INNOVATION IN PREFORM FABRICATION TECHNOLOGIES

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ABSTRACT
The paper reviews recent innovations in preform fabrication technologies for telecom and specialty fibers. A new fabrication technique based on pure granulated silica sand is presented.

INTRODUCTION
The steps of fibers fabrication include fabrication of Core Preform, cladding the preform, draw the preform into fiber, and test the quality of the fiber. While core affects mainly the performance of the fiber, cladding controls it's cost. For specialty fibers, flexibility of fabrication is the key to allow fabricating complex fibers.

1. CORE PREFORM FABRICATION
The table below presents a comparison of the suitability of each process for core preforms.

	VAD 	FCVD 	OVD 	PCVD 
Productivity	+++	+	+++	++
Direct costs	Low	Med	Low	Med
Investments	High	Low	High	Med
Low OH	+++	++	++	++
Large cores	+++	++	+++	++
Complex profiles	-	++	++	+++

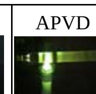
1.a VAD core process: Widely used for single mode fibers, being axial deposition, is most suitable for standard SMF652 and Zero water fibers. The direct production cost (materials, energy) remains the lowest with OVD Core. It is suitable to produce also pure silica but not adapted for multimode, NZDSF or fibers with custom profiles.. Conventional VAD deposition technology uses concentric-ring quartz burners, fabricated by glass working shops, and small deposition chamber air-flow with natural air flow. Nextrom has developed a novel VAD process, using metallic aperture burners and large forced air flow deposition chamber enabling a precisely repeatable process.

1.2 OVD core process: The OVD (Outside Vapor Deposition) process, is also a flame hydrolysis process. Productivity tends to be higher because of higher deposition rates, but OVD fibers show a higher hydroxyl ion absorption peak than do VAD fibers. The process being layer by layer, is suitable for more complex profiles, however protected by IP of Corning for LWPF.

1.3 MCVD and FCVD core processes: The MCVD (Modified Chemical Vapor Deposition) process, and it's enhanced version using a Furnace (FCVD) in place of a burner, is widely used still, but mostly adapted to fibers with more complex profiles, such as DSF, NZDSF, Graded Index, doped fibers for EDFA, Bend resistant fibers, PM fibers, ... While direct production cost are higher, investments in process equipments and infrastructure are kept lower than in soot processed. The use of a furnace instead of burners (FCVD) allows reducing OH during deposition, enables producing low water peak fibers, improving productivity and preform geometry, and by using low B/A and larger deposition tubes, enable producing preforms of about 120 mm diameter.

1.4 PCVD core process: The Plasma activated Chemical Vapor Deposition PCVD process, invented by Philips in 1980s, proprietary of Draka, is like MCVD/FCVD, an inside deposition process. The heat source used to sinter the deposited soot inside the substrate tube is created by an inside low pressure plasma, by an RF field, which allows to achieving very accurate control of layers sintering, giving more precise control of the index profile, particularly for graded index fibers, but also allows high incorporation of dopants, and fluorine for depressed fibers.

2. PREFORM CLADDING FABRICATION
The cladding affects mainly the main cost of the fiber and has in principle no influence on the optical fiber performance. The widely used processes include: OVD Clad, APVD (Plasma), and Sleeving with tube (RIT or RIC). A recent new process using Granulated Synthetic Silica Sand (SCT) from Silitec / Nextrom is presented.

	OVD 	APVD 	RIC 	Sand 
Productivity	High	Med	High	High
Direct costs	Low	Low	Med	Low
Investments	High	Med	Low	Med
B/A of core	Med	Med	Low	Low
Preform size	High	High	Very high	Med

2.1 Soot OVD Cladding: The most widely used, with low direct production costs . This is achieved only with a high yield process, large preforms, and high deposition rates machines. Because it is a "wet" process, the B/A of the core preforms been to be larger than when using dryer materials such as tubes or granulated silica. The investments for process equipments and infrastructure tend to be larger and are suitable for large plants with production volumes.

2.2 APVD Plasma Cladding : Advanced Plasma and vapor Deposition is a proprietary process from Draka, consisting of depositing natural granulated silica crystal sand through a Plasma torch towards a core rod, and growing the glass layer by layer. Direct costs are also low. The core rods need to have typically larger B/A than when tube sleeving is used, because the natural granulated silica can not be too close to the deposited core.

2.3 RIT/RIC Sleeving with Fuse Silica tubes: The Rod in Tube and Rod In Cylinder are the simplest cladding processes, and consist of sleeving the core rod with purchased high quality tube, from commercial vendors such as Heraeus. The sleeving can be offline or online during the draw process. Large cylinders with diameters up to 180 – 200 mm are available, and contribute to reduce direct material costs. This technology requires much less investments, in exchange of a more expensive material costs. Typical investments consist of large draw furnaces and preform handling tools.

2.4 A Novel Granulated Silica (Sand) Clad technology Silitec Fibers in Switzerland developed a novel flexible and cost effective cladding technology. In this casting process, silica sand is fused around the core rod with the help of a furnace [1].

Figure: Online Draw of a sand preform

The assembly, consisting of a core surrounded by a large thin wall tube, is filled by gravity with silica sand The sand is then fused into glass, either directly during draw process or separately on a vertical lathe. This last version allows using lower cost jacketing tubes which can be grinded prior to drawing. Silica sand is available is various forms, such as sol gel, synthetic crystal sand, fume silica. The process is relatively simple, and requires only limited infrastructure, i.e no scrubbers. The process has been used by Silitec Fibers since 2004, in its online version and since 2008 in the offline version.

3. DOPED PREFORMS FABRICATION

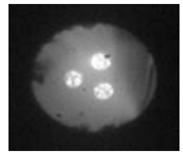
Doping fibers for EDFA or Laser applications require incorporating Rare Erath materials precisely, uniformly into the core, avoiding clustering, scattering. Core sizes tend to increase in high power applications and concentrations higher.

3.1 Solution Doping core MCVD preforms : The most widely used method consists of soaking the core rod with a doping solution containing rare earth materials. It is a cumbersome method which has it limits in repeatability and core sizes, limited by the MCVD process

3.2 DND : Liekki , now nLight developed a Direct nano-particle Deposition (DND), which is very similar to an OVD core process incorporating rare earth elements into the core burner in liquid form. The proprietary technique allows good repeatability, high RE concentrations and limited clustering.

3.3 Vapor Phase Doping : RE doping is achieved by delivering low vapor pressure high temperature reagents into a MCVD core process in gas phase; the control accuracy, repeatability and distribution have shown to give excellent results. Concentrations of Yb of 21 000 ppm and Er 10 000 ppm were achieved.

3.4 Doped Sand Technology : Silitec has developed a method for doping Sand used in core material. Silica sand can be easily doped by rare earth (RE) oxides. A Silica tube is filled with RE doped silica sand prepared from the solution doping technique or directly from RE oxides powders. The process is described in [1] is presented in this conference. The method has been used to produce LMA Yb3+ fiber and core rods up to 20 mm in diameter, with a high control of index homogeneity. The results are presented in this conference [2]. Ytterbium concentrations of about 3600 wt-ppm were estimated.



4. CLADDING OF MICROSTRUCTURED (PCF) AND MULTICORE PREFORMS

For PCF fibers, the stack and draw technique uses an assembly of capillaries around a central core. Maintaining good geometry and longitudinal uniformity is a challenge. For multicore or Panda fibers, drilling is required.

A novel technology, derived from the Sand Clad process has been developed by Silitec Fibers which introduces an elegant and flexible process for creating complex multicore or PCF fibers. The possibility to fix and stabilize complex and asymmetric structures in the sand before solidification is a key advantage. Capillary assemblies can be surrounded by sand including the interstitial voids between capillaries. The overall assembly can be solidified and collapsed to obtain a micro structured preform which can be qualified in geometry prior to draw. Silitec produced LMA PCF fibers with excellent geometry with this technique.

Conclusion

Fabrication technologies for telecom fibers are evolving driven by economic reasons, and tend to favor the most cost effective technologies combinations and larger preforms. Nextrom has introduced a wide range of new technologies, for VAD, OVD Clad, Sand clad, FCVD, and Large draw solutions to support this challenge. The fabrication technologies for Specialty fiber market is driven by new product requirements and significant innovations such as granulated silica techniques open the door to new ranges of fiber designs.

REFERENCES

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