

A Novel VAD Process

Arnab Sarkar, Bedros Orchanian and Angela Chan

Nextrom USA Inc.

4730 Calle Quetzal, Camarillo, CA 93012

arnab.sarkar@nextrom.com

Abstract

Vapor Axial Deposition (VAD) process, invented in the 1970s in Japan¹, is known to produce the highest quality zero-water peak single mode fibers in the world. Although it has the highest market share of core preforms production in the world, and is used by 50% of top-10 preform producers in the world, it is also known as a very difficult process for industrial manufacturing. In this paper we present the key differences of this novel VAD equipment and process, with those of conventional VAD equipment and process information published to date, terms of degree of difficulty of implementing the VAD process by engineering improvements & component design changes, without compromising product quality. Finally, we present results of low-water single mode fibers produced by this process.

Keywords: Optical fiber; preform; VAD; low-water single mode fiber.

1. Introduction

VAD process, is a form of chemical deposition process, called flame hydrolysis, in which nanoparticles of glass forming oxides are formed a vapor phase reaction, by reacting vaporized reactants of glass forming oxides at high temperatures with water vapor generated in a oxy-hydrogen flame. The particles formed in the vapor phase in a quasi-laminar reaction zone deposit axially on the tip of a vertical rotating quartz handle by thermophoretic deposition².



Figure 1. Photograph of the deposition zone

To form the two-refractive index core-clad structure of an optical fiber, a core burner deposits core of germanium dioxide doped silicon dioxide glass axially at the tip of the handle and

simultaneously a second clad burner deposits silicon dioxide or fluorine doped silicon-dioxide glass at the side of the cylindrical core soot. Figure above is a photograph of the deposition zone of the VAD process.

As deposition occurs, using a position control device at the tip of the preform the handle is moved upwards forming a cylindrical porous soot body. When the length of the soot-preform reaches a certain target length deposition is stopped, the preform is taken out and it is dehydrated and sintered into a clear dense glass rod, consisting of the core and the light-carrying cross-section of the fiber structure. The core preform is then furnace-elongated into a small diameter rod, over which additional glass is added to form the complete glass preform. There are many processes of forming the clad glass, and in our case we have used a proprietary sand-clad process, which is now used in low volume mass production³.

In this work core rod is produced using prototype equipment in our facility in Camarillo, CA and the rod is clad, drawn & tested in our sister organization in Boudry, Switzerland.

2. Equipment Description:

2.1 VAD Deposition System

The automated VAD deposition system, in accordance to the concepts of this work is shown below in Figure 2.

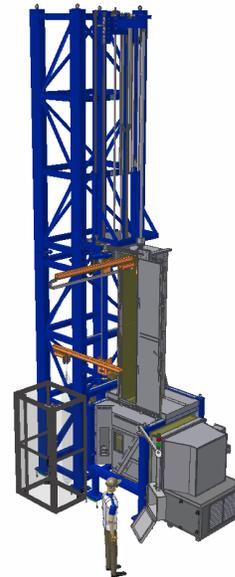


Figure 2. Conceptual drawing of a VAD machine

In this deposition system, the chemical vapor delivery system, common to all VAD systems is not shown. All the electronics of the system is mounted on the flame, isolated from the corrosive

deposition chamber atmosphere. The frame is also equipped with a semi-automatic material-handling fixture for ease of handling of the soot preform. The small chamber above the deposition chamber has the access door for inserting the preform handle in the rotation spindle and flame aligning the handle on to the rotation axis prior to start of deposition.

The metallic deposition chamber is made of special anti-corrosion high temperature material for long equipment life. It also houses two metallic aperture type oxy-hydrogen flame burners and is equipped with class 100, forced airflow of controlled velocity, which flows across the deposition burners for enhanced flame stability. The chamber is equipped with two exhausts with separate exhaust velocities for core and clad burners. Pressure is controlled by at the exhausts and inside the deposition chamber by pressure transducers and motorized exhaust baffle valves. Special care is taken to align the rotation axis exactly vertical and minimize vibration of the long spindle assembly. Deposition surface temperature can be monitored by a pyrometer and the deposition chamber has ports for equipping it with a CCD camera. Conventional feed back controls are provided for position of preform tip and control of growth rate.

2.2 Preform Sintering System:

The sintering system is designed for a zone-drying, zone sintering sequential sintering system³, a conceptual drawing of which is shown below in Figure 3.



Figure 3. Conceptual drawing of a sintering system

The furnace used is a single zone molybdenum-disilicide furnace operating at atmospheric air. A quartz-muffle inside the furnace encloses the entire preform inside a controlled atmosphere through out the process. The gas panel is not shown in the drawing. The top of the muffle is fitted with an all-glass dynamic

seal and pressure is monitored in the chambers of the seal and the muffle.

This fully automated sintering system allows floor level loading and unloading of preforms, a dual-speed drive allowing rapid loading and unloading and controlled low speed down-feed during dehydration and sintering.

2.3 Preform Elongation System:

The fully engineered vertical, furnace elongation system, was originally developed to elongate finished preforms with a high dimensional control. It has been adopted for core rod elongation and is equipped with a three-chuck operation and a cut-off saw permitting continuous rod drawing operation. Figure 4 below shows a photograph of the graphite induction furnace and two of the chucks during an elongation operation. The system is equipped with two-diameter monitors, one within the furnace and above and a pyrometer for on-line monitoring of draw temperature.



Figure 4. Photograph of an elongation system

2.4 Sand Clad Process:

The sand-clad process⁴ now in low-volume mass production, can be used with on-line thermal vitrification of high-purity sand or in an off-line operation. Figure 5 below shows an assembly of a sand clad preform ready to be drawn and two sections of the sand-clad preforms.

In this process, high purity, but relatively low-cost sand is filled in a glass assembly consisting of the core rod in the center and a jacketing tube in a controlled atmosphere. Prior to fiber draw the assembly is fully sintered into clear glass and is simultaneously drawn into fiber.

Both on-line and off-line sand clad process has been in production for over one year.



Figure 5. Photographs of sand-clad preforms

3. Process

3.1 Process Description

In this two-burner VAD deposition process, typically we produced soot diameters of 160 \pm 10mm for 8 hours at a nominal steady state deposition rate 6.0g/m. The deposited soot preform was dehydrated and sintered into a core glass preform typically 80-85mm in diameter. After handle attachment the preform was elongated into a core rod of nominal diameter of 25mm.

The core rod was then assembled into a clad preform and sintered & drawn on-line sand-clad process. The fibers were tested using commercial testing equipment used for production & sales of fiber in Silitec Fibre, SA.

3.2 Novel Features

The two major design changes relative to conventional VAD equipment used for the last two decades are shown below in Table 1.

Table 1. Novel features of VAD equipment

Component	Conventional VAD	Nextrom VAD
Burners	Quartz – concentric tube	Metallic – aperture rings
Chamber design	Natural air-flow	Forced air-flow
Exhaust	One exhaust for both core & clad burners	Separate exhaust for core & clad burners

The change in burner design was based on the observation that concentric quartz burners were hand fabricated by glass workers had had significant dimensional variability. Thus conventional VAD processes required significant amount to tuning after each burner change, resulting in VAD machines in the same factory operating with different set points for gas flows. One objective of replacing quartz burners with precision machined aperture type burners, so that all VAD machines operating in a factory could run with one recipe and also to eliminate the tuning requirement after burner replacement. Another advantage of the aperture type burner is that by changing the aperture size it allows independent control of gas

flow and gas velocity. This minimizes gas consumption for a given deposition rate and allows flame shape control by changing velocity profile of the exit gases. Also the metallic aperture type burners do not require argon gas flow for burner cooling.

However, in metallic aperture type burners, to ensure a stable deposition flame controlled airflow in-line with the flame and the exhaust velocities is essential. This is best provided by a forced air co-flow from behind the burner, which is not required in concentric burner quartz burners.

In all VAD chambers during deposition prevention of secondary deposition at the sides of the core and clad soot is essential to prevent cracking and also for control of fiber performance, particularly fiber dispersion. This secondary deposition in the clad soot is prevented by chamber airflow, burner angle and flame width. No special features were required to control secondary deposition at the side of the clad soot. Putting the clad burner in close proximity of the core burner so that the clad burner flame impinges on the core burner flame prevents this secondary deposition. It is also possible to prevent secondary deposition with airflow down the side of the preforms. In this case, we have opted to add a second exhaust for the core, which prevents secondary deposition on the side of the core soot and as shown in Figure 1 we have chosen to position the clad burner vertically separating the two flame so that they do not interfere with each other. Procedures for starting and stopping deposition have been modified so that preform end-loss and cycle-time remains unchanged relative to conventional VAD process.

4. Fiber Performance

Figure 6 below shows a typical refractive index profile of a G652 single mode fiber produced by this process.

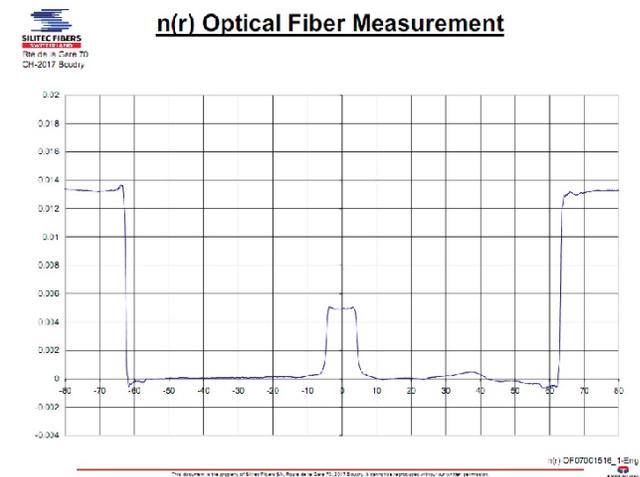


Figure 6. Typical refractive index profile of VAD fiber produced with metallic aperture type wide flame burner

A typical attenuation spectrum of fiber from a VAD core rod of 5.0 \pm 0.3 is shown in Figure 7. Those skilled in the art would appreciate that the fiber water peak in the VAD process depends of the water content of the sintering gases, the quality of the dynamic seal and the B/A of the core rod. Even though we have used helium gas from cylinders, with the use of appropriate driers we have been able to reduce the water peak to the level shown in Figure 7. Fiber manufacturers using dry liquid helium supply are expected to obtain a significantly lower water peak.

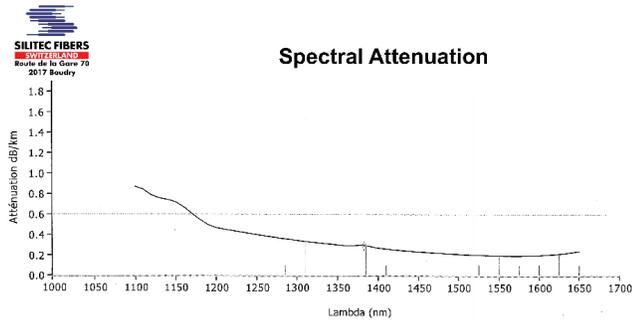


Figure 7. Attenuation spectra of a G652 single mode fiber

Fiber performance tested for all G652 single mode specifications is shown below in Table 2

Table 2. G652 fiber performance

Parameter	Units	Results
Attenuation @1310nm	dB/km	0.333
Attenuation@1383nm	dB/km	0.302
Attenuation @1550nm	dB/km	0.197
Mode Field Diameter	microns	9.545
Cut-off Wavelength	nm	1197
Zero Dispersion Wavelength	nm	1313.18
Dispersion Slope	ps/nm ² .km	0.086
Dispersion @1550nm	ps/nm.km	16.76
Core eccentricity	microns	0.16
Clad non-circularity	%	0.30

The above results is for work done in the technical feasibility phase of development of the novel VAD process and as we gather more production experience further details of repeatability & reproducibility of this process will be presented.

5. Conclusions

A novel state of the art process for manufacturing low-water peak single mode fibers, has been developed using a unique VAD equipment design, with precision machined components for high equipment reliability and process repeatability

6. Acknowledgments

The authors acknowledge the contribution of the engineering team of Silitec Fibres, SA, a Knill Gruppe company, led by Mr. Frederic Sandoz, Managing Director

7. References

- [1] N. Niizek, N. Inagaki and T. Edahiro "Vapor-Phase Axial Deposition Method", Chapter 3, Optical Fiber Communication Vol. 1, Fiber Fabrication, edited by T. Li, *Academic Press* (1983)

- [2] A. Sarkar, B. Orchanian and A.Chan, "Thermophoretic Driving Force of VAD Clad Deposition," *IWCS Proceedings* (2006).
- [3] T. Edahiro, M. Kyoto, G. Tanaka and T. Kuwahara, "Process for Producing Glass Preform for Optical Fibers," *US Patent* 4,338,111 (1982)
- [4] C. Pedrido: "Optical fiber and its preform as well as method and apparatus for fabricating them". *Patent WO 2005/1029747 A1*. (2005).

8. Pictures of Authors



Dr. Arnab Sarkar is presently Vice President of Nextrom (U.S.A) Inc. He is a graduate in Chemical Engineering from IIT, Kharagpur, India and he obtained his Ph.D in Materials Science in USA. Dr. Sarkar specializes in preform fabrication technology and has authored or co-authored 4 chapters in scientific books, over 50 scientific publications and 20 US patents.



Bedros Orchanian is presently the Engineering Manager for soot products at Nextrom USA. He has a bachelor degree in Mechanical Engineering from the University of Alexandria, Egypt. He has 24 years experience in the OVD/VAD technologies, and in the development and manufacturing of preform fabrication equipment.



Ms. Angela Chan is presently working as process engineer for Nextrom (U.S.A.). She obtained her bachelor degree in Chemical Engineering from University of California, Los Angeles. Angela has seven years of experience in OVD and VAD preform fabrication.