

The Importance of Minimizing Hydrogen Aging Losses and Alkali Impurities

OFS AllWave® Zero Water Peak (ZWP) Fiber



by Dr. Kai Chang*

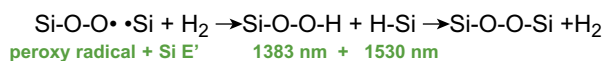
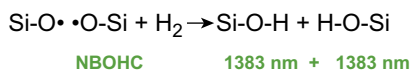
To reliably support many decades of revenue generating services the optical loss in fibers should not degrade with time. For some fibers, however, there is a significant risk that the optical loss could increase due to the chemical reactions between the atomic defects in fibers and the trace amounts of molecular hydrogen inevitably present in or around optical cables. Selecting the right fibers made with the proper process and high purity silica material can guard against hydrogen aging loss increases and help ensure decades of reliable network service.

There are basically three types of hydrogen aging losses that must be avoided in Ge-doped silica fibers to help ensure reliability in optical transmission over an expected service lifetime of 25 years or more. These hydrogen aging losses are caused by different types of atomic defects or impurities present in the silica fibers. The severity of hydrogen aging loss degradation is dependent on the fiber manufacturing process and the purity of the silica material involved.

The first two types of hydrogen aging losses involve two extremely reactive silica defects: NBOHC (non-bridging oxygen hole center Si-O•) and peroxy radical/Si E' defect (Si-O-O••Si). These silica defects (involving Si and O atoms only and no Ge), even at room temperature, can react almost instantaneously with trace amounts of hydrogen and cause significant loss increases. Up to several tenths of dB/km loss increases at the 1383 nm OH peak and at the 1530 nm "SiH" peak have been observed.

Figure 1 shows the hydrogen aging loss increase at the 1383 nm OH peak due to the NBOHC defects in a matched-clad single-mode fiber made by OVD. It has a 2.0dB/km max loss spec for the water peak region and does not guarantee H2 aging performance.

The hydrogen reaction mechanisms with the two silica defects can be described as follows:



It is important to minimize the above silica defects in the fiber manufacturing process by adjusting the oxidation/reduction conditions in dehydration and consolidation as

well as the fiber draw. In addition to managing the manufacturing process to achieve minimal defects, OFS has been using a patented deuterium treatment process on fiber spools. The combination of excellent preform manufacturing process control and this fiber treatment process minimize the hydrogen aging losses due to these reactive silica defects. The deuterium reactions work in a similar way as the hydrogen reactions above:

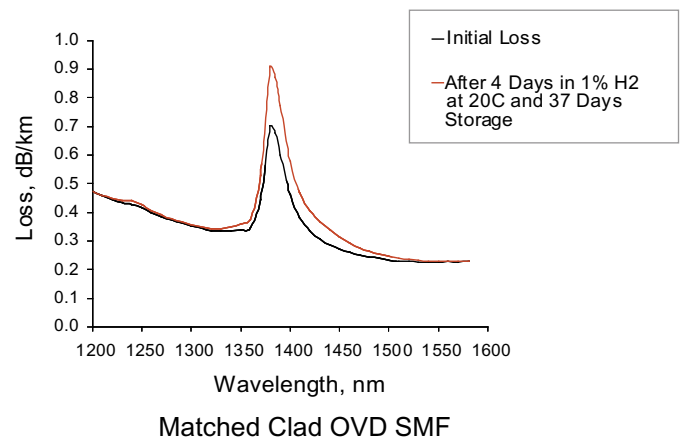
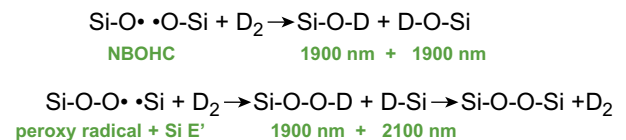


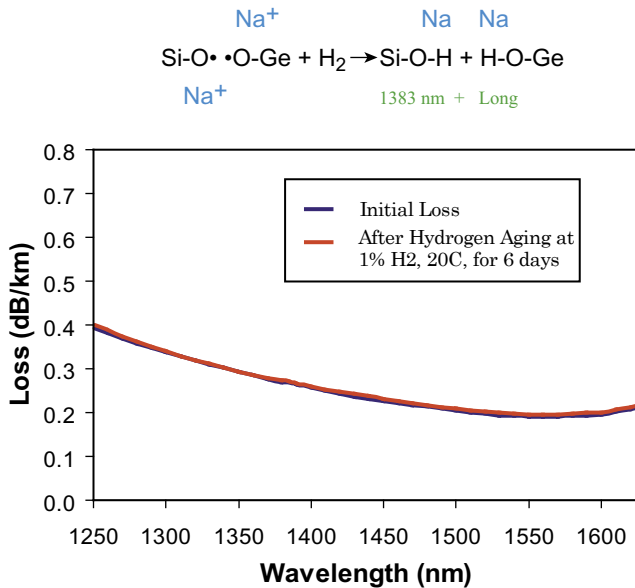
Figure 1. An example of the hydrogen aging loss increase at the 1383 nm OH peak in a matched clad single-mode fiber made by OVD

But the OD and SiD absorption losses are now harmless because they occur at much longer wavelengths (>> 1625nm) and are outside the normal operating wavelength windows. Furthermore, the reactive silica defects after being passivated by deuterium reaction will no longer be able to cause additional hydrogen aging loss in the field.

Figure 2 shows a deuterium treated OFS AllWave ZWP Fiber with negligible hydrogen aging loss. The third type of hydrogen aging loss that is of concern is when there is alkali (Na, Li, K, etc) contamination. This contamination can be as low as a fraction of ppma (parts per million atomic) in Ge doped silica fibers and still have critical consequences. This is because the activation energy for hydrogen reaction is greatly reduced when the normal

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and unavoidable high-activation Ge(3) defects interact with alkali impurities. The hydrogen reaction can be described as follows:



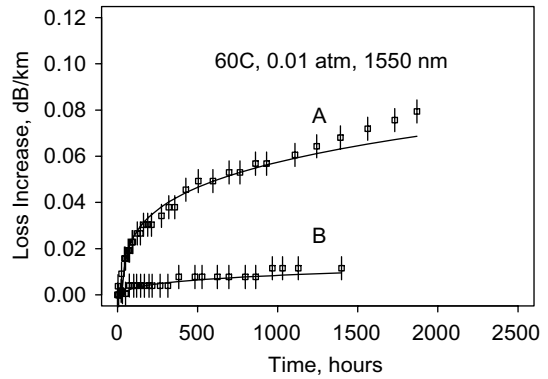
**Figure 2. OFS Patented D₂ Treated Fiber:
Negligible Hydrogen Aging Loss
Permanent Low Loss for the Full Spectrum from 1260 to 1625 nm**

Alkali contamination can arise from the use of natural quartz material with alkali impurities, insufficient purification or contamination in preform processing. When there is alkali contamination, the hydrogen aging loss has an OH peak as well as a long wavelength characteristics, affecting wavelengths > 1360 nm.

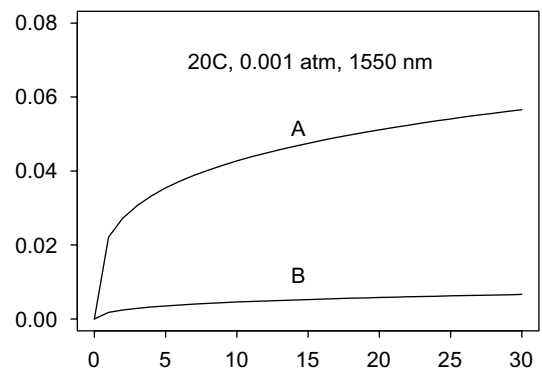
OFS has developed an accurate quantitative model in our extensive hydrogen studies. The model predicts a hydrogen aging loss of the order of 0.02 to 0.04 dB/km (i.e. 10% to 20% loss increase) or more in the C-, S-, and L-band as well as the OH peak after 25 years under typical cable operating conditions (20C & 400 ppm H₂) for a Ge doped fiber with as little as 1 ppma alkali contamination. Figures 3 & 4 show enhanced hydrogen aging loss for a fiber (Fiber A) with 1.35 ppma Na+Li alkali contamination versus a fiber (B) with < 0.3 ppma Na+Li.

Hydrogen aging loss may require expensive amplifiers and attenuators to be included in the network. As the fiber ages, the attenuators will need to be removed which is an out-of-service procedure. Conversely if no allowance is given for a fiber that ages severely, there will ultimately be bit errors and potentially loss of signal when the loss margin is exceeded. Using AllWave ZWP Fiber makes network planning and operation much easier and less expensive.

**Figure 3. Alkali Effect:
Predicted Hydrogen Aging Loss at Long Wavelength**



**Figure 4 Alkali Effect:
Predicted Hydrogen Aging Loss under Service Conditions**



Summary

To minimize the hydrogen aging losses, it is critical to eliminate the reactive NBOHC, peroxy radical and Si E' defects and avoid any alkali contamination. This is necessary to help ensure optical transmission reliability over the lifetime of the Ge-doped fibers. The use of high purity synthetic glass, excellent preform process control, and fiber treatments in deuterium are required for long-term reliability of optical fiber networks. OFS AllWave ZWP Fiber meets all of these requirements!

For additional information please contact your sales representative. You can also visit our website at: <http://www.ofsoptics.com> or call: 1-888-fiberhelp.

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