

20th Anniversary of Evactron® Plasma Cleaners for SEMs and FIBs

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XEI Scientific invented the Evactron De-Contaminator, a practical plasma cleaning system for Scanning Electron Microscopes (SEMs) in 1999 [1] that could be mounted on the chamber to clean *in situ*. Plasma cleaners have now become a standard accessory to quickly and effectively remove hydrocarbons from vacuum chambers and specimens. Eliminating hydrocarbons prevents contamination artifacts such as black squares, scan deposits, and carbon peaks in EDS spectra. The Evactron plasma radical source uses a unique RF hollow cathode to create a low-temperature RF plasma in a vacuum that is able to make oxygen radicals from air. These radicals (oxygen atoms) gently combine with hydrocarbons in the vacuum chamber to form CO and H₂O gases that are removed by viscous flow to the vacuum pump.

Hydrocarbon contamination causes measurement errors in high resolution FESEM, CD SEM and TEM due to deposits created by the interaction of the electron beam with contaminants. Narrow line width and small feature sizes demand the lowest contamination levels for analytical laboratory applications and on production and inspection floors. The demands of semiconductor production and inspection require that SEM and FIB (Focused Ion Beam) instruments stay cleaner than in the past in order to image and measure sub-10 nm features. Chamber residue on surfaces, components, and traces residing on specimens are all sources of hydrocarbons that are polymerized by the electron beam on scanned areas, causing image blurring and loss of resolution. Periodic Evactron plasma cleaning has been proven to be effective for controlling these hydrocarbons [2, 3].

The original Evactron design used a simple manually operated micro-needle valve as a metering valve for the air entering the plasma to make oxygen radicals. This Evactron model used a constant rotational speed vacuum pump such as a rotary vane pump, and the pressure was only easily adjusted once when the system was installed. When open, the leak valve and roughing pump always came to the same equilibrium pressure. Newer SEM evacuation system designs use a turbo pump that accelerates during pump down. In response a servo-controlled flow valve was added to an Evactron model in 2004 to stabilize pressure. Control logic was switched to a microprocessor and time, power, and pressure became programmable in 2008.

XEI developed the use of quartz crystal monitors to measure hydrocarbon removal rates in 2007 [4]. This direct testing method was used in research to improve cleaning rates. Switching plasma pumping to the turbo molecular pump so that plasma could be run at lower pressures (5 to 40 mTorr) decreased losses of radicals to recombination collisions and increased the cleaning of surfaces in the whole chamber. This led to the Evactron Zephyr models that operate at pressures between 10 to 30 mTorr.

Recently the effort has switched to reduce the cost of *in-situ* plasma cleaners and allow striking the plasma at lower chamber pressures. POPTM ignition, allowing a small burst of air into the plasma chamber at the same time that the RF is initiated, ignites the plasma at high vacuum. A simple constant low flow rate of air into the plasma gives satisfactory cleaning over a wide range of pressures with a variety of pumping speeds. This allows a fixed orifice to control input flow and has removed the need

for adjustable valves. The newest Evactron 50 model produces a higher power and clean 50 Watt plasma by means of moving the hollow cathode outside of the plasma.

References:

- [1] R Vane, US Patents 6,105,589 (issued Aug. 2000) and 6,452,315 (issued Sept. 2002).
 [2] AE Vladár et al., Proc. SPIE **4344** (2001), p. 835.
 [3] E Kosmowska et al., Microsc. Microanal. **23 (S1)** (2017), p. 74.
 [4] CG Morgan, MM Gleason and R Vane, Microsc. Microanal. **13 (2)** (2007), p. 1736.



Figure 1. Three generations of Evactrons mounted on SEMs. 1) Evactron 10 PRS in 2004 first servo control of pressure, 2) Evactron 25 PRS with shroud over the valve manifold. 3) Evactron 50 PRS in 2018 high performance cleaning at 50 watts, external hollow cathode and lower cost.



Figure 2. Evactron products represent continuous innovation to improve the cleanliness of vacuum chambers.