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ibss Comparison of EM plasma cleaners
Ibss 电镜等离子清洗器的比较

Typical EM benchtop plasma cleaner

Early EM bench top plasma cleaners, Figure 1,produce an ionized gaseous state by a DC or RF accelerating potential in which electrons, ions and radicals co-exist. The interactions with a solid surface cause three basic phenomena that lead to surface cleaning:

I. Heating from electron-specimen interaction
II. Sputtering from ion-specimen interaction
III. Ashing from radical-specimen interaction

Although the combination of all plasma species is efficient in terms of cleaning rates, it can cause irreversible surface specimen modification and undesirable sample surface heating[1].

典型的电镜台式等离子清洗器

早期的电镜台式等离子清洗器，如图 1 所示，通过直流或射频加速电子、离子和自由基共存的电位并产生电离气态。与固体表面的相互作用导致三种可清洁表面的基本现象：

I. 电子-样品相互作用导致的加热清洗
II. 离子-样品相互作用导致的溅射清洗
III. 自由基-样品相互作用产生的化学清洗

尽管从清洗速度来看，所有等离子种类的组合都是有效的，但会导致不可逆的表面样品改性以及不需要的样品表面加热 [1]。

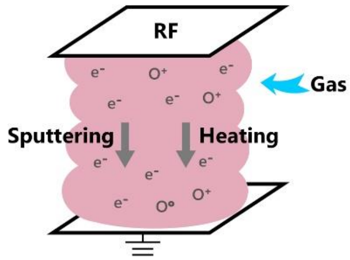


Figure 1

Antenna CCP sources

In the late 1990s, a Capacitively Coupled Plasma (CCP) source, technically called antenna source, was developed at the Bessy[2] Synchrotron Light Source (Berlin, Germany). This source is similar to Evactron models although larger in diameter. In Capacitively Coupled Plasma sources the central cylindrical aluminum antenna is connected directly to the RF that generates the plasma between anode and cathode. During RF plasma generation, a negative DC bias of several hundred volts results across the anode/cathode from the inherent kinetic properties of the electrons and ions within the plasma. The resulting enhanced ion kinetics have the potential to sputter anode material into the plasma.

天线 CCP 源

20 世纪 90 年代末，在 BESSY II 研究所（德国柏林）同步辐射光源开发了一种电容耦合等离子（CCP）源，技术上称为天线源。这个源类似于 Evactron 模型，尽管直径更大。在电容耦合等离子源中，中心圆柱形铝天线直接与射频连接，射频在阳极和阴极之间产生等离子。在射频等离子产生过程中，由于等离子中电子和离子的固有动力学特性，在阳极/阴极上产生几百伏的负直流偏压。由此产生的增强离子动力可将阳极材料溅射到等离子中。

Static Gas Flow Mode

These antenna sources can be operated either in static or dynamic plasma driving gas supply flow mode. In the static mode the driving gas flows uninterrupted into the source making a continuous plasma that is always ignited but requires ~500 millitorr pressure to remain ignited. At this relatively high pressure, the short mean free path lengths of the active plasma species results in high recombination rates which limits cleaning to within the local chamber volume near the source. The Zephyr gas flow mechanism produced a continuous flow of gas into the source at ~500 milli Torr, Figure 2.

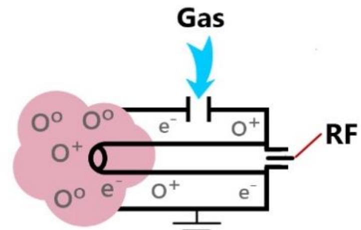


Figure 2

静态气流模式

这些天线源可以在静态或动态等离子驱动气体供应流模式下工作。在静态模式下，驱动气体不间断地流入源中，形成总是处于点燃状态的、连续的等离子，但需要约 500 毫托的压力才能保持点燃状态。在这个相对较高的压力下，活性等离子粒子的短的平均自由程长度导致了高的复合率，这限制了清洗的范围，即在靠近源的局部腔室体内。Zephyr 气流机制在进入源时产生连续的气体流动，约 500 毫托，见图 2。

Dynamic Gas Flow Mode

The dynamic gas flow mode is implemented in antenna sources because the plasma must be ignited at high pressure. After ignition the gas is turned off to lower the chamber pressure during cleaning. The purpose to transport the plasma through the chamber at lower pressure is to benefit from long mean free paths at lower pressure. Also, the plasma lifetime is greater at lower pressure. When the pressure drops below the critical plasma sustaining pressure the plasma becomes weaker, the cleaning rate drops off until the plasma is extinguished.

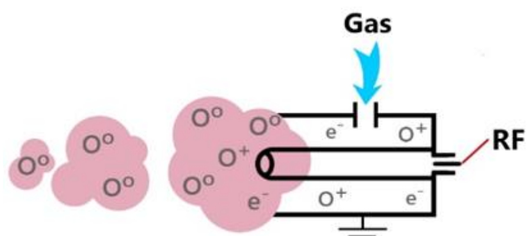
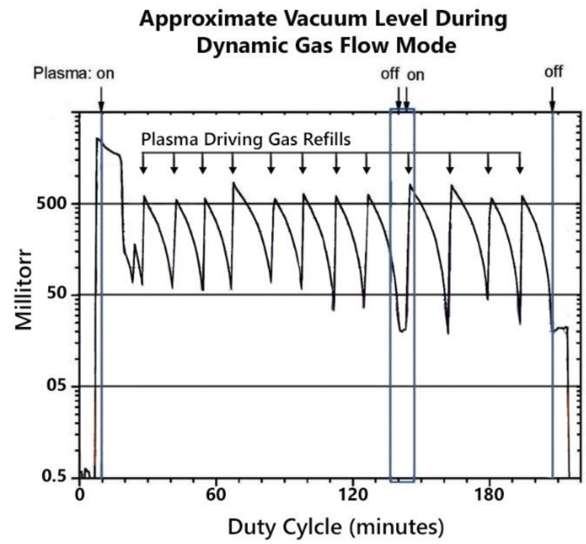


Figure 3

动态气流模式

在天线源中执行的动态气流模式，由于等离子必须在高压下点燃。点燃后，在清洁过程中关闭气体以降低腔室压力。在较低压力下通过腔室传输等离子的目的是利用较低压力下的长的平均自由程。此外，在较低的压力下，等离子的寿命更长。当压力降到临界等离子维持压力以下时，等离子变弱，清洗速率下降，直到等离子熄灭。



To keep the plasma ignited the inlet gas valve is opened again to repeat the cycle. The cleaning rate depends on the duty cycle typically 100%, see Figure 4. Therefore, the life time of the active species is dependent on the duty cycle. To achieve this performance a software modification has been made to the latest XEI Evactron that opens and closes the plasma driving gas valve to benefit from longer MFPs. The software pulses the gas flow valve on/off in an attempt to overcome inefficient plasma delivery of the Evactron, Figure 3. The momentary low pressure permits the plasma to expand into the chamber as the MFP increases.

Figure 4

The overall on/off time trend is shown by the typical saw-tooth pattern for an antenna source, similar to the Evactron operated in this fashion. Fresh driving gas must be supplied in regular intervals due to total pressure decrease as a function of time to provide sufficient gas flow to prevent plasma collapse.

为了保持等离子的点燃状态，再次打开进气阀以重复循环。清洁率取决于占空比(4)，通常 <100%，见图 4。因此，活性物种的寿命取决于占空比。为了实现这一性能，我们对最新的 XEI Evactron 的软件进行了修改，它可以打开和关闭等离子驱动气体阀，从而受益于更长的 MFPs。该软件对气体流量阀进行脉冲式的开启/关闭，以克服 Evactron 的等离子输送效率低的问题，如图 3 所示。瞬时低压允许等离子随着 MFP 的增加而膨胀进入腔室。

天线源的典型锯齿模式显示了总的开/关时间趋势，类似于以这种方式操作的 Evactron。由于总压力随时间而降低，必须定期供应新的驱动气体，以提供足够的气体流量，防止等离子的崩溃。

ibss Inductively Coupled plasma source

In contrast to the above, the principle of plasma transmission by the GV10x DS Asher occurs at low milli Torr range, ~0.1 Torr at the source and<5 milli Torrin the downstream chamber. This is very different from the traditional antenna source because the plasma is developed in a separate volume upstream from the chamber. The downstream low pressure provides vacuum conditions to allow the plasma and UV to expand into the chamber on all component surfaces with a 100% duty cycle.

ibss 感应耦合等离子源

与上述不同的是，GV10x 顺流等离子清洗器的等离子传输原理发生在较低的毫托范围内，在源端约为 0.1 托，在下游腔中<5 毫托。这与传统的天线源有很大不同，因为等离子是在腔室上游的一

个单独的容积中形成的。下游低压提供真空条件，允许等离子和紫外线以 100%占空比扩展到腔室中所有部件的表面。

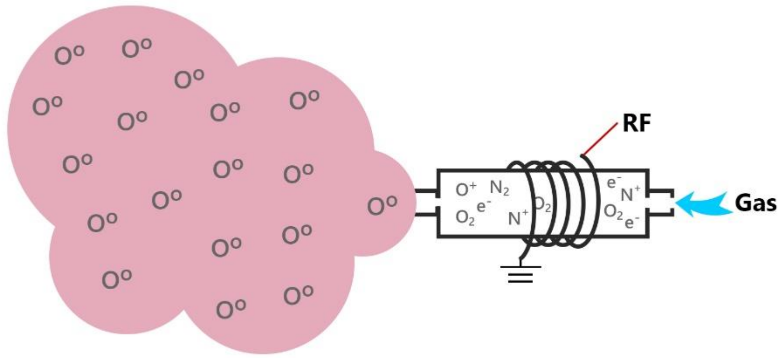


Figure 5

The low downstream chamber pressure facilitates distribution of the chemically active species throughout the chamber volume and the fact that the primary RF coupling coil is located outside the plasma volume results in chemically clean plasma free from any metallic sputtering products that could be generated by sputtering off from in-vacuum antenna source. The most prominent result susing the GV10x DS Asher cleaning as compared with the traditional antenna source operation in static or dynamic modes are the increase in cleaning rate and efficiency throughout the chamber, on specimens and detector surfaces. This improved cleaning efficiency rate compared with the traditional RF gun is probably due to a combination of three aspects:

1. A more efficient and continuous supply of neutral OI (or O^o) radicals for cleaning in conjunction with enhanced mean free path lengths of the chemically active species.
2. No plasma ‘self-intoxication’ by derivatives of CO or CO_2 due to the removal of these carbon gas species by using the continuous static gas supply mode.
3. UV assisted breaking of carbon bonds and/or carbon oxidation

较低的下游腔室压力有助于化学活性物质在整个腔室容积内的分布，主射频耦合线圈位于等离子体积之外，这就导致以化学方式进行等离子清洁，而不会有任何从真空天线源中产生的金属溅射产物。与静态或动态模式下的传统天线源操作相比，使用 GV10x 顺流等离子清洗器的最显著结果是提高了整个腔室、样品和探测器表面的清洗速度和效率。与传统微波电子枪相比，这种清洁效率的提高是以下三个方面的结合：

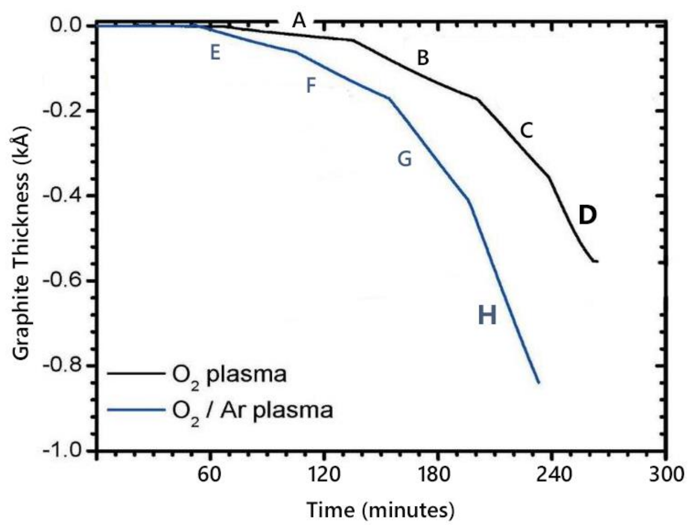
1. 更有效和持续的中性 OI（或 O^o）自由基供应可用于清洁，同时增加化学活性物质的平均自由程长度。
2. 使用连续静态气体供应模式去除这些碳气体物种，而不会导致一氧化碳或二氧化碳衍生物的等离子“自毒”现象。
3. 紫外辅助碳键和/或碳氧化断裂

Table 1 -Shows GV10x DS Asher removal rate of amorphouscarbon by two different plasma driving gases at four different power levels and two operating pressures. Each segment of the blue and black slopes, A through H,corresponds to the pertinent removal rates with parametersas shown in the tables.

图表 1-显示了两种不同的等离子驱动气体在四种不同的功率水平和两种工作压力下，GV10x 顺流等离子清洗器的非晶碳去除率。蓝色和黑色斜坡 A 到 H 的每一段对应于相关的去除率，其参数如表所示。

纯氧气			
	射频(W)	压力 (mTorr)	去除率 (kÅ/min)
A	25	7.5	0.46
B	50	7.5	2.28
C	98	7.5	4.93
D	98	3.75	8.43

混合 96%氧/ 4% 氩			
	射频 (W)	压力 (mTorr)	去除率 (kÅ/min)
E	25	7.5	1.2
F	50	7.5	2.3
G	98	7.5	5.8
H	98	3.75	11.6



图表 1

References supplied upon request

应要求提供的参考资料