Technical Memo

Solarization of Fiber Optics

Scope: The intent of this note is to discuss the effect commonly known as “solarization” as it relates to fiberoptics and to offer a brief of what is known in the industry regarding fibers that are somewhat resistant to this effect. This information comes from years of experience and none of the information contained herein is cited.

Definition: Solarization is a decrease from initial measured transmission intensities for wavelengths in the UV. This process is commonly described as the “darkening” of the fiber at certain wavelengths or over certain wavelength regions and is caused by the formation of absorbing “centers” due to the UV flux.

Background: What has come to be known as UV solarization of fiberoptics occurs in silica core materials primarily in two regions. The increase in optical losses occurs when a UV photon breaks molecular bonds within the material resulting in atomic elemental forms being created that absorb rather than allow the transmission of light.

The NBOH solarization zone is an increase in loss that extends from about 185nm to 350nm and is centered around the wavelength 265nm.

The E’ solarization zone is an increase in loss centered at 215nm. The primary and deepest part of this effect starts at about 185nm and extends to about 260nm.

The long term transmission curve for silica based fibers in the UV is then a combination of these solarization curves added to the normal transmission curve for the silica base material

Many people think that the transformation to an E’ center defect is related to the existence of strained Si-O, Si-Cl or Si-H bonds. These “precursor” defects are thought to be formed during the preform and/or fiber fabrication processes and therefore may be able to be controlled. It seems clear that variability in the draw process for a given preform can influence the degree of solarization resistance a particular fiber will have. This is supported by the widely varying results that are seen by different fiber manufacturers when using the same base material preform, but it is the IP of manufacturers determining which drawing parameters need to be controlled, and how, to produce the best results.

It can also be reasonably inferred that variability in the preform fabrication would yield varying degrees of precursor defects. This might explain why some fibers take a dip in transmission when exposed to UV radiation and then level off while other seemingly identical fibers continue to degrade in transmission. This line of thinking says that the precursors are present in a certain concentration and once they have been converted to absorbing centers no additional loss is seen. Thus, control of the preform process to reduce or eliminate these precursor defects would seem important.

There is, however, a school of thought that believes that the fundamental limits inherent in the chemistry of silica will limit us to small improvements in the ultimate solarization resistance of these fibers. These fundamental limitations, however, have not as of yet been defined.

Interestingly, absorbing defects have been shown to be "somewhat recoverable" in the presence of molecular hydrogen. In this case the free Si formed when the strained precursor bonds were split, thereby forming an absorbing center, are recombined with half the molecular hydrogen to create a non-absorbing molecule. Fibers that do not recover at all from solarization induced losses have been shown to have particularly low concentrations of molecular hydrogen.

Recently, it has also been shown that adding fluorine in the presence of molecular hydrogen permanently binds the hydrogen making these fibers unique in that they are expected to display their "resistance" to solarization permanently whereas the "hydrogen doped" fibers sees their hydrogen migrate out of the glass structure and hence their resistance diminishes over time. But these fibers have limited availability and are very expensive.

Low Solarization Fibers: First, take careful note that no reputable purveyor is claiming "no solarization fiber", they are merely claiming that particular fibers show an increased resistance to solarization. No one has yet to publish definitively why this might be the case, though theories abound and have even been patented!

There seems to be two approaches to fabricating a low solar fiber.

The first is to fabricate the preform in such a way as to minimize defect center creation. This is the trade secret of the preform manufacturers but we assume they are trying to minimize strain in the Si-X bonds, and then hope the fiber drawing process doesn't undo that work.

The second is to saturate the fiber, after it is drawn, with molecular hydrogen or hydrogen combined with fluorine in an effort to provide an environment where the absorbing centers can be annealed.

In the first case, the results vary widely as different manufacturers using the same base material preform have different draw parameters. It may also be the case that within the same manufacturer, variation in draw parameters lot to lot occur. It appears that the only way to know what you've got is to perform testing of the fiber material. Unfortunately, some of these fibers will demonstrate widely varying results. This is not to say that there is no low solar fiber out there that satisfies certain applications. It is just to say that it is not well understood how to control for the best possible results every time. And of course those fiber manufacturers who are able to produce good low solar fibers some, or most of the time, are keeping their comments to themselves in this highly competitive niche.

In the case of hydrogen loading alone, the solarization resistance appears to be temporary. This should not be a surprise as the molecular hydrogen will eventually "leak out" (a process related to the fiber size and other environmental factors such as temperature). The point is that once the hydrogen is gone it must be "re-loaded" (a difficult and potentially dangerous process). Some manufacturers have reported better results by coating the fiber in a hermetic material such as aluminum but this has yet to be explored in any serious way or for any reasonable explanation to be advanced.

In the case of hydrogen loading in combination with fluorine, the testing seems to yield good results. The real difficulty with this material is its limited availability and the current restrictions upon fiber size and coating types so it simply can't be applied as widely as we might wish. It is also quite expensive when it is available and can easily double or triple the cost of an assembly or cable.

It should be stated that results indicate that while some fibers described here do indeed work better at certain wavelengths (to reduce the known absorbing centers), this same material may not be as good as "standard" UV grade silica at the other wavelengths for which it might be typically used. Again, this remains a bit of a mystery right now as no formal investigation appears to have been done. It is clear that the chemistry of the material has been altered and this may be another of those cases where the optimization of a specific characteristic may yield compromises in other areas.

What Are The Manufacturers Doing? There are new silica based materials being espoused by various manufacturers claiming "better low solarization" characteristics. The claims are unfortunately being retracted almost as fast as they are being published as "results have not yet been able to be reproduced".

Recently, there was information released about a new low solar fiber claiming very low induced loss at 248nm. Of course 248nm is on the edge of the E' center curve and some don't even recognize solarization as being a big problem at this wavelength. This same company released what appeared to be astounding results however at 193nm, which would have made their fiber a truly unique product, only to have to retract their statements since they could not reproduce the results. It was "unique" in the literal sense of the word!

Another claim regarding a "secret process" produced a fiber that exhibits better characteristics than most other manufacturers. However, the company claiming the secret process ended up not sure why or how they produce the fiber. They have to make a large number of fiber lots and then test them to see which ones are "good."

Then there is the hydrogen loading and "hermetic" jacketing technique, claiming better results yet o one has explained exactly how a thin metallic coating acts to "hold in the hydrogen".

The one fiber that appears to be able to be made consistently is one of the fibers that appears to suffer from lower transmission in the non-solarizing regions of the spectrum.

All of this should be taken as hopeful, not discouraging. There are a lot of people working on trying to figure out the problem. It may be that the mechanisms for forming absorption centers can be controlled. It may be that the industry will be able to get fiber working right up against the Raleigh scattering edge without the creation of absorbing centers with certainty every time. Certainly there have been enough glimmers to think it could happen and that the answer is out there. The only question really is when will we be able to buy something commercially that we can count on and will we have a satisfying explanation as to why and how it works.

What Do We Do In The Meantime? RSOF suggests that anyone interested in using fiber with low solar characteristics first acquire a set of test cables comprised of the various currently available materials. These cables should then be tested in a way that mimics the actual application as closely as possible. Then a decision can be made on the basis of relevant results in your actual application.

RSOF can provide cables for the purpose of evaluating materials at a somewhat discounted price. We typically recommend one standard UV cable, and two low solar cables made from two different low solar materials. If desired we can also fabricate cables from hydrogen doped material or the latest HF doped material (within its restrictions).

RSOF Billing: PO Box 822
Lightfoot VA 23090
Phone: (757) 645-2911
www.rsofibers.com

Shipping: 5248 Old Town Rd, Suite 12/13
Williamsburg VA 23188
Phone: (757) 645-2911
www.rsofibers.com