



Alternative heat source for MCVD process

Improving capability & competitiveness of MCVD process



MCVD Process Today (1)

MCVD is a versatile process for fabrication of different types of optical fiber preforms:

- ✍ over nearly two decades it has proven itself capable of producing competitive telecommunication fibers and excels in fabrication of many specialty fiber types
- ✍ market situation has changed significantly, bringing additional requirements on fiber quality and new fiber types, while sales prices dropped significantly
- ✍ fiber makers, using MCVD technology, have to recognize these trends and adapt by:
 - ✍ reducing fabrication costs
 - ✍ increasing productivity through larger core preform size and improved jacketing
 - ✍ producing more sophisticated products with higher quality (low water peak, homogeneity)

Where are the limitations in improving MCVD process ?

- ✍ **in productivity:**
 - ✍ very thick cladding layer is required as a barrier against hydroxyl diffusion during high temperature processes
 - ✍ limited heat transfer from outer wall of the substrate tube (usually heated by a H₂/O₂ burner) to the inner wall
- ✍ **in attaining low water peak:**
 - ✍ presence of hydroxyl ions in the substrate tube
 - ✍ residual contamination of gases and reagents by hydrocarbons or hydroxyl
 - ✍ sensitivity to H₂ contamination
- ✍ **in preform homogeneity:**
 - ✍ uneven or deformed hot zone shape caused by heat source fluctuations
 - ✍ variations of tube diameter and wall thickness
 - ✍ uneven cooling conditions around the substrate tube
 - ✍ unstable reagent flow caused by fluctuations in gas delivery system



MCVD Process Limitations (2)

What process characteristics cause limitations in MCVD ?

- ✎ **the most important limitation comes from the fact that chemical reaction and vitrification of newly deposited glass layers happens inside a substrate tube:**
 - ✎ this protects the reaction and produced glass from contact with environment but
 - ✎ severely limits heat transfer from outer wall of the substrate tube (heated usually by a H₂/O₂ burner) to the inner wall or reaction zone
 - ✎ substrate tube outer surface has to be heated to a very high temperature for enough heat to be conducted to the inner tube surface, often causing tube bending, diameter changes and ovality
 - ✎ when deposition of glass layers advances, the tube wall becomes progressively thicker, further reducing the efficiency of heat transfer and eventually preventing successful vitrification of deposited glass layers
- ✎ **substrate tube purity is another limitation:**
 - ✎ hydroxyl ions are present in traces (typically 0,1 ppm) in the substrate tube and diffuse into deposited glass during high temperature process stages (collapse, jacketing, fiber drawing), causing so-called **water peak**
- ✎ **heating through thick wall by H₂/O₂ burner often results in reduced preform homogeneity:**
 - ✎ preform has dimensional variations of deposited layers both in thickness and refractive index
 - ✎ preform is bent or tube and preform walls are deformed, affecting future fiber geometrical and optical characteristics



Overcoming MCVD Process Limitations (3)

How to overcome process limitations ?

- ✂ while waiting for substrate tubes with reduced hydroxyl content, analysis shows us that any improvements to MCVD process depend strongly on heat transfer from outer to inner substrate tube wall
- ✂ **H2/O2 burners as heat sources for fabrication of larger and more homogenous preform have several limitations:**
 - ✂ heat transfer from the burner to the tube is inefficient
 - ✂ the heat conduction from outer to inner tube surface is slow and it decreases quickly with increased wall thickness
 - ✂ burner generates uneven hot zone pattern and pressure field on tube, possibly leading to deposition and vitrification inhomogeneities
 - ✂ many burner models are difficult to maintain and set, some of them may cause glass contamination
- ✂ therefore, the first step in improving MCVD process is the replacement of H2/O2 burner by more efficient and consistent heat source
- ✂ **the new heat source should provide:**
 - ✂ improved heat transfer from tube outer to inner wall
 - ✂ stable and uniform preform hot zone
 - ✂ vitrification of thicker layers
 - ✂ fast collapse
 - ✂ reduce heat source influence on preform and fiber geometry
- ✂ **furnace as heat source meets above requirements:**
 - ✂ furnaces are common in fiber factories and everybody knows how to use them
 - ✂ heat is transferred mostly by radiation and does not rely on heat conduction through insulator as it is the case with the burner
 - ✂ furnace provides uniform and axially homogenous hot zone
 - ✂ test results show that furnace gives better results than other solutions



Heat transfer:

- ✂ heat transfer from heating body (graphite) to the tube is similar to draw furnace, i.e. by radiation
- ✂ this eliminates the need to heat the tube outer wall excessively, creating large temperature gradient between outer and inner tube wall
- ✂ the lag (or distance) between hot zone position on outer and inner wall is also minimized
- ✂ tube remains transparent during deposition process and permits more exact temperature control of the process to enhance dopant incorporation and reduce cost
- ✂ furnace is equipped by a pyrometer, but process control can be done by furnace power control
- ✂ concern:
 - ✂ tube temperature is one of the main parameters in MCVD deposition, can a pyrometer be used efficiently with a furnace?
 - ✂ **pyrometer can be used, but its main function is calibration and detection of variations in furnace performance (graphite element deterioration, variations in power, ...)**



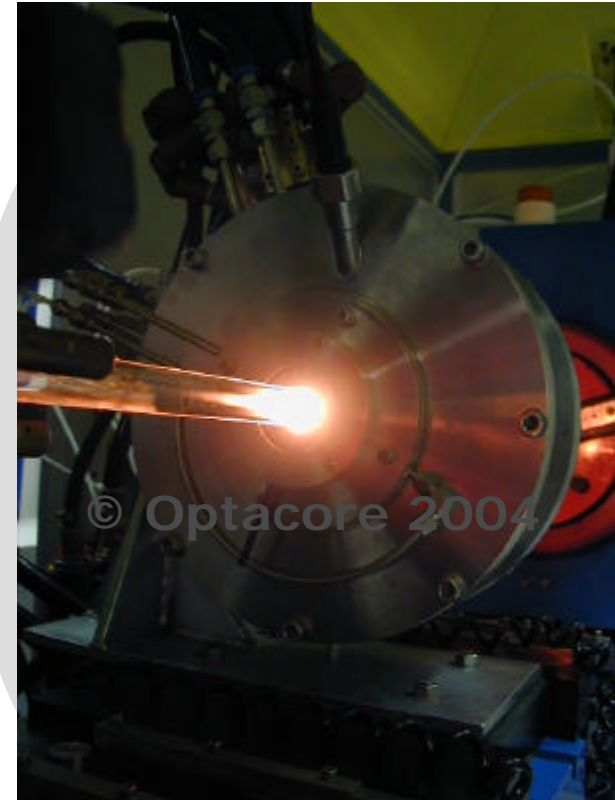


Hot zone homogeneity:

- ✂ furnace hot zone shape is axially and longitudinally more stable and better defined as burner hot zone
- ✂ use of furnace allows hot zone length and shape to be re-designed and adapted, if it influences final product characteristics
- ✂ heat is supplied from all directions, not only from half-circle as with common MCVD burners
- ✂ concern:
 - ✂ burner flame supports the tube, will it not sag in the hot zone even more if a furnace is used?
 - ✂ **no, rotation is sufficient to prevent sagging, careful design and proper gas flows actually improve preform geometry!**

Flame losses

- ✂ when H₂/O₂ burners are used, a large amount of silica is evaporated from tube surface due to:
 - ✂ impact of gas (water vapor) against hot tube wall
 - ✂ reaction of water molecules with silica
- ✂ there is practically no flame loss when using furnace
- ✂ concern:
 - ✂ burner flame purifies the tube surface by etching away glass—what will happen when furnace is used ?
 - ✂ **preforms need to be properly surface etched before jacketing process !**





Temperature control and stability:

- ✍ temperature control is stable, but allowance has to be made for furnace thermal inertia
- ✍ process can be run by furnace power setting without a pyrometer in a control loop, but it is safer to use pyrometer to check on furnace operating conditions
- ✍ deposition process is less sensitive to temperature variations (vitrification conditions) than in process using burner
- ✍ concern:
 - ✍ not being able to see the hot zone will prevent engineers from properly controlling reaction and deposition conditions
 - ✍ **it takes some time for process specialists and operators to adapt to new procedures, but once mastered this situation does not interfere with process control!**

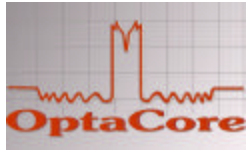
Collapse speed:

- ✍ with the same tube size and deposition thickness, furnace provides nearly double collapsing speed, saving about 20 - 25% of overall fabrication time (depending on preform type)
- ✍ in optimized conditions the geometry of the preform remains excellent or may even improve from deposition stage
- ✍ collapsing conditions favorably influence fiber optical characteristics



Current activities:

- ✍ At the moment different furnace types and constructions are under consideration to determine:
 - ✍ the difference between inductive and resistive furnace design as to the achieved results, cost and obtained fiber characteristics
 - ✍ the optimum length of the hot zone for different process conditions
 - ✍ whether one design can be equally well used for deposition and collapse process
 - ✍ furnace designs for use on horizontal as well as on vertical lathes
 - ✍ pyrometer sensing techniques which can work with leak tight internal furnace construction
- ✍ Confirm that fibers produced with this process do not have any defects or inferiorities compared to fibers made by standard process
- ✍ Calculate or evaluate costs and benefits of a change from burner to furnace, to show feasibility to a large or small scale fiber plant
- ✍ Show advantages of furnace supported process (in fabrication of single mode or multimode fiber preforms) in our lab in Ljubljana, Slovenia
- ✍ Develop and optimize inductive furnace design for CVD use in cooperation with Photonium Oy, Finland



Conclusions:

- ✍ Furnace is a suitable heat source for MCVD process and it is a good replacement for H₂/O₂ burners, but it has to be custom developed for typical deposition and collapse conditions, to provide optimum results, both in regard to fiber quality and production cost
- ✍ Optacore will further develop MCVD process using furnaces, as well as participate in furnace design, to ensure this process stays competitive to other fabrication processes, both in standard and special fiber fabrication
- ✍ Optacore is interested to offer its support to interested customers in choice of hardware, implementation of furnace process or in common development of process or equipment