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Wavelength Dependent Performance Loss in the Ultraviolet

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Optical samples measured in a vacuum change while we watch—the vacuum environment contributes to measureable changes in optical performance. We measured optical transmission samples in high vacuum and then in dry nitrogen. We then quantified vacuum environment contamination and polymerization in a manner easily demonstrated and repeated. These results are useful for metrology laboratories and manufacturers of analytical instruments, semiconductor process control, material scientists, and other researchers. It may be time to revisit standards for the deep ultraviolet 120 to 300 nm region!

We measured a series of samples in a vacuum spectrophotometer (1). It uses a high vacuum turbomolecular pump with a molecular drag roughing pump. Vacuum level during measurements was better than 5×10E-5 Torr. The instrument used a 30-Watt deuterium lamp with magnesium fluoride window, a scanning monochromator, and collimated measuring beam. All sample measurements have a new reference and correction scan. All samples were tested from 115 to 220 nm. The samples are magnesium fluoride windows 25×2 mm thick. Magnesium fluoride was used because it transmits ultraviolet light well, especially less than 140 nm. Samples were handled with gloves and exposed to the lab atmosphere as little as possible. Orientation marks maintained consistent mounting. Cleaning consisted of methanol and Kimwipe™ to remove particulate or gross contamination and UV-ozone scrubbing.

We then measured the same samples in a nitrogen purged spectrophotometer. This was the same spectrophotometer that was used for vacuum testing except the vacuum pump was removed and dry nitrogen gas flowed instead. Each sample was cleaned as before and the transmission was measured.

The experiment shows that regardless of how clean a sample is, or how good the vacuum level, some wavelength dependent losses occur in the vacuum environment. Wavelength dependent transmission loss is most obvious at shorter wavelengths and on clean samples. These types of materials are transmitting or reflecting wavelengths very easily absorbed by various contaminants (2). The experiment also shows that the cleaner a surface is, the quicker contamination begins to be measureable. All measured values are better or higher in nitrogen. Even with no UV illumination, nucleation or particle and ion condensates (3) in vacuum result in optical performance losses. Nitrogen system performance remains stable over longer timescales too.

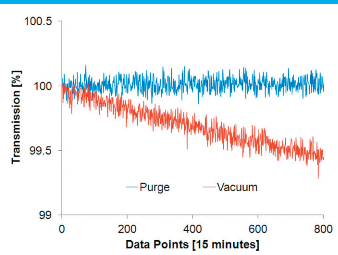

Figure 1: Deep ultraviolet transmission loss at 121 nm occurs rapidly in vacuum systems (red) and is much more stable in nitrogen purge (blue).

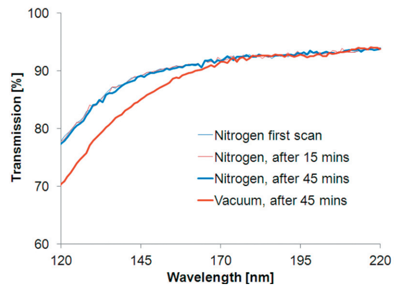

Figure 2: Wavelength dependent performance loss of plasma cleaned sample in vacuum (red) compared to same (cleaned) sample measured in nitrogen purge (blue) at 15, 30, and 45 min.

Improved and reliable cleaning methods have allowed us to serially clean a sample and subsequently measure it in different ways. The measurement and quantification of vacuum environment contamination on UV transparent materials becomes obvious when compared to measurements made in purged systems. Measurements in other purged systems indicate the vacuum environment is the cause of contamination that may become polymerized, and UV exposure alone does not polymerize contamination until the vacuum helps deposit it. Implementing reproducible cleaning methods, in combination with a nitrogen purged VUVAS spectrophotometer provides the most accurate deep ultraviolet data currently possible.

References

(1) McPherson specification sheet VUVAS 2000.
(2) J. R. Vig, UV/Ozone cleaning of surfaces, Surface Contamination, (1979).
(3) D.M. Mattox, "Handbook of Physical Vapor Deposition (PVD) Processing," 142, Elsevier (2010).

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