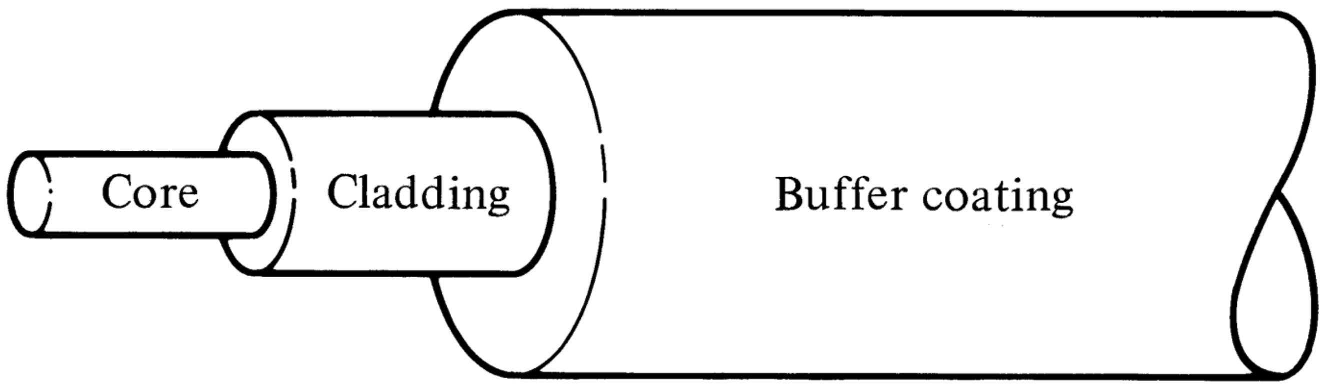
OPTICAL FIBER Materials

Manufacturing-II

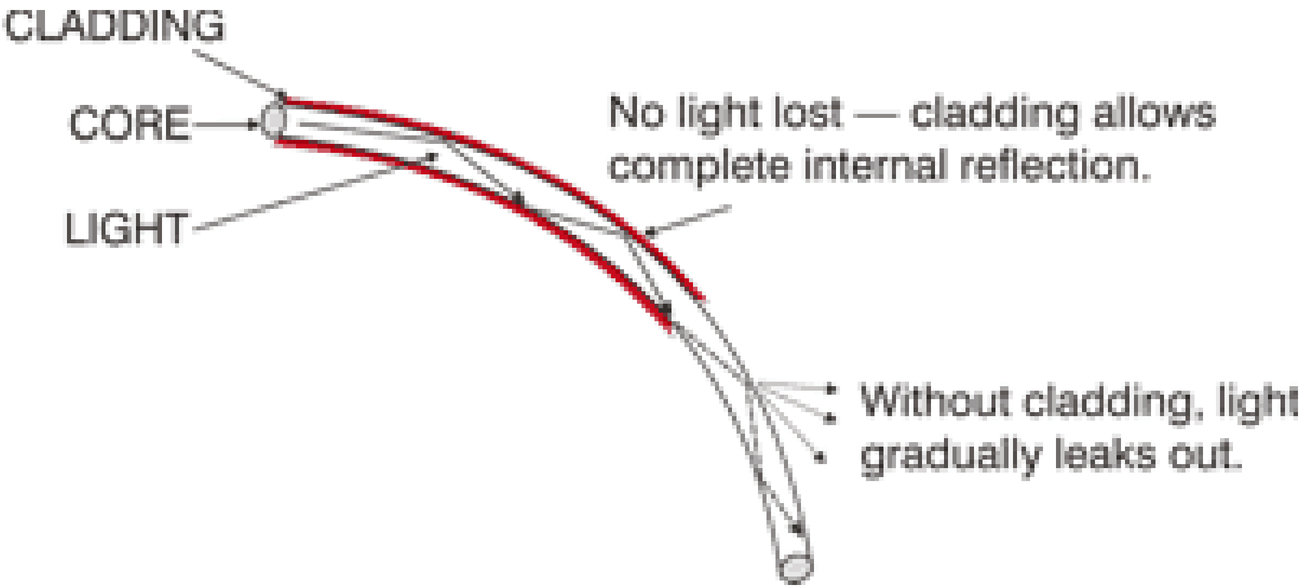
Fiber Structure



- An optical fiber is a long cylindrical dielectric waveguide, usually of circular cross-section, transparent to light over the operating wavelength.
- A single solid dielectric of two concentric layers. The inner layer known as **Core** is of radius **'a'** and refractive index **'n_1'**. The outer layer called **Cladding** has refractive index **'n_2'**.

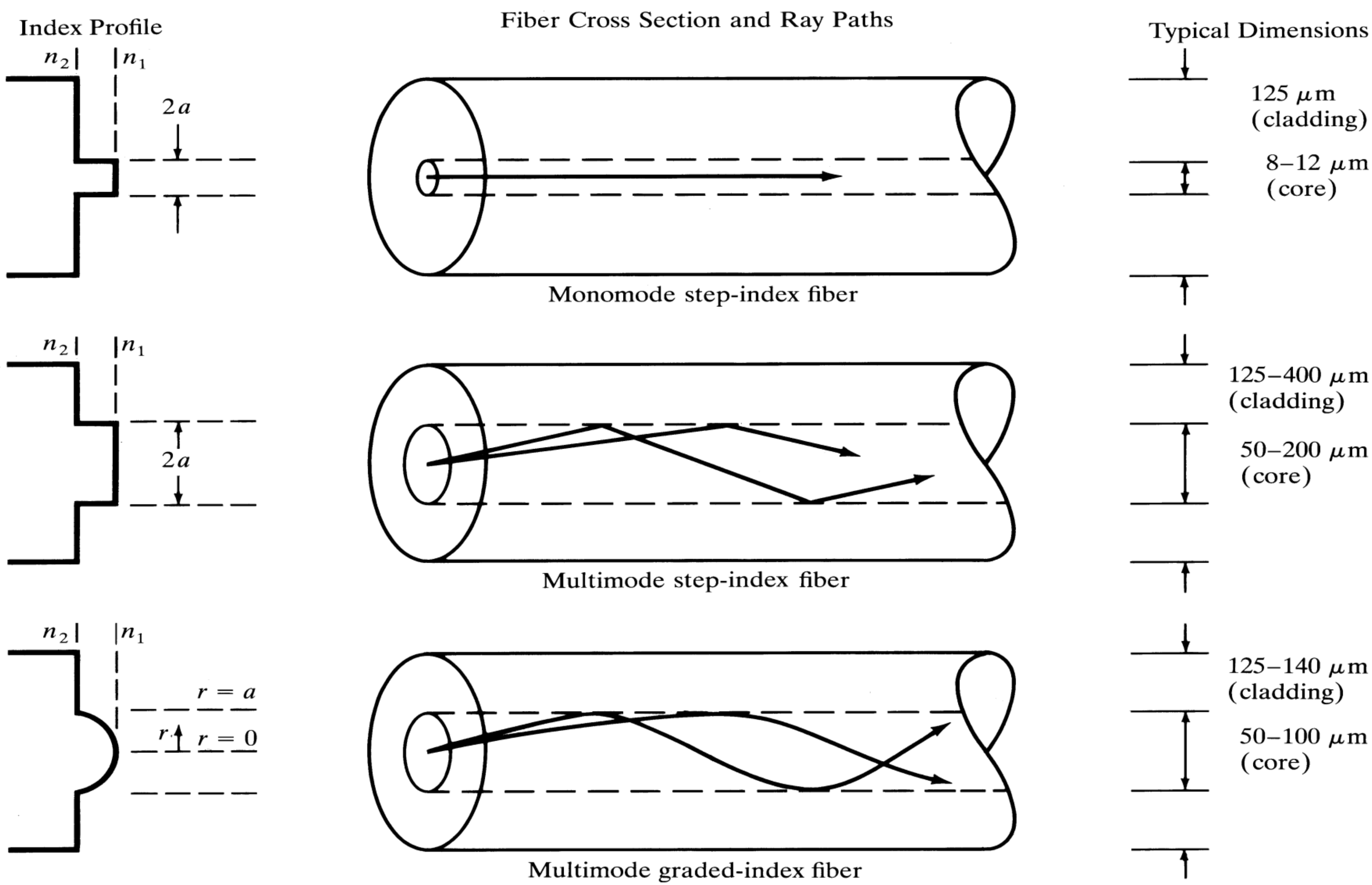
$n_2 < n_1$ → **condition necessary for TIR**

Light Propagation through Optical Fiber



- **Must meet the conditions for Total Internal Reflection (TIR)**

Step Index / Graded Index



DESIGNER'S PARAMETERS

Numerical Aperture (NA) : NA = $\sin\theta_a = [(n_1)^2-(n_2)^2]^{1/2}$

0.12-0.15 for SMF, 0.15-0.25 for MMF

Relative Refractive Index Difference (Δ):

$\Delta = (n_1 - n_2)/n$; n- the average refractive index

$< 0.4\%$ for SMF, $>1\%$ for MMF

Normalized Frequency or **V-Number:**

$V = [(2\pi a)/\lambda]$ NA

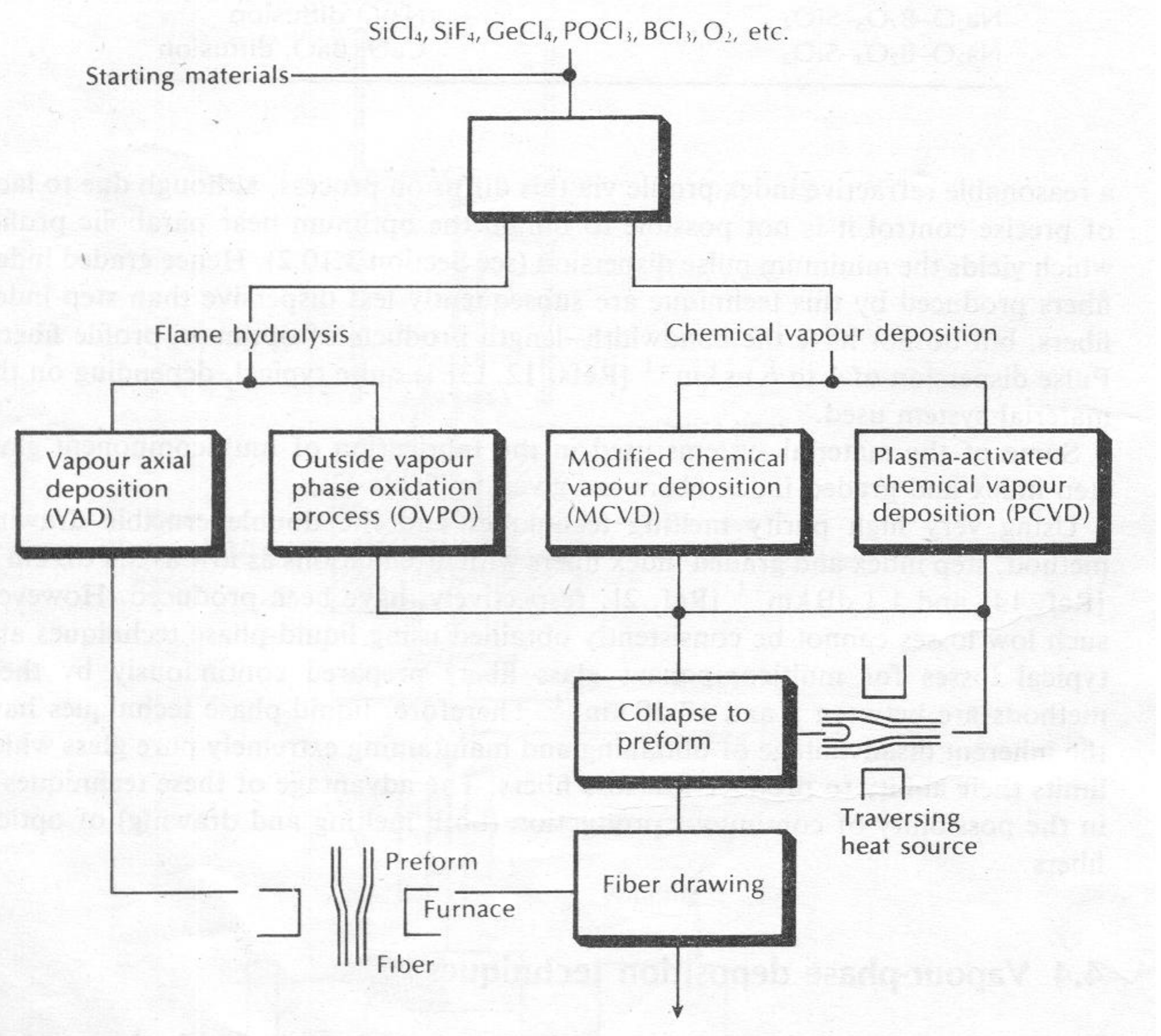
$V \leq 2.405$ for SMF; ≥ 10 for MMF

Schematic of Vapour-Phase Deposition Techniques

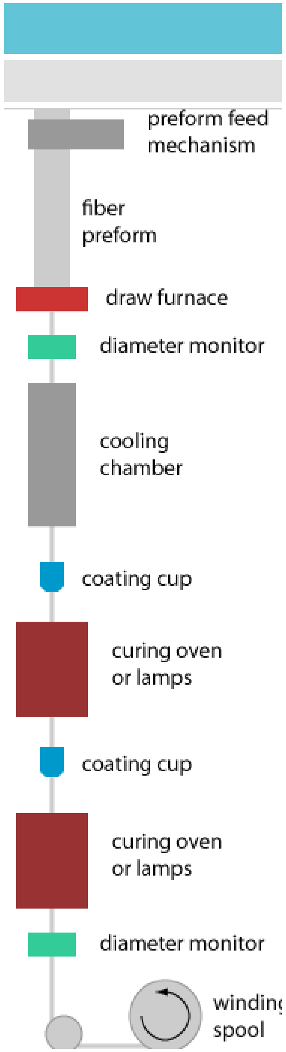
- **For Silica rich glasses**

✓ High transperency

✓ Optimuml optical properities.



Step-II-Fiber Drawing

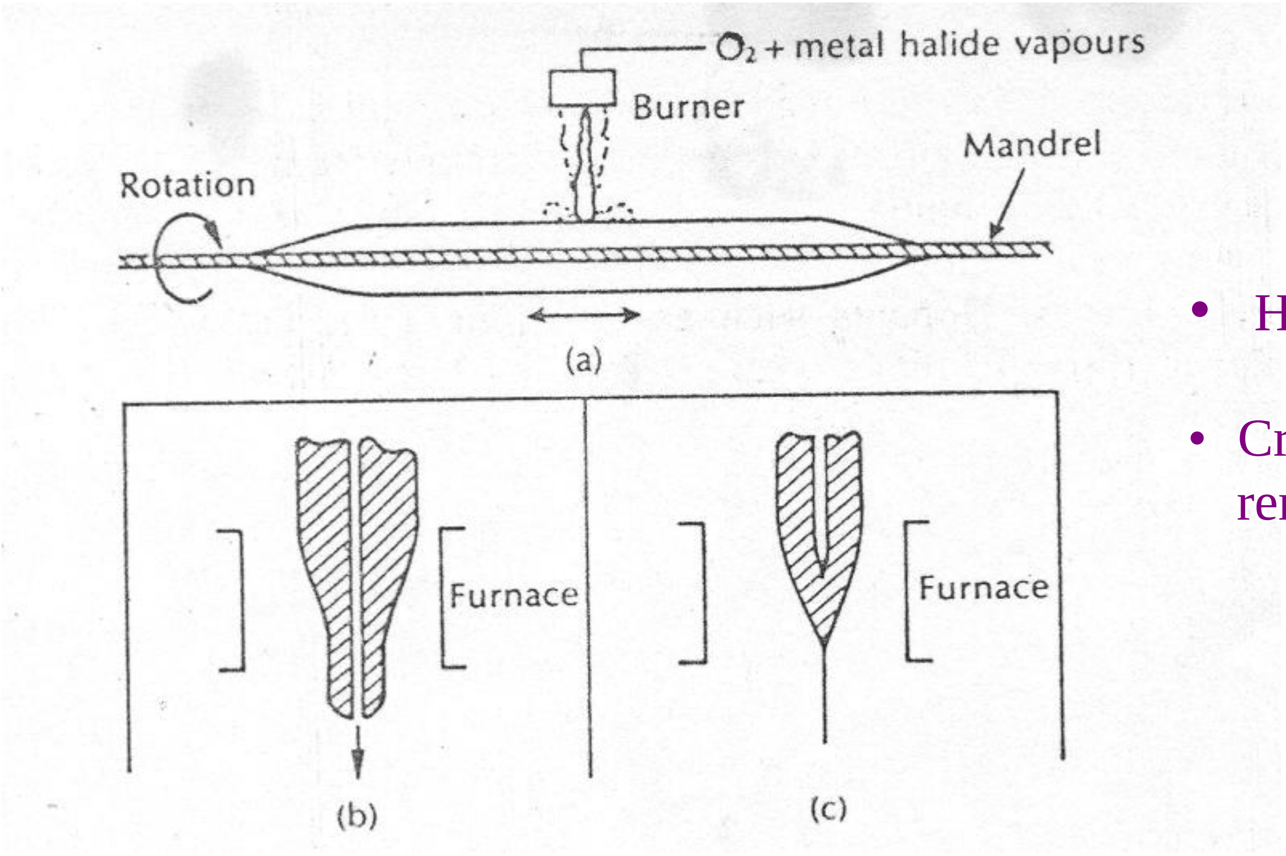


- **Rod in tube** process
- Useful only for Step Index fibers with large core and cladding diameters.
- ***Bubbles & particulates*** at interfaces
- 5-10 dB/km loss

Optical Fiber from a Preform.

Outside Vapour-Phase Oxidation (OVPO) Process

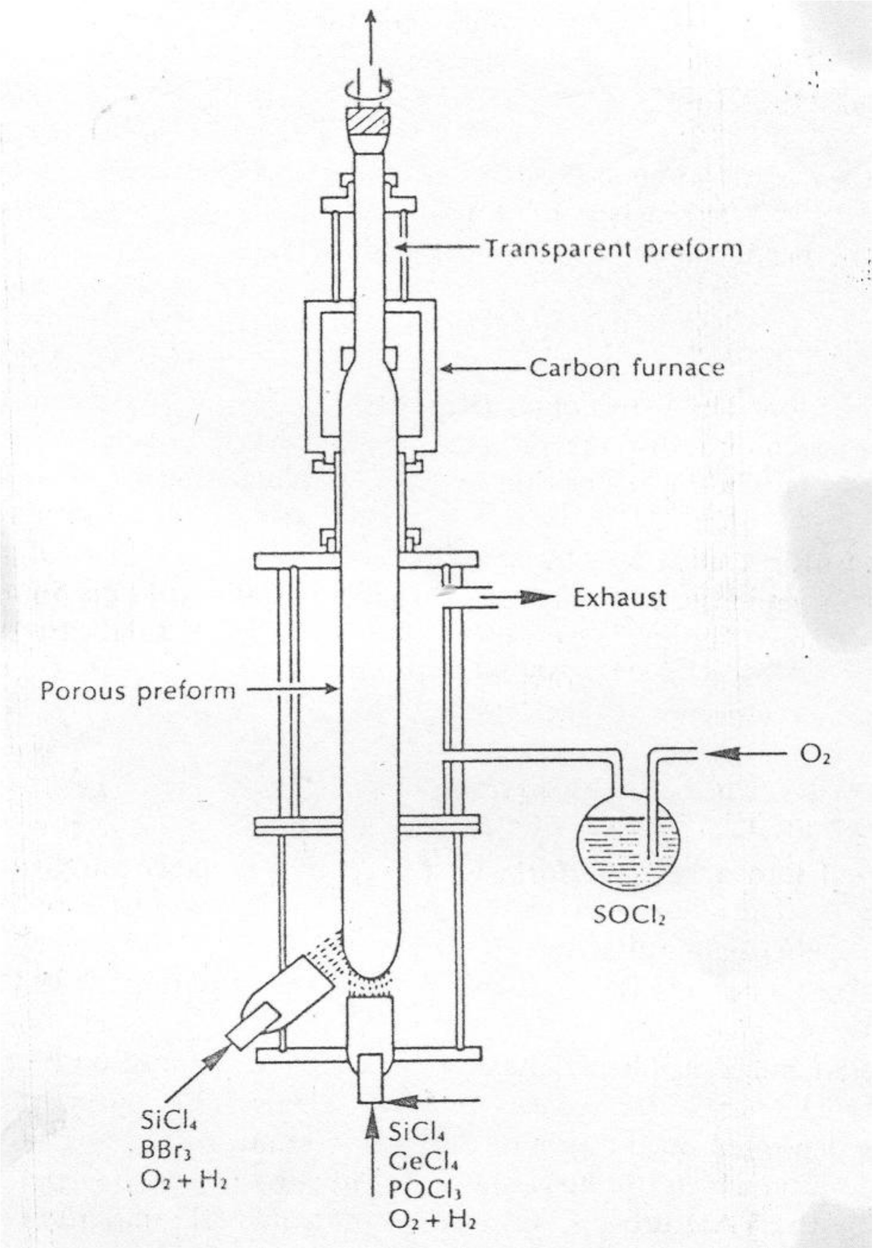
- Uses Flame hydrolysis for **'Soot'** Formation



- High OH impurity content
- Cracks during mandral removal

OVPO Process: (a) Soot deposition, (b) Preform Sintering (c) Fiber Drawing

VAD Process



The VAD Process

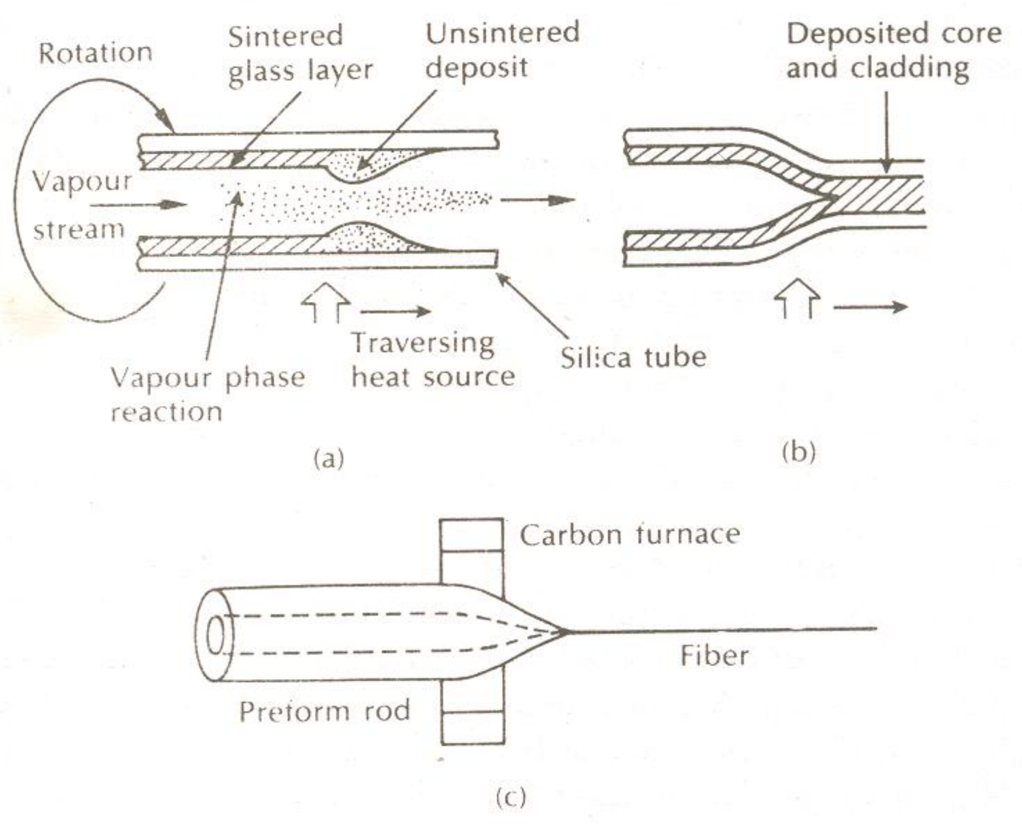
- End-on deposition
- Typical OH content between 50-200 PPM
- Reduced by applying chlorine as drying agent
- Typical Temp. 1500 ^{O}C
- Losses as low as 2 dB/km

Difficulties:

- Cracks while removing mandral
- Depression in RL profile near centre due to collapsed hole.

MCVD Techniques

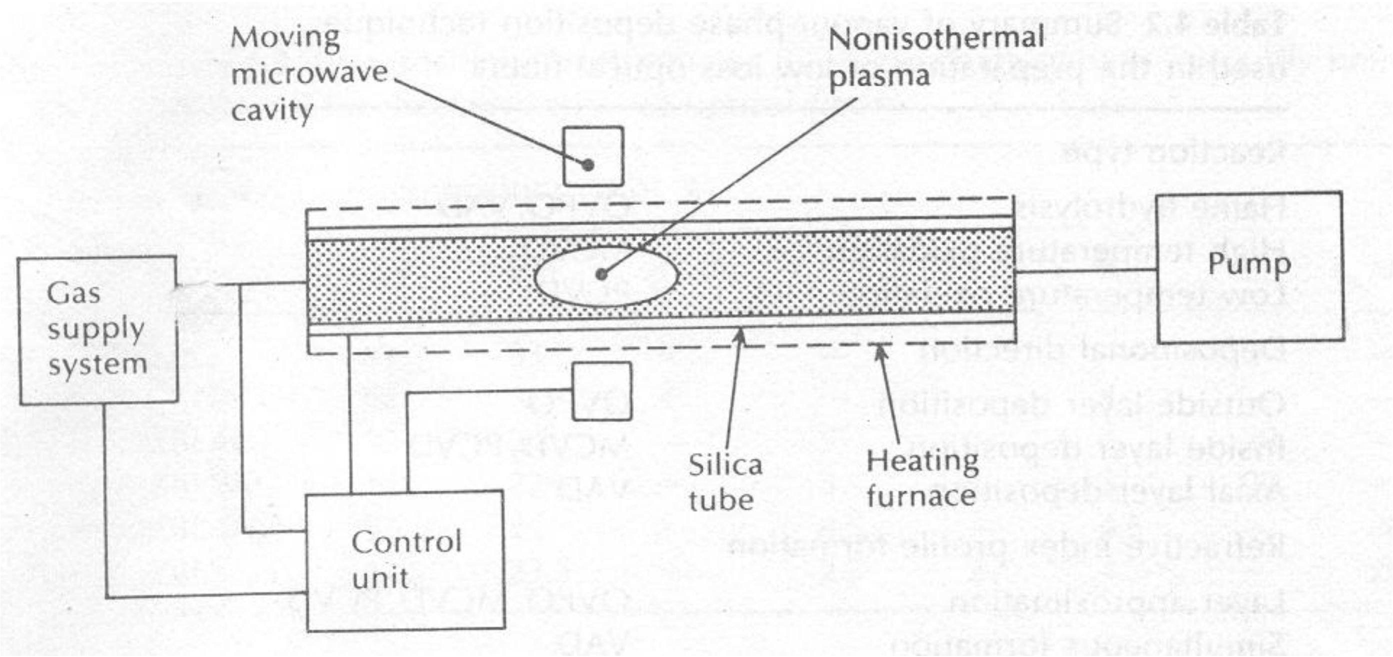
- Modified Chemical Vapor Deposition (MCVD)
  - An inside vapour phase oxidation (IVPO) method
  - vaporized raw materials are deposited into a pre-made silica tube



- Deposition within an enclosed reactor-very clean environment
- Fiber formation 1400-1600 ^{O}C, drawing at 2000 - 2200 ^{O}C
- Reduced OH impurity
- Minimum losses of only 0.2 dB/km at 1550 nm

PCVD Technique

- Plasma Activated Chemical Vapour Deposition
  - A variation on the MCVD technique to use plasma to supply energy for the vapour-phase oxidation of halides.
  - Film deposition at around 1000 ^{O}C

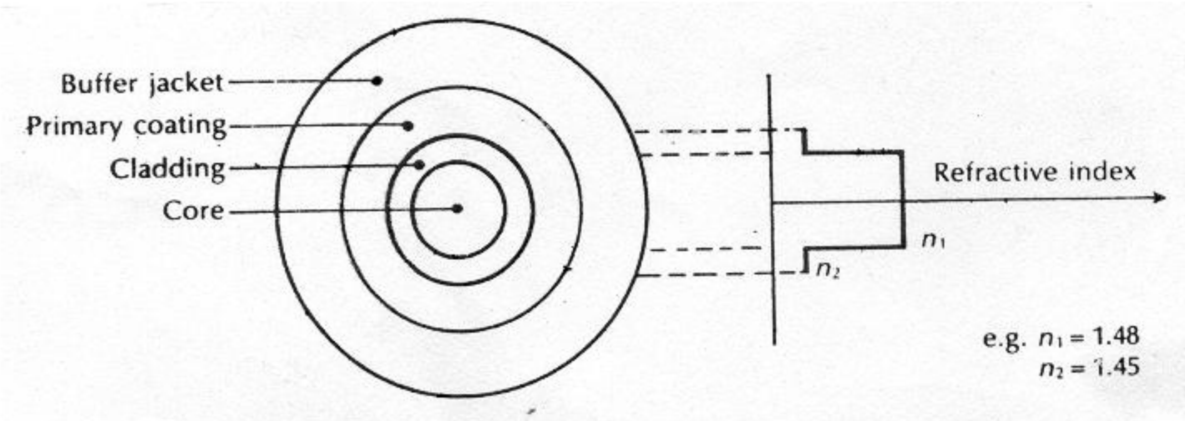


➢ Provide controlled and high uniformity of layers

Different types of Commonly used OFs:

- Multimode step index fibers
- Multimode Graded index fibers
- Single mode fibers
- Plastic clad fibers
- All Plastic fibers

Multimode Step Index Fibers



Typical structure for a glass multimode step index fiber.

Structure

Core Diameter	:	50 to 400 μm
Cladding Diameter	:	125 to 500 μm
Buffer Jacket	:	250 to 1000 μm
Numerical Aperture	:	0.16 to 0.5

- Fabricated from either from multicomponent glasses or doped silica.
- Have reasonably large core diameters and large NAs to facilitate efficient coupling to incoherent sources such as LEDs.

- Performance characteristics depends on the materials used and the methods of preparations
- Doped silica fibers exhibit the best performance

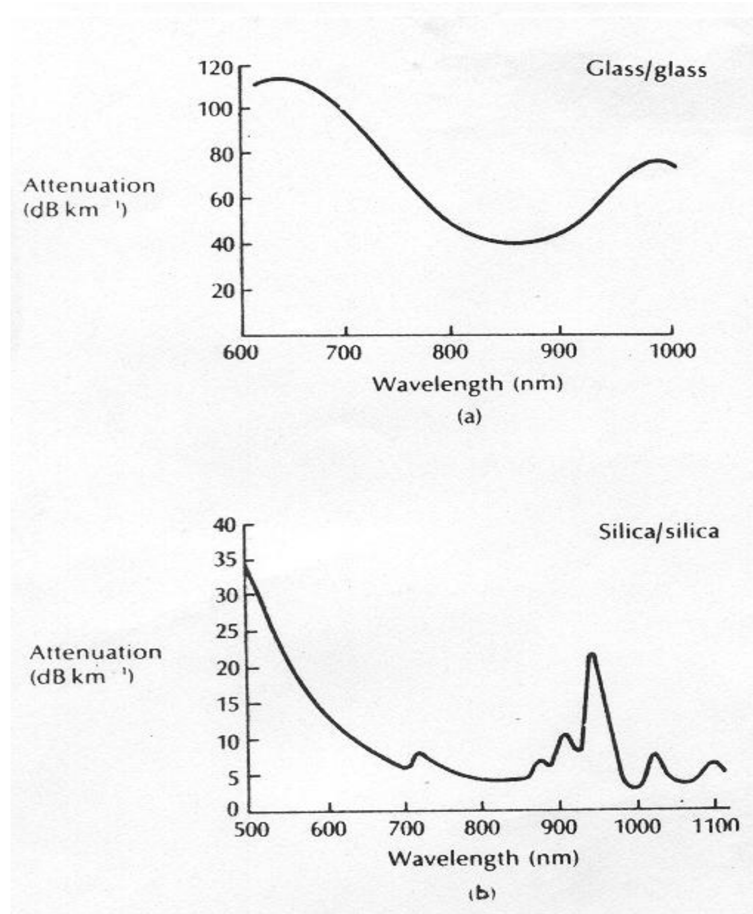
Attenuation : 2.6 to 50 dB/km at 850 nm,

  - Limited by absorption or scattering.
  - Wide variation in attenuation is due to differences between two preparation methods

Bandwidth : 6 to 50 MHz km.

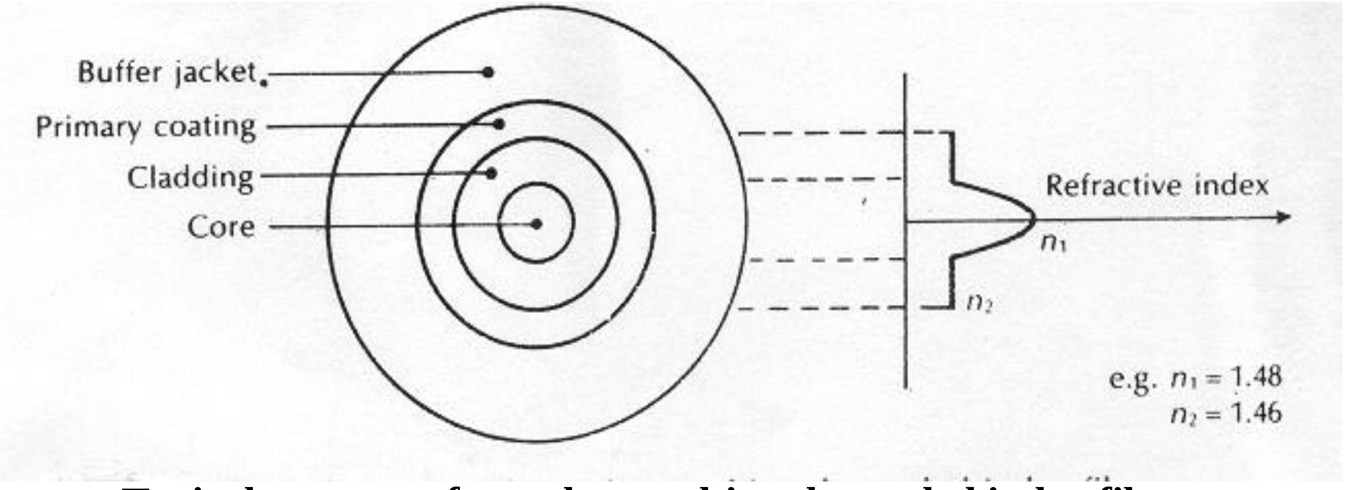
Applications: Best suited for

  - short-haul,
  - Limited bandwidth and
  - Relatively low cost applications.



Attenuation Spectra for MMSIF:
(a) Multicomponent glass fibers
(b) doped silica fibers.

Multimode Graded Index Fibers



Typical structure for a glass multimode graded index fiber.

Structure

Core diameter	:	30 to 100 μm
Cladding diameter	:	100 to 150 μm
Buffer jacket diameter	:	250 to 1000 μm
Numerical aperture	:	0.2 to 0.3.

- Fabricated using MC glasses or Doped Silica
- Manufactured from materials with higher purity
- Better performance due to **index grading** and **lower attenuation**

Performance Characteristics

Attenuation:

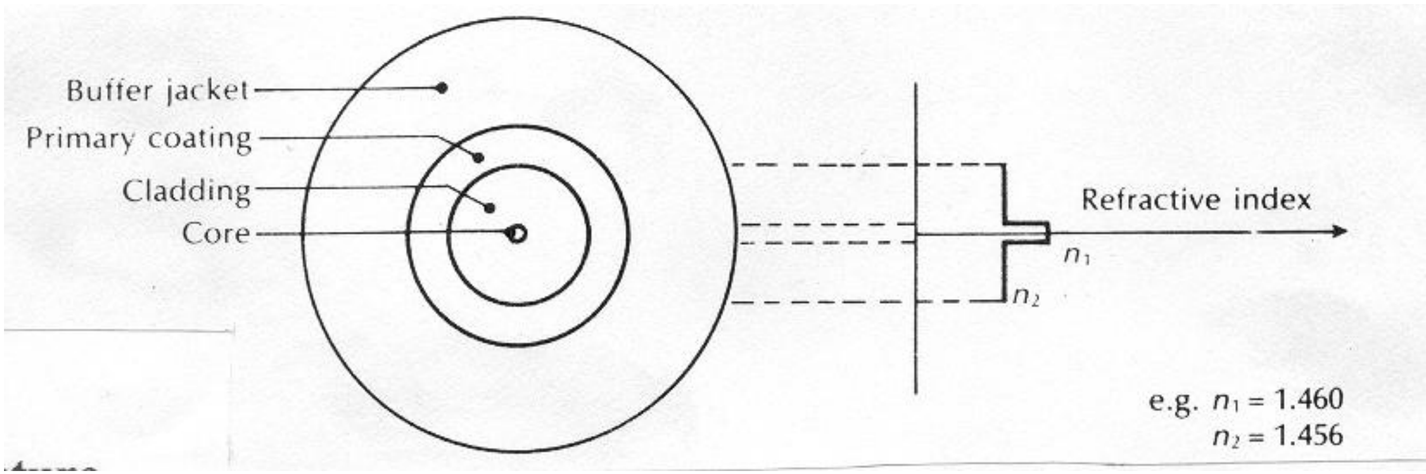
- 2 to 10 dB km^{-1} at a wavelength of 850nm with generally a scattering limit.
- Average losses of around 0.4 and 0.25 dB km^{-1} can be obtained at wavelengths of 1.3 and 1.55 μm respectively.

Bandwidth: 300 MHz km to 3 GHz km.

Applications:

- Best suited for medium-haul, medium to high bandwidth applications using incoherent and coherent multimode sources (i.e. LEDs and injection lasers respectively).

Single-Mode Fibers



Typical structure for a silica single-mode step index fiber.

Structure

Core diameter	:	5 to 10 μm, typical around 8.5 μm
Cladding diameter	:	generally 125 μm
Buffer jacket diameter	:	250 to 1000 μm
Numerical aperture	:	0.08 to 0.15, usually around 0.10.

Single-Mode Fibers

- Have either Step index or Graded index Profile
- GI Profiles
  - Provides dispersion modified SMF
  - Produce polarization maintaining fibers (PMF)
  - Expensive; Not utilized within OFC systems
- Commercially available SMFs are usually SI profile
- High quality fibers; Generally fabricated from doped silica (SCS)

Performance Characteristics

Attenuation:

- 2 to 5 dB km^{-1} with a scattering limit at 850 nm.
- 0.35 and 0.21 dB km^{-1} at 1310 and 1550 nm

Bandwidth:

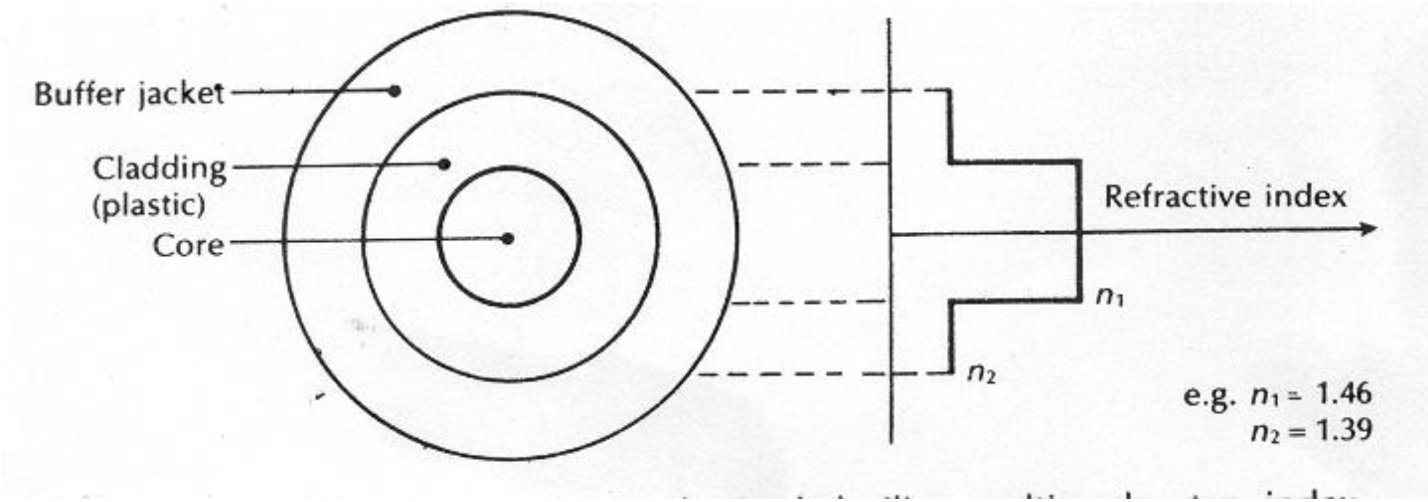
- Greater than 500 MHz km. of 0.85 μm.
- More than 10 GHz km at a wavelength of 1.3 μm.

Applications:

Ideally suited for high bandwidth very long haul applications using single-mode injection laser sources.

Plastic Clad (PCS) Fibers

- MMF; either SI or GI profile



Typical structure for a plastic-clad silica multimode step index fiber.

Structure	**Step Index**	**Graded Index**
Core diameter :	100 to 500 μm	50 to 100 μm
Cladding diameter :	300 to 800 μm	125 to 150 μm
Buffer jacket diameter:	500 to 1000 μm	250 to 1000 μm
Numerical aperture :	0.2 to 0.5	0.2 to 0.3.

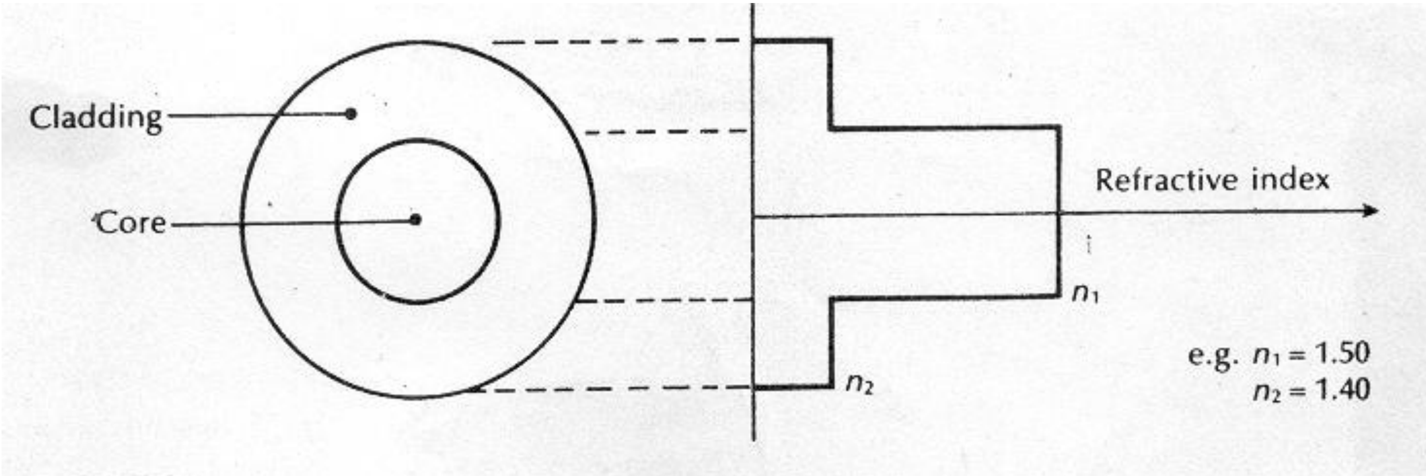
Performance Characteristics

Attenuation:	Step index	5 to 50 dB km^{-1}
	Graded index	4 to 15 dB km^{-1}

- PCS fibers exhibit lower radiation –induced losses than SCS.
  - **Have improved performance in certain enviornments**

- Generally cheaper than the corresponding glass fibers
  - **Have more limited performance characteristics**

All-Plastic Fibers (PCP)



Typical structure for an all plastic fiber.

Structure

Core diameter	:	200 to 600 μm
Cladding diameter	:	450 to 1000 μm
Numerical aperture	:	0.5 to 0.6.

All-Plastic Fibers

- Exclusively of MMF SI type with large core and cladding diameters.
- Reduced requirement for buffer jacket, protection and strengthening
- Cheap and Easy to handle
- Limited use in communication applications
- Large NA:- Easy coupling to light sources
- Fabricated with Polymethyl methacrylate (PMMA) and Fluorinated polymer cladding

Performance characteristics

Attenuation : 50 to 1000 dB km^{-1} at 650 nm

Bandwidth : Not usually specified as transmission is generally limited to tens of meters.

Applications : only be used for very short haul (i.e. 'in-house') low cost links.

- Fiber coupling and termination are relatively easy and do not require sophisticated techniques.

THANK YOU