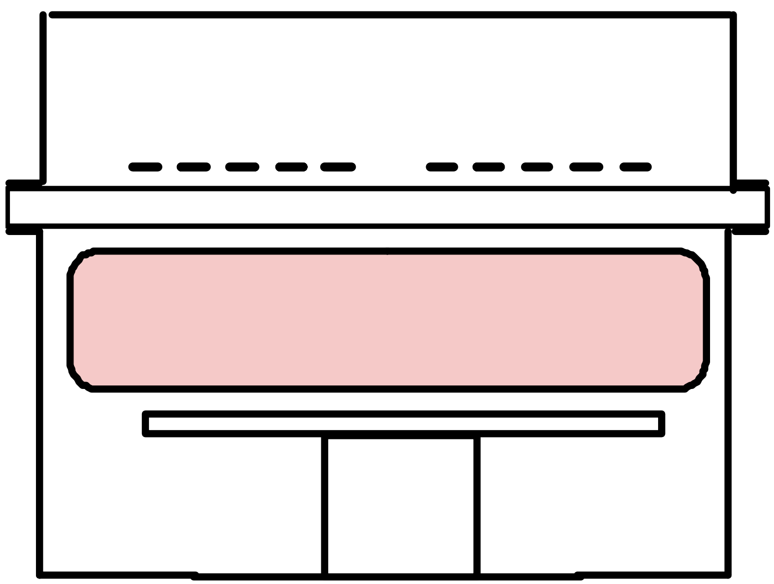
New ICP Technology for Semiconductor Material Processing

V. A. Godyak

RF Plasma Consulting
egodyak@comcast.net

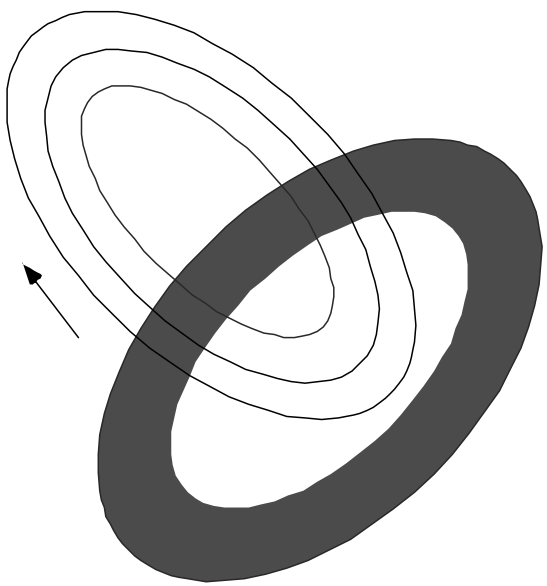
A new class of rf plasma sources has been developed that utilize an inductive coupling enhanced with ferromagnetic cores. This approach allows for effective control of the rf power space distribution and for a great improvement in the power transfer efficiency to the plasma. Novel inductive plasma sources are suitable for volume and surface plasma processing and free of many problems inherent to existing ICPs, such as transmission line effect and capacitive coupling. They have no need in expensive matching devices and are able to operate at considerably low rf frequency than existing ICPs. The unique feature of these plasma sources is their ability to automatically self-control of the plasma uniformity over a large processing area, thus offering an alternative way for processing large wafers and flat panel displays. Simple and compact design of these plasma sources significantly reduces the system cost and facilitate its maintenance.

Conventional ICP for Plasma Processing



Few kV and tens Amperes on inductors,
Cos φ << 1, requires matcher
Large power loss and low power transfer
Efficiency
Capacitive coupling (window erosion and
Plasma contamination, high rf plasma
potential affect minimal ion energy)
Transmission line effect (azimuthal
nonuniformity)
Plasma-dielectric contact (problems with
Conductive material deposition)
High cost of rf power sources and matching
devices

ICP with Ferromagnetic Inductor



Strong coupling

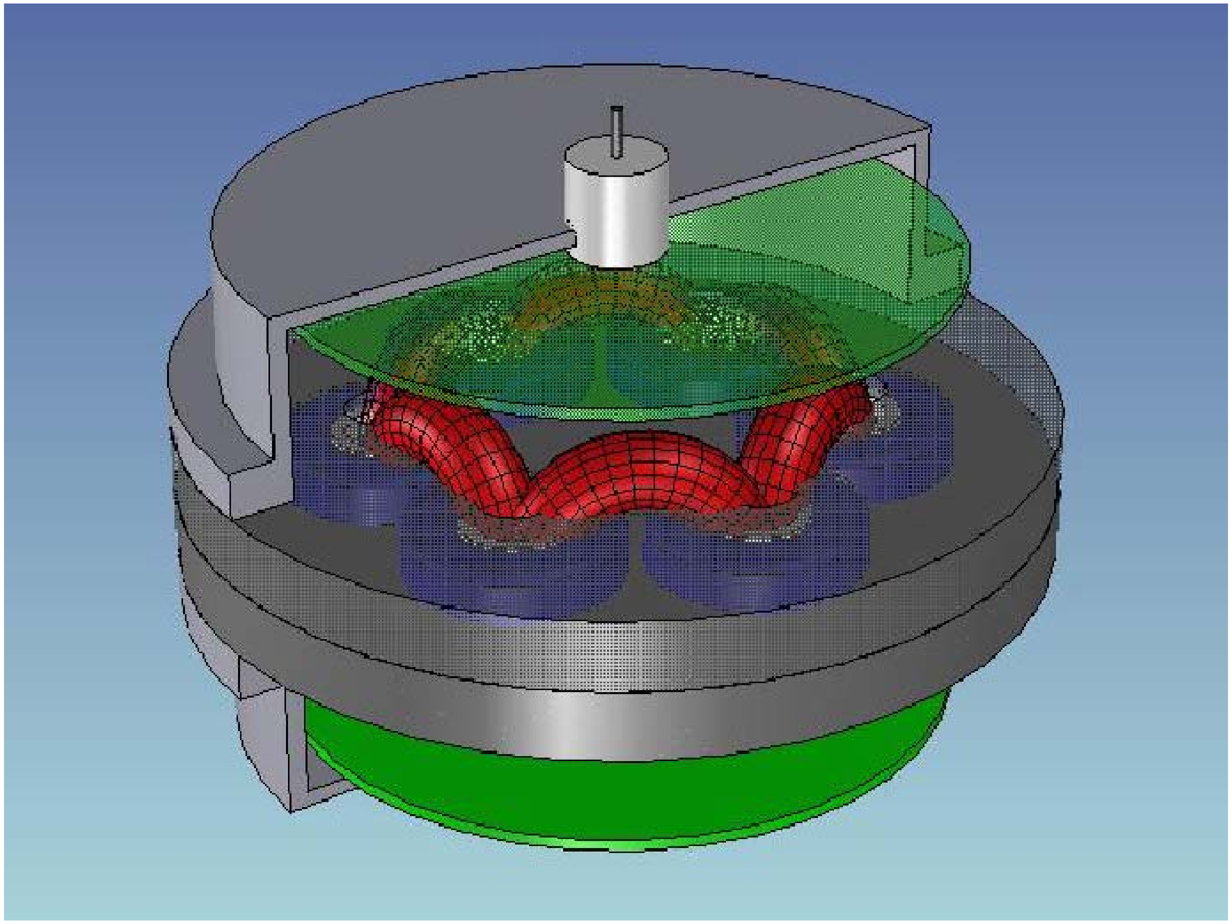
Large Cos   1

High power transfer efficiency

Low operation frequency

Tokomaks, Stelarators, RF lamps, Remote plasma sources for chamber cleaning.

ICP Reactor with Distributed Ferrite Core Inductors



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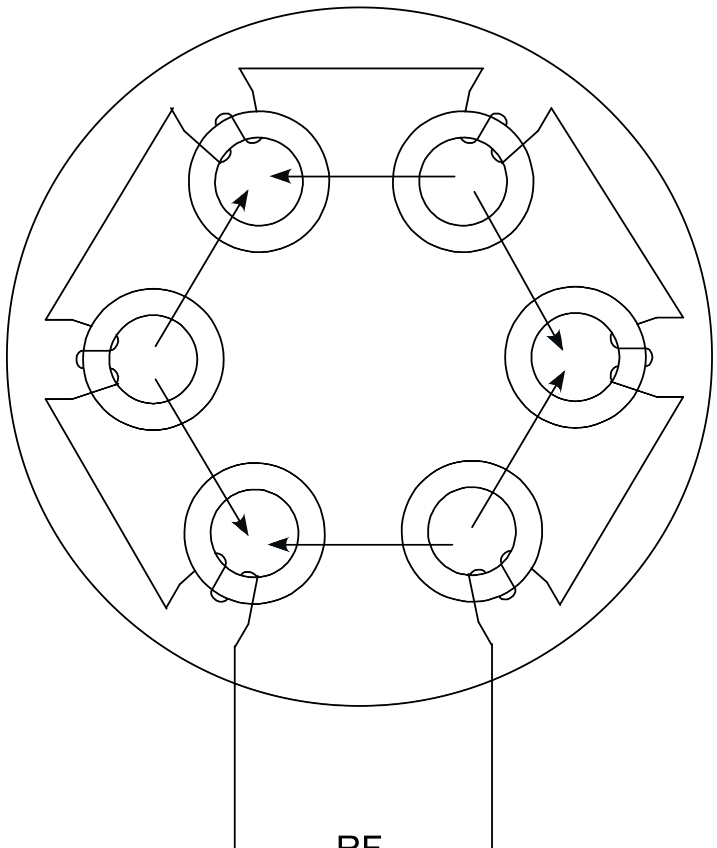


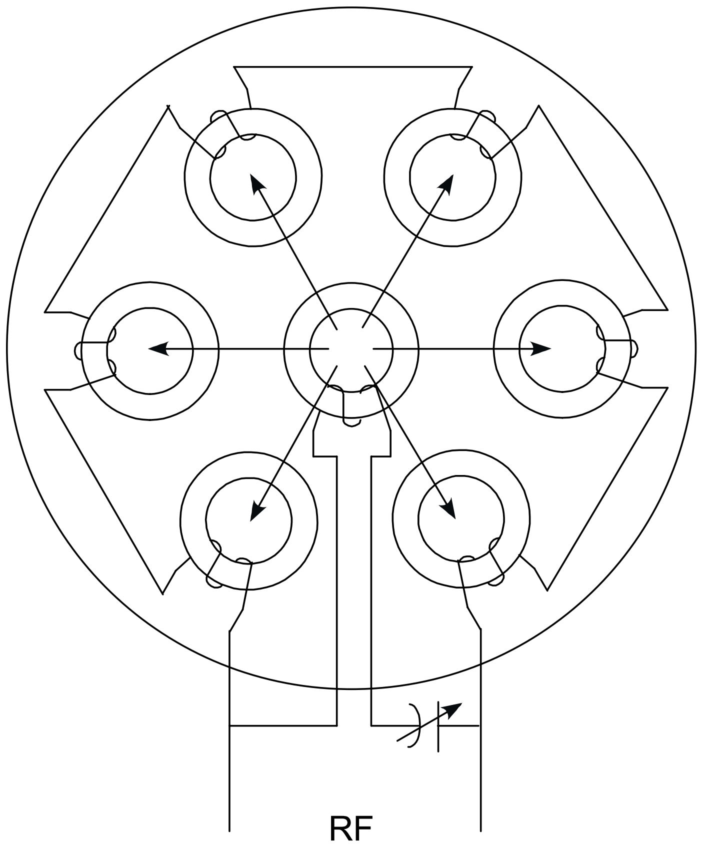
Ridged construction & cooling

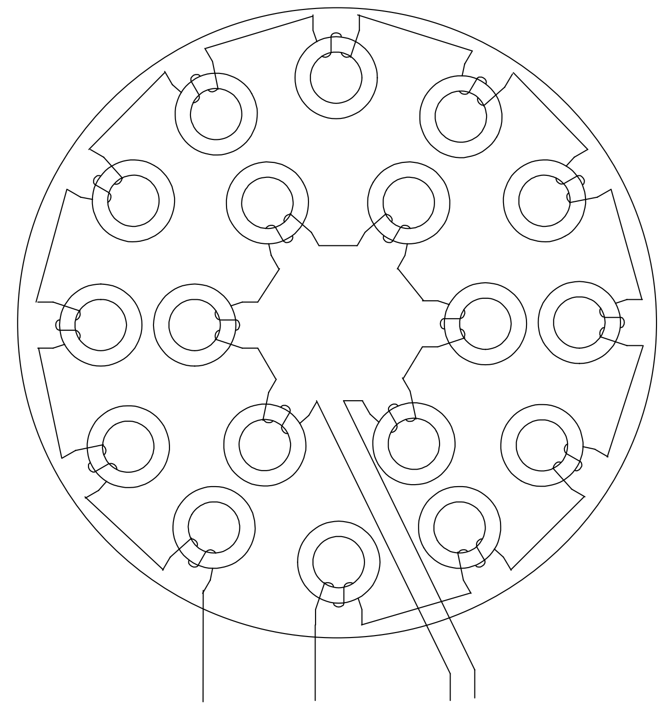
Ridged construction & cooling

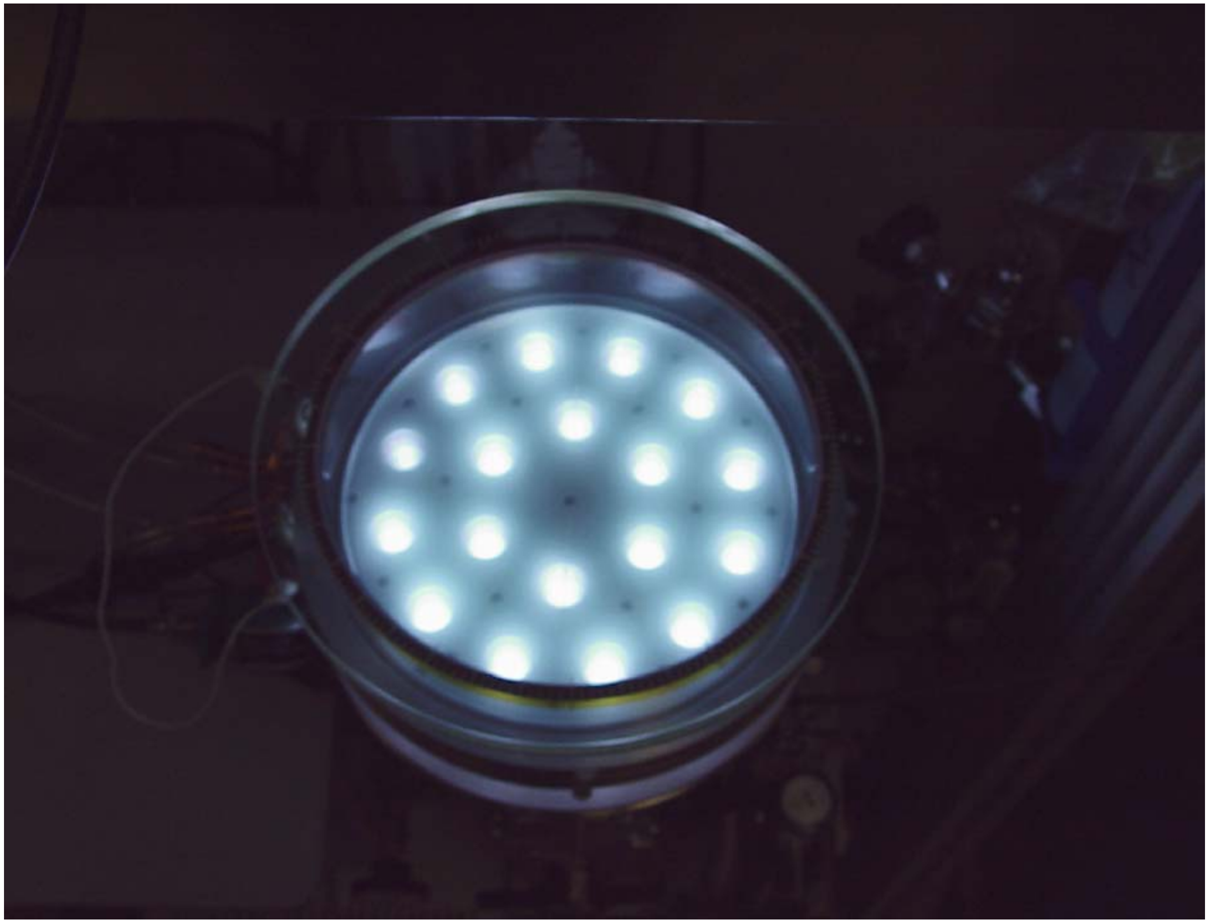
Negative feedback equalizes plasma density azimuthal uniformity and suppress temporal instability (feed-back plasma stabilization)

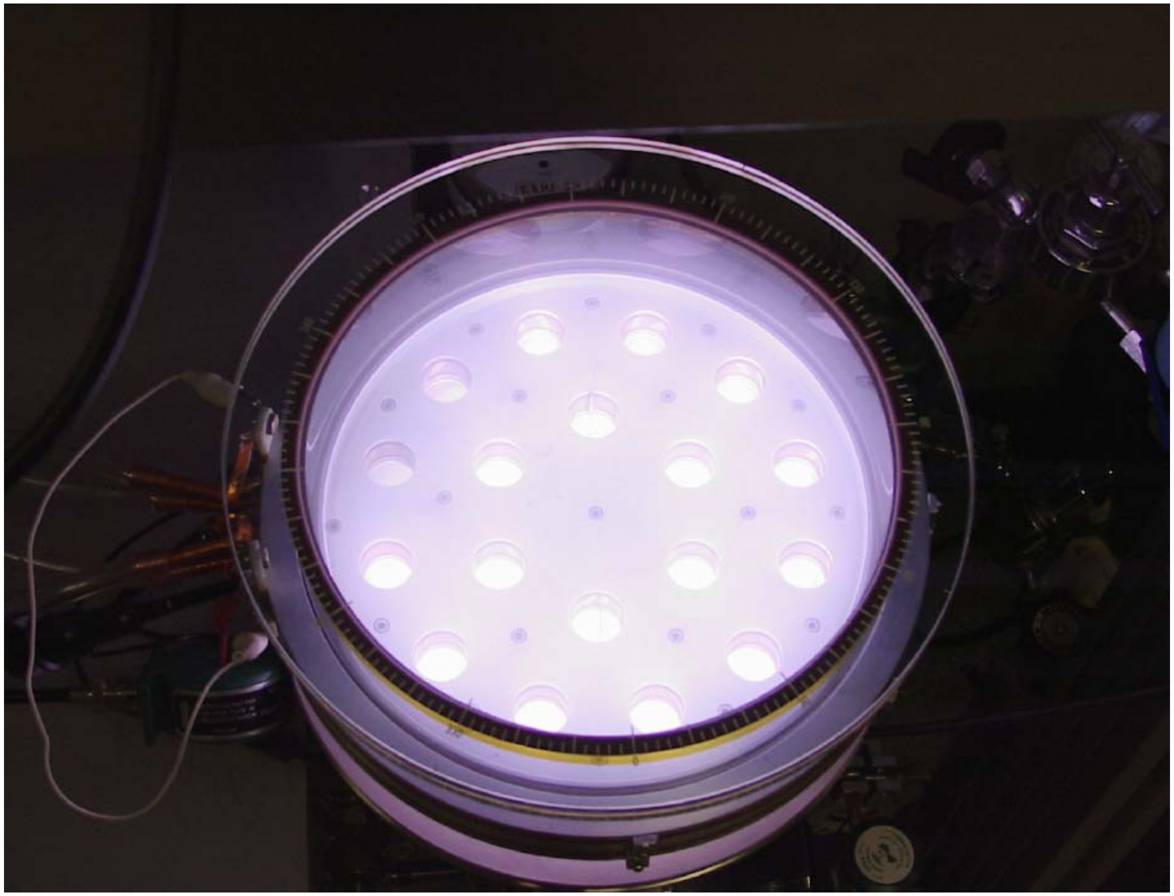
The same mechanism equalizes plasma density along the dc positive column

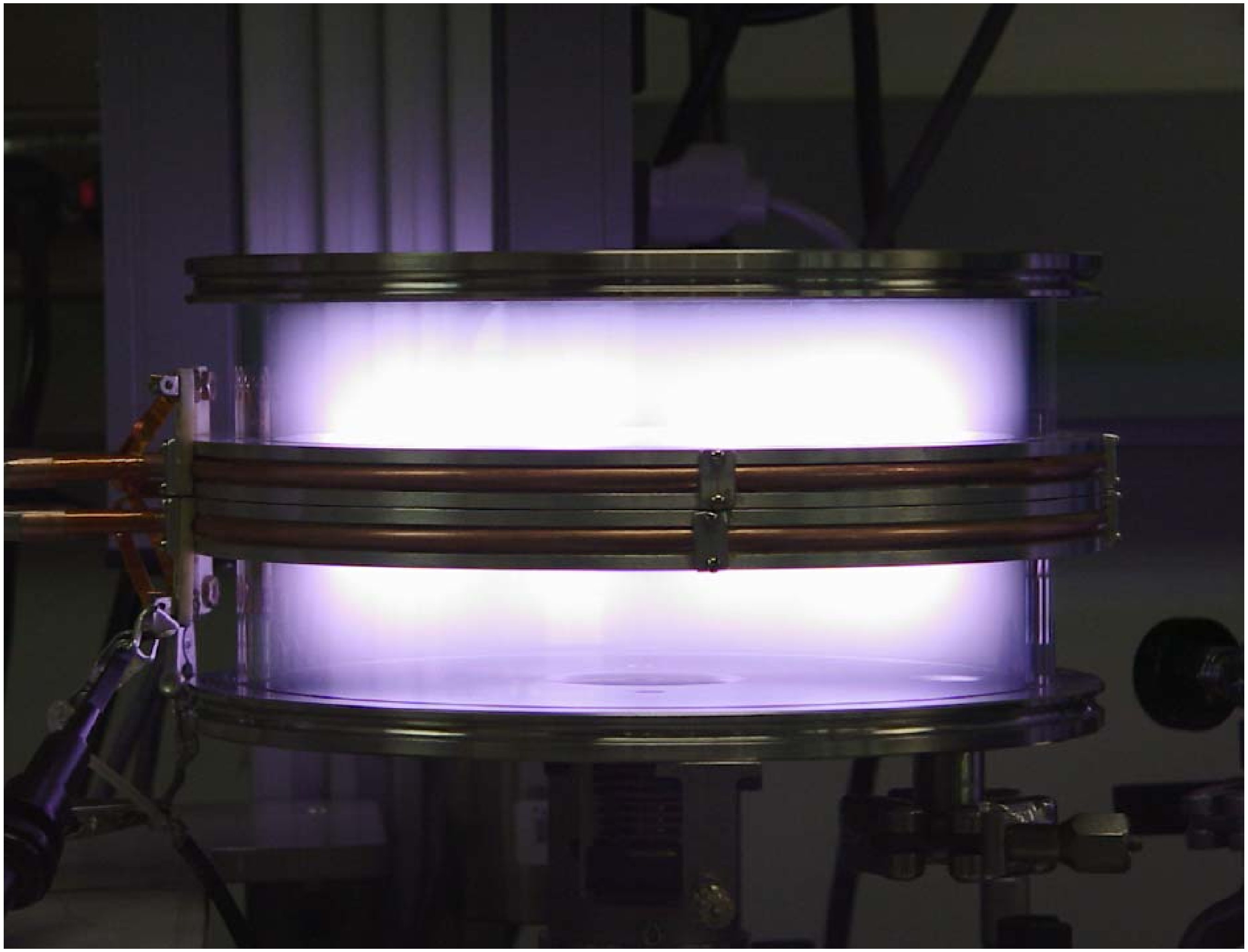
$$P = I^2R, \quad R \sim n^{-1}, \quad P \sim n^{-1}$$


RF

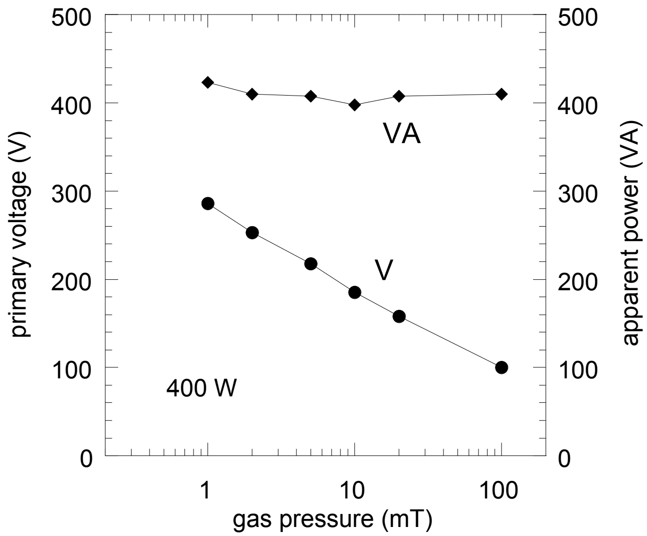




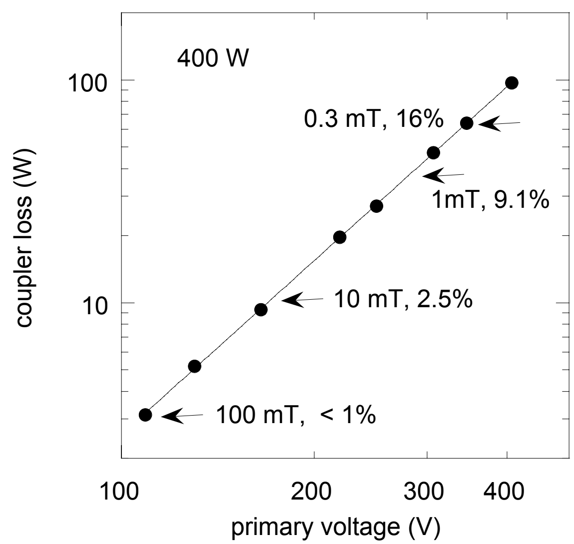




Electrical Characteristics

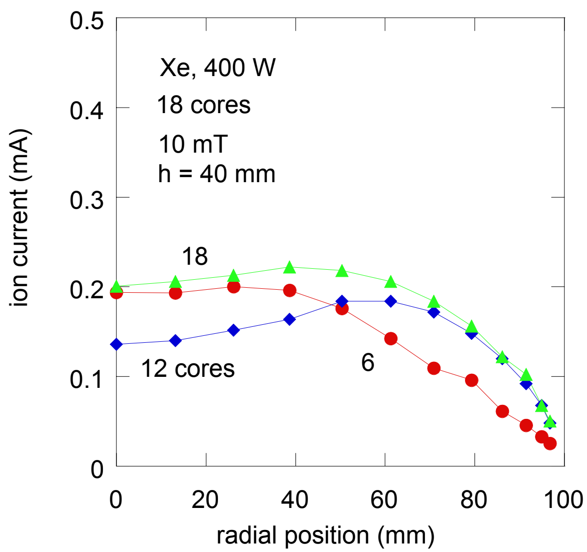


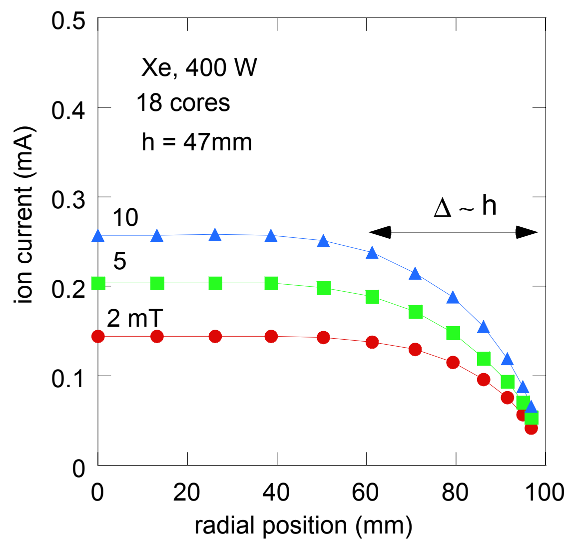
Cosφ = 0.95-0.97



Order of magnitude lower
than in conventional ICP

Plasma Uniformity





@10 mT, $n_0 = 4.7 \cdot 10^{11}$, $n_w = 2.7 \cdot 10^{11} cm^{-3}$

Summary

Significant reduction in RF frequency (up to hundreds of kHz).
Increased power transfer efficiency from rf power source to plasma (up to 99%).
Large plasma density dynamic range (continuous, up to 2 orders of magnitude).
No need in expensive resonant-matching device.
Low power factor dramatically reduces rf voltage and current applied to inductor.
Utilizing of low cost and efficient (90-95%) rf power supplies.
Eliminated capacitive coupling and transmission line effects.
Self-controlled space uniformity and dynamic stabilization features.
Considerable increase in uniform processing area of wafers and display panels.
Higher overall system efficiency (from power line to the plasma) than that in the plasma processing reactors (80-90% versus existing10-30%).
No external EM-fields (EMI).
Allows for elimination plasma contact to dielectric.
Simple, compact and rigged design.
Overall system cost is much less than conventional ICP system.