A Novel electron based process for the reduction of residual gas species and surface contamination in SEM, FIB and S/TEM vacuum systems

Hoyle, D.[1]

[1] Hitachi High-Technologies Canada Inc., Canada

Contamination due to hydrocarbons is a common issue that frequently limits data collection when using a TEM, Scanning TEM (STEM), FIB or SEM for observations. Often this contamination is a result of residual hydrocarbons that remain in the vacuum system and then become deposited at the site of the impinging beam interaction by EBID[1] (electron beam induced deposition). The reduction of these residual gases has been done using various methods such; as gas purging, vacuum baking , plasma bombardment, ion bombardment and UV photons[2]. Electrons have been shown[3] to desorb surface gases from substrates in vacuum systems but have not previously been used for cleaning the vacuum system itself.

This specific system, using electrons was developed to clean and reduce contamination in Transmitted Electron Microscopes, Scanning Electron Microscopes, CDSEMs, FIB and Dual beam FIB systems, but is not limited to use only on these instruments, but any medium to ultra high vacuum instruments, that require a low background of hydrocarbons, to reduce process or observed contamination. At the same time if properly adjusted the cleaning system may also be used for cleaning specimens while in-situ of the vacuum chamber. The energy was selected to reduce the possible damage to materials frequently found in microscope systems, as well as to reduce any possible damage to specimens, which can also be cleaned in-situ by the electron cleaning system, if so desired.

A broad beam, low energy electron source was designed and then adapted to an SEM chamber that had been shown to cause excessive specimen contamination. The electron based system was shown to be effective at reducing the contamination to an undetectable amount. The cleaning test was to expose a specimen to the electron beam, for a significant amount of time, 10 minutes at a 200kx magnification and low accelerating voltage of 1kV, so as to induce a high amount of EBID,, if any hydrocarbon gas is present. This follows the suggested procedure as outlined by NIST in the "contamination specification for dimensional metrology SEMs"[4].

The electron cleaning system was then compared against a known UV specimen decontamination system, ZONE SEM. This test was conducted by cleaning a PMMA layer sample (a photoresist used by the semiconductor industry), on a silicon substrate and the resulting cleaning rates were measured by the use of an Ellipsometer. It was found that the electron based system can remove the hydrocarbons up to 4 times faster than the UV based system even though the electron based system used less system power and was at a longer effective working distance then the UV based system. This makes the system suitable for in-situ cleaning of samples in a high vacuum system.

It has been shown that this newly devised system can be used to clean existing electron microscope vacuum systems of hydrocarbon contamination effectively and rapidly. When used in the correct manner it can also be used for gentle in-situ cleaning of samples, allowing the end user to obtain the best possible results from their specimens. The system has now been installed in several SEM and STEM systems and found to produce a clean environment and to clean specimens as required.

References:
[1] T Bret, Microelectronics Engineering, 78-79. Elsevier (2005) pages 300-306

[2] S. Danielson U.S. Patent 4660297 4/1987
[3] D. Hoffman, B. Singh and T.H.Thomas,III, Handbook of Vacuum Science and Technology, Academic Press. Pages 53-54, 596-598,793-795.

[4] A.E. Vladar, K.P. Purushotham, M.Postek, Proc. Of SPIE, Vol. 6922-692217-1
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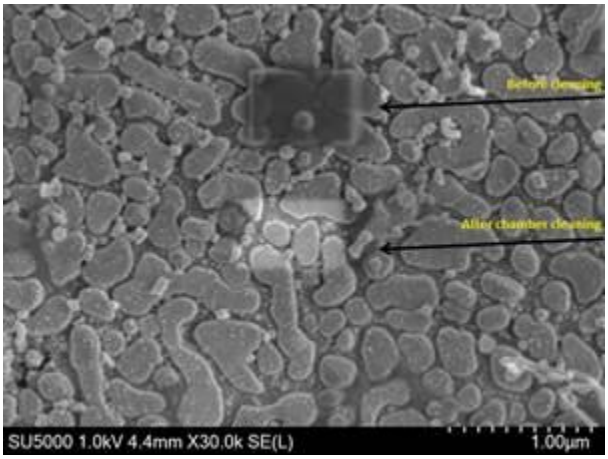

Figure 1. Specimen EBID before/after a SEM chamber was cleaned with the electron based cleaner

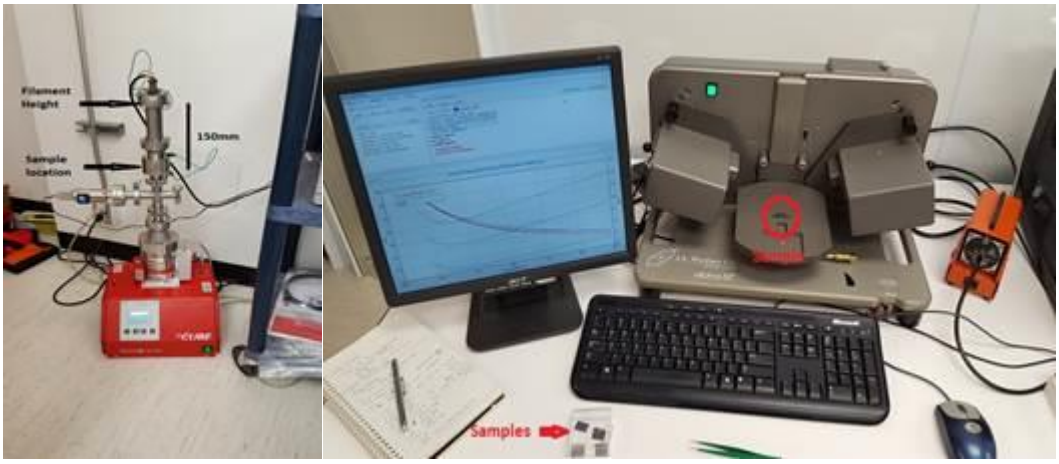

Figure 2. Test setup for rate of PMMA removal and Ellipsometer setup