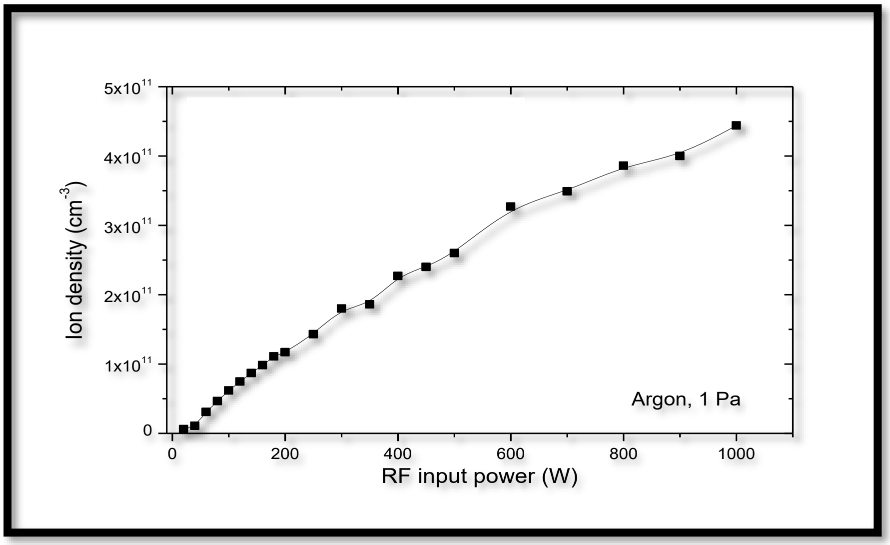
Dielectric window sputtering causes contamination and shortens the dielectric window's lifetime. The RF power is wasted to undesired ion acceleration, so that less power is left for the plasma chemistry. As a result there are fewer active species (ions, radicals and excited atoms/molecules) and the process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

To mitigate these problems, competitors use a faraday shield in their plasma source, which leads to contamination and maintenance issues every six months to replace faraday shield liners. Due to the low-inductance novel antenna design, the associated issues with a faraday shield are avoided.

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