Manufacturing of optical Fibers

Preparation of optical fiber

For proper performance of optical fibers it is essential that :

1) Optical fibers may be produced with good stable transmission charac. in long lengths at a min. cost & with max. reproducibility.
2) A range of optical fiber types with regard to size, RI & index profiles, operating wavelengths, materials etc., be available in order to fulfill many diff. system applications.
3) The fibers may be converted into practical cables which can be handled easily.
4) fibers & fiber cables may be terminated & connected together easily.

→ Variation of RI inside the OF is required..
at least two diff. materials which are transparent to light over the major operating wavelength range (0.8 to 1.7 μm) are req.

→ Material should show low absorption & scattering losses & low attenuation.
∴ glasses or monocrystalline structures like plastics.

→ For graded index fibers, glass is suitable.

...tion of glass fibers is a 2-stage ...in which initially the pure glass is ...duced & converted into a form (rod or ...form) suitable for making the fiber. A drawing or pulling tech. is then employed to acquire the end product.

2 major categories for preparing pure optical glasses :-

a) conventional glass refining techniques in which the glass is processed in the molten state (melting methods) producing a multi-component glass structure.

b) vapor-phase deposition methods producing silica-rich glasses which have melting temperatures that are too high to allow the conventional melt process.

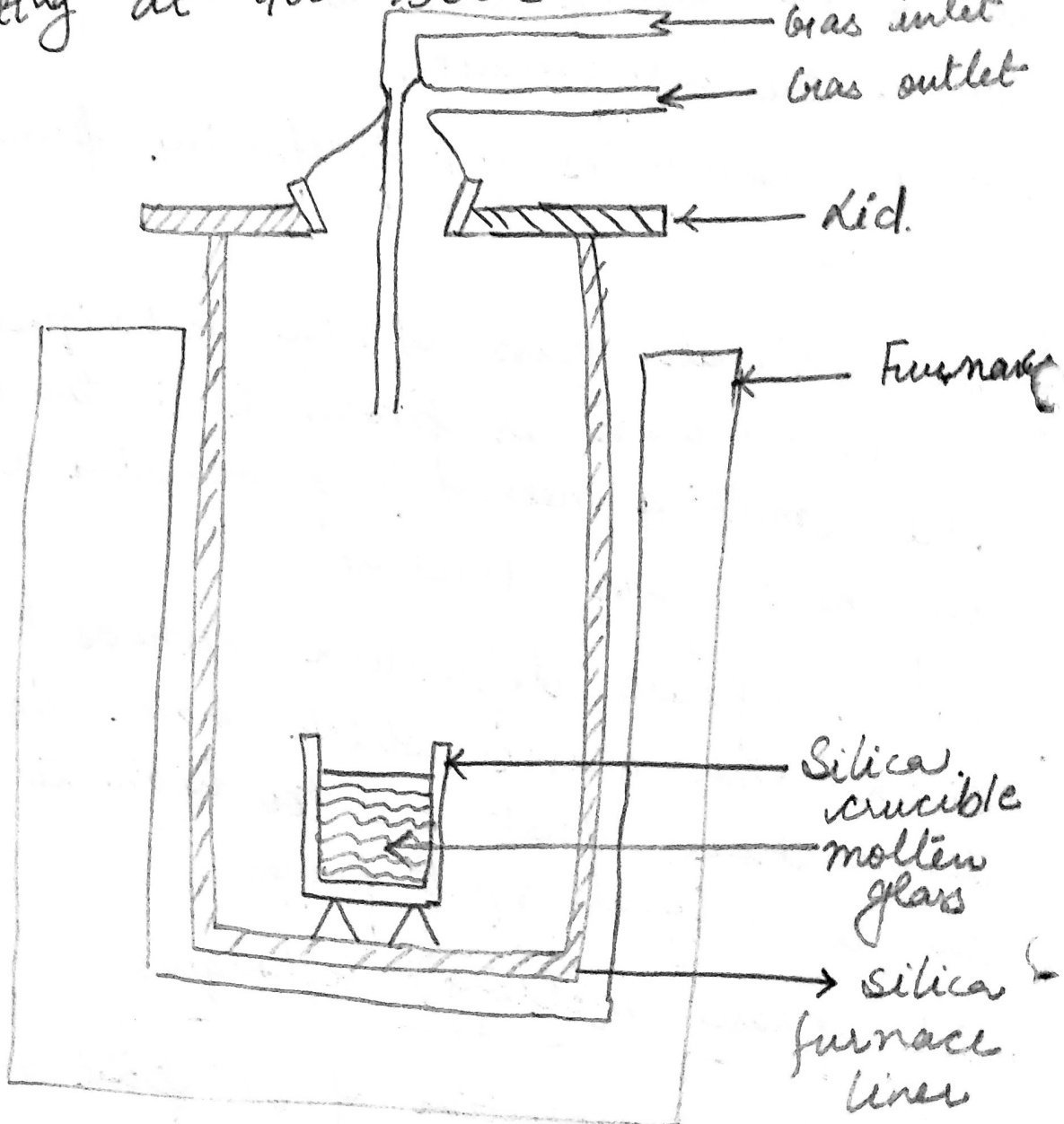
Liquid-phase (melting) techniques

→ Firstly the preparation of ultapure material powders which are usually oxides or carbonates of the req- ~~cosite~~ constituents. eg :- SiO_2, GeO_2, B_2O_2 & A_2O_3 & Na_2CO_3, K_2CO_3, $CaCO_3$ & $BaCO_3$

→ melting of ~~ki~~ these high-purity, powdered, low-melting-point glass materials to form a homogeneous, bubble-free multicomponent

→ RI variations are achieved by either a [illegible] the composition of various constituents or by exchange when the materials are in the molten phase.

→ melting at 900 - 1300°C in silica crucible.



Glassmaking furnace for high-purity glasses production.

→ silica crucible can give dissolution into the melt which may introduce inhomogeneities into the glass.

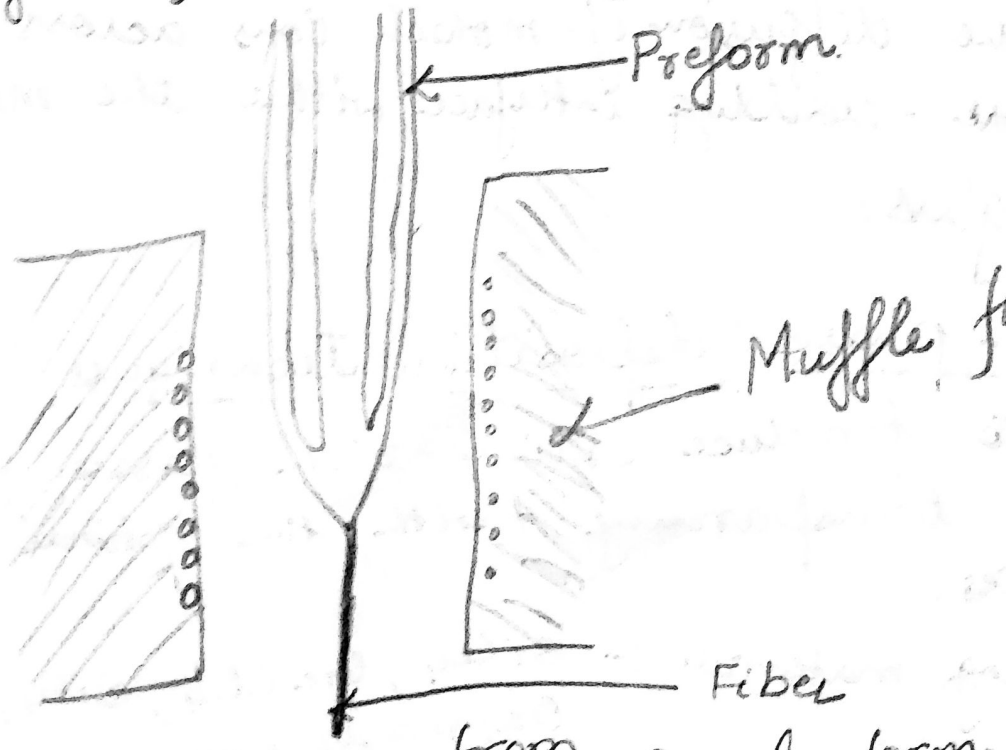
→ another option :- RF induction furnace.

is homogenized & dried by bubbling pure ~~glass~~ gases through the melt, while protecting against any airborne dust particles either originating in the melt furnace or present as atmospheric contamination.

→ After that melt is cooled & formed into long rods (cane) of multicomponent glass

Fiber Drawing

→ Original technique :- to make a preform using the rod in tube process. A rod of glass was inserted into a tube of cladding glass & the preform was drawn in a vertical muffle furnace.



Optical fiber from a perform

→ problem of attenuation, can be used for SI fibers

→ Double-crucible method :-
(especially for graded index fibers)

⇒ cored & cladding glass in the form of separate rods is fed into two concentric platinum crucibles.

→ assembly is located in a muffle furnace capable of heating the crucible contents to a temp. of b/w 800-1200°C.

→ crucibles have nozzles in their bases from which the clad fiber is drawn directly from the melt.

→ Index grading may be achieved through the diffusion of mobile ions across the core-cladding interface within the molten glass.

Vapor-phase deposition techniques

→ used to produce silica-rich glasses of the highest transparency & with the optimal optical properties.

→ Starting materials :- $SiCl_4$, $GeCl_4$, SiF_4, BCl_3, O_2, BBr_3 & $POCl_3$

→ vapor-phase dopants (for RI) :- TiO_2, GeO_2, P_2O_5, Al_2O_3, B_2O_3 & F.

used for ST fibers

mixtures of the silica-containing compound, doping material & oxygen are combined & hence the deposition of oxide occurs.

→ deposition is usually onto a substrate or within a hollow tube & is built up as a stack of successive layers. Hence the dopant concentration may be varied gradually to produce a graded index profile.

→ directly results in a solid rod or preform whereas the hollow tube must be collapsed to give a solid preform from which the fiber may be drawn.

flame hydrolysis
chemical vapor deposition (CVD)

Outside vapor-phase oxidation process.

→ uses flame hydrolysis

→ required glass composition is deposited laterally from a 'soot' generated by hydrolyzing the halide vapors in an oxygen-hydrogen flame.

→ Oxygen is passed through the appropriate silicon compound which is vaporized, removing

any impurities.

→ Dopants such as $GeCl_4$ or $TiCl_4$ are added the mixture is blown through the oxygen hydrogen flame!

$$SiCl_4 + 2H_2O \xrightarrow{heat} SiO_2 + 4HCl$$

$$\text{f } SiCl_4 + O_2 \xrightarrow{heat} SiO_2 + 2Cl_2$$

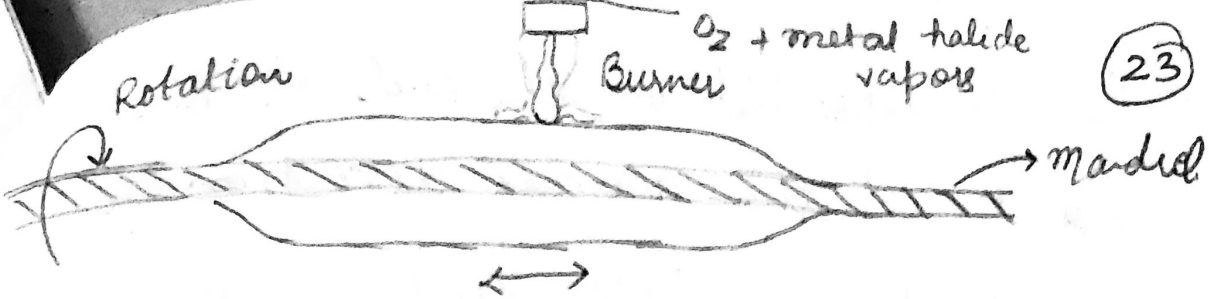
$$GeCl_4 + O_2 \xrightarrow{heat} GeO_2 + 2Cl_2$$

$$\text{or } TiCl_4 + O_2 \longrightarrow TiO_2 + 2Cl_2.$$

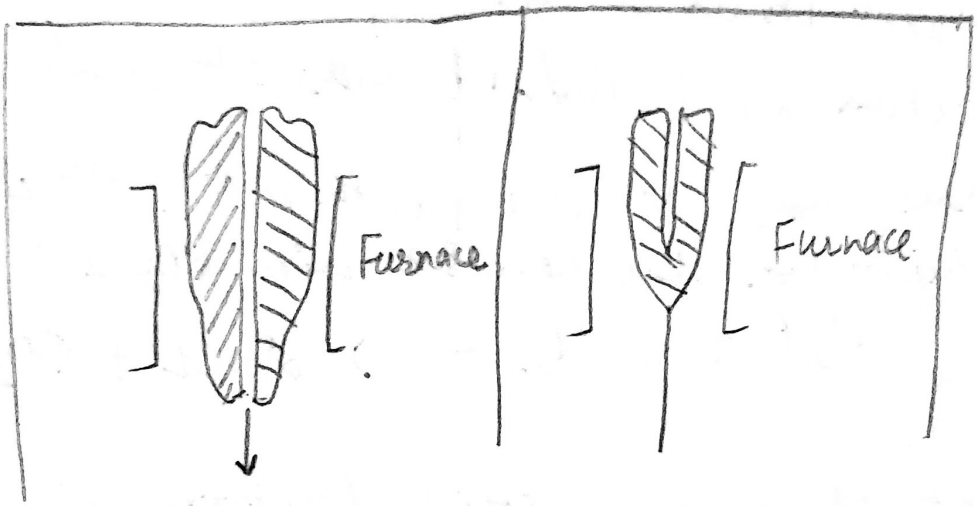
→ Silica is generated as a fine soot which is deposited on a cool rotating mandrel.

→ the flame of the burner is reversed back & forth over the length of the mandrel until a sufficient no. of layers of silica are deposited on it.

→ When this process is completed the mandrel is removed & the porous mass of silica soot is sintered.



a) soot deposition



b) fiber drawing.

→ Fine control of the index gradient for graded index fibers may be achieved using this process as the gas flows can be adjusted at the completion of each traverse of the burner.

Vapor axial deposition (VAD)

Fig 4.8

→ uses an end-on deposition onto a rotating fused silica target.

→ vaporized constituents are injected from burners & react to form silica soot by flame hydrolysis -

→ this is deposited on the end of the start. target in the axial direction forming a solid porous glass preform in the shape of a boule.

→ preform which is growing in the axial direction is pulled upwards at a rate which corresponds to the growth rate. It is initially dehydrated by heating with $SOCl_2$:-

$$H_2O + SOCl_2 \longrightarrow 2HCl + SO_2$$

→ sintered into a solid preform in a graphite resistance furnace at an elevated temp. of around 1500°C.

→ A spatial refractive index profile may be achieved using the deposition properties of $SiO_2 - GeO_2$ particles within the oxygen-hydrogen flame.

→ Suffer from some OH impurity content due to the flame hydrolysis.

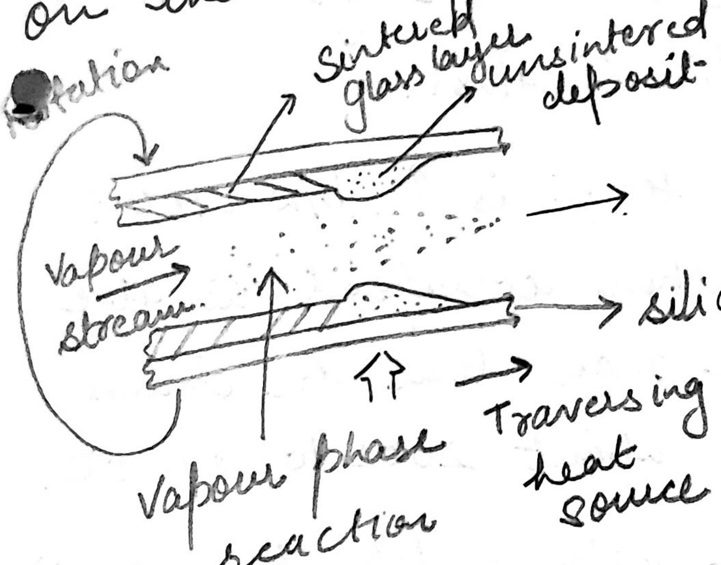
Modified chemical vapour deposition (MCVD)

→ An easily oxidized reagent such as SiH_4 diluted by inert gases + mixed with oxygen is ~~boog~~ brought into contact with a heated silica surface where it forms a glassy transparent

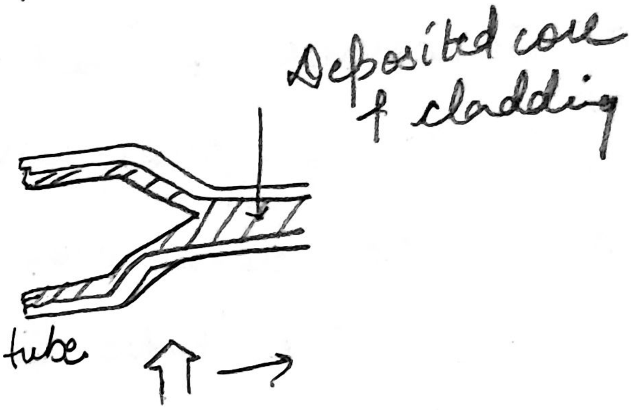
film.

& MCVD, the vapour phase reactants (halide and oxygen) pass through a hot zone so that a substantial part of the reaction is homogeneous.

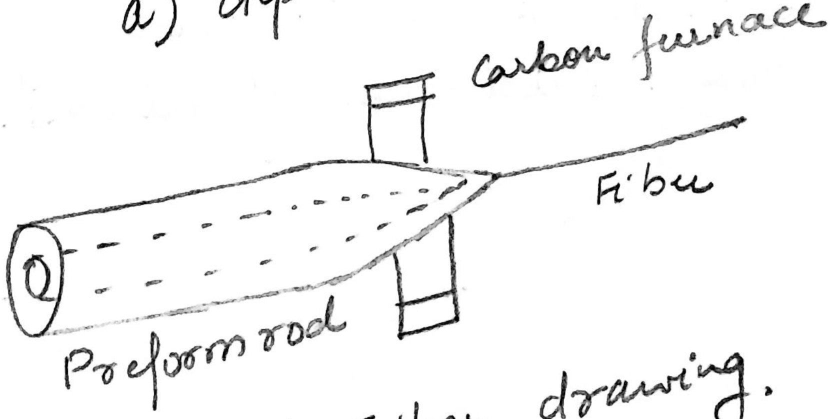
→ Glass particles formed during this reaction travel with the ~~glass~~ gas flow & are deposited on the walls of the silica tube.



a) deposition



b) collapse to produce a preform



c) Fiber drawing.

→ The hot zone is moved back & forth along the tube allowing the particles to be deposited on a layer basis giving a sintered transparent

silica film on the walls of the tube.

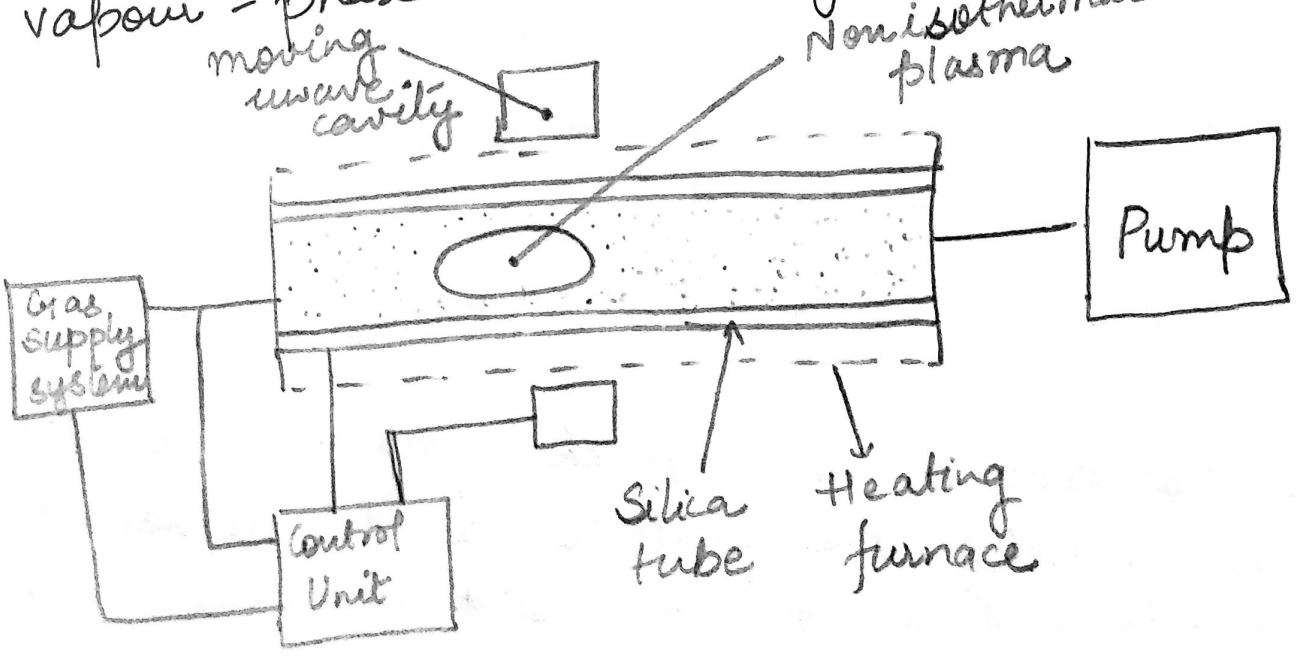
→ When sufficient thickness has been formed the successive traverses of the burner to the cladding, vaporized chlorides of germanium ($GeCl_4$) or phosphorous ($POCl_3$) are added to the gas flow.

→ core glass is formed by the deposition of successive ~~added to~~ layers of germano-silicate or phosphosilicate glass.

→ After the deposition, temp. is ↑ b/w 1700 & 1900°C. The tube is then collapsed to give a solid preform which may then be drawn into fiber at temp. of about 2000 to 2200°C.

Plasma-activated chemical vapour deposition (PCVD)

→ Use of plasma to supply energy for the vapour-phase oxidation of halides.



ulation of oxide formation by means
non-isothermal plasma maintained at
pressure in a microwave cavity (2.45 GHz)
ch surrounds the tube.
stile reactants are introduced into the
e where they react heterogeneously within
uwave cavity, & no particulate matter
formed in the vapour phase.

he reaction zone is moved backwards &
forwards along the tube by control of the
uwave cavity & a circularly symmetric layer
growth is formed.

1050°C.

When the plasma zone is moved rapidly
backwards & forwards along the tube, very
thin layer deposition may be achieved
giving the formation of upto 2000 individual
layers. This enables very good graded index
profiles to be realized which are a close
approximation to the optimum near parabolic
profile.