

WE WORRY ABOUT HYDROGEN BONDING IN MOISTURE ANALYSES

What does stainless steel have in common with water molecules and why is it a problem with gas cells applied to ppb moisture analyses?

Over the years, CIC Photonics and its customers working with the purity of the electronic specialty gases have demonstrated that long path gas cells constructed of stainless steel do not offer the highest sensitivity for the quantitative measurement of moisture as an impurity in those gases; however, the electroplating of a nickel layer on the inside surfaces does extend the sensitivity to the ppb level.

The problem with bare or electropolished stainless steel, whether it be 304, 316, or 316L, is the exposed chromium (Cr) atoms at the surface. Those Cr atoms are almost always associated with oxygen atoms in the form of Cr-O species; and those exposed O-atoms are great bonding sites for moisture molecules—i.e. H-O-H. The H-atom of a moisture molecule will hydrogen-bond to the exposed O-atom; which could lead to Cr-O--H-O-H.

Those hydrogen bonds are relatively strong and not easily broken by vacuum pumping and/or low-temperature heating. A combination of purging and baking and pumping will reduce the absorbed moisture molecules; but as soon as the stainless steel surface is exposed again to moisture, hydrogen bonding takes place.

However, nickel does not readily form Ni-O sites, so the absence of exposed O-atom sites at the surface of nickel-plated stainless steel prevents the occurrence of hydrogen bonding with any moisture molecules in the electronic specialty gas sample. Obviously, this allows for higher sensitivity detection of moisture as an impurity.

With two exceptions, CIC Photonics manufactures all of its long path gas cells with nickel-plated 316L stainless steel. One exception is when the end user needs to measure CO as a primary species at elevated temperature in a gas sample. Nickel will react with CO and form nickel carbonyl as a vapor species, which introduces it as an impurity and alters the CO concentration. For this application, we provide electropolished 316L stainless steel.

The second exception is the moisture impurity analysis of anhydrous HBr. HBr reacts with Ni to produce a yellowish deposit which can be dissolved and cleaned up with a solvent. So again we recommend electropolished stainless steel for the long path gas cell.

The commonality between stainless steel and water molecules is the attraction between surface bound O-atoms and the H-atoms of H-O-H molecules to form hydrogen bonds.