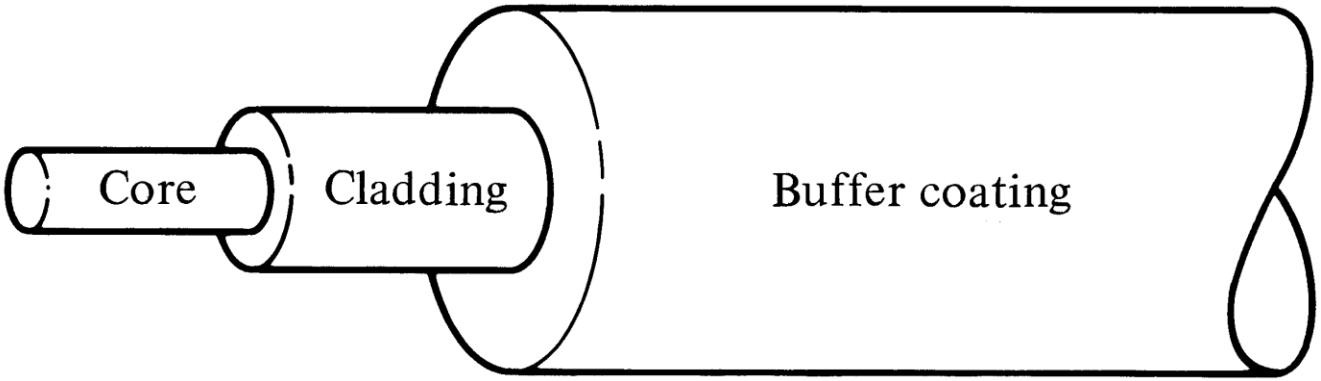
OPTICAL FIBER Materials,

Manufacturing & Cabling

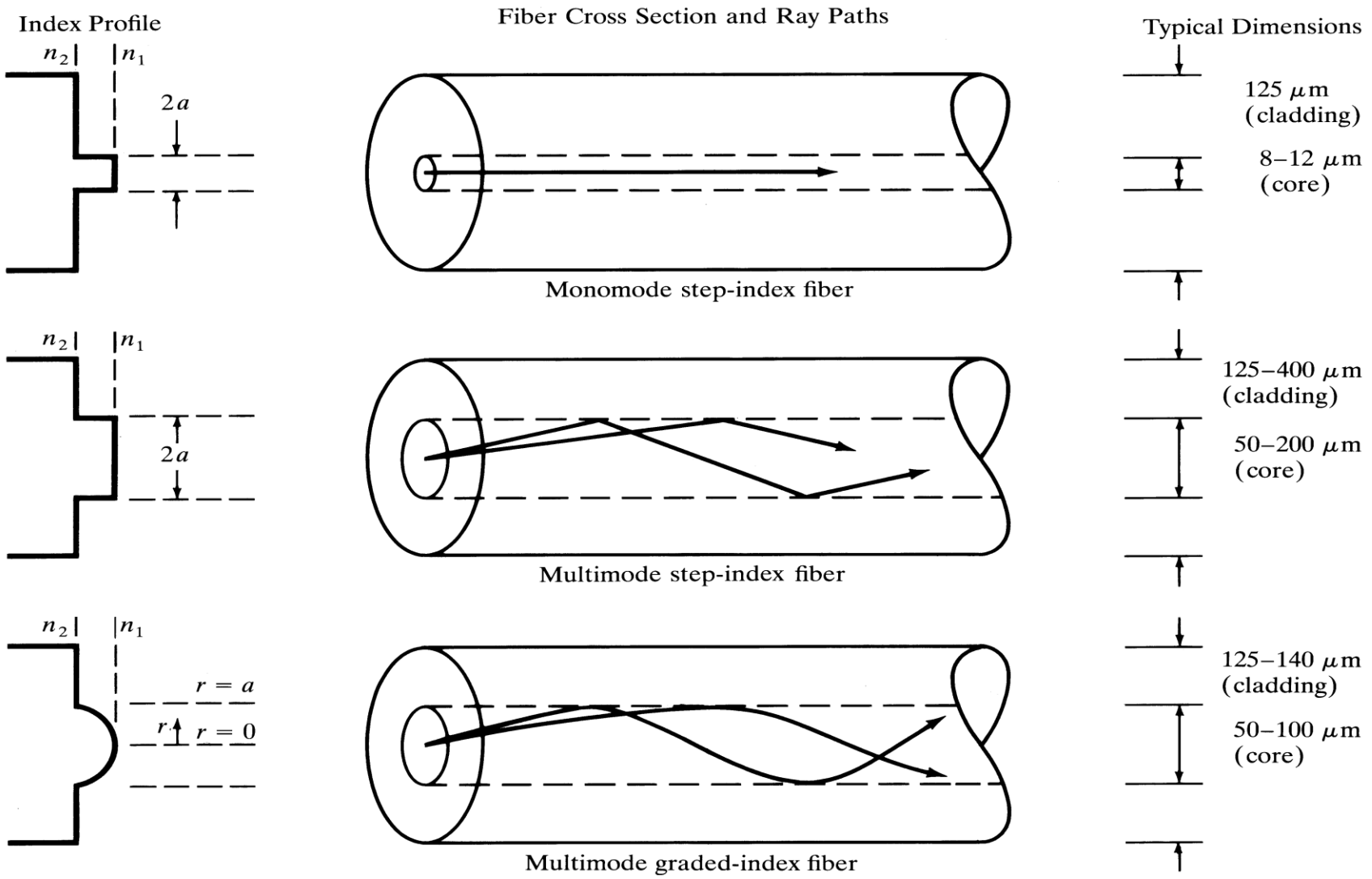
Fiber Structure



- 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'**.

$n_2 < n_1 \rightarrow$ **condition necessary for 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:**

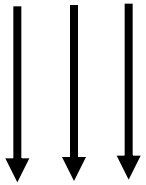
$V = [(2\pi a)/\lambda] NA$

$V \leq 2.405$ for SMF; ≥ 10 for MMF

FIBER MATERIALS

Requirements to be satisfied in selecting materials:

- It must be possible to make long, thin, flexible fibers from the materials.
- Material must be transparent at a particular wavelength in order for the fiber to guide light efficiently
- Physically compatible materials having slightly different refractive indices for the core and cladding must be available.



Suitable Materials are either

- Glasses or glass like materials (Silica or Silicates)
- Monocrystalline Structures (Plastics)
- Heavy Metal Fluorides (Nonsilicates)

MANUFACTURER'S CONSIDERATIONS

- Refractive Index Profile
- Material Composition and Density fluctuations
- Core-Cladding Interfaces
- Ecentricity
- Diameter

PREPARATION OF GLASS FIBERS

TWO STAGE PROCESS

- Purification of powdered glass materials and Conversion into rod or **Preform**
  - Drawing and Pulling Techniques; To acquire end products

METHODS: Two major categories

a) Conventional Glass Refining Techniques (Melting Processes)

- Liquid Phase Techniques (MC Glasses only)

b) Vapour Phase Deposition Methods (VPD)- Silica rich Glasses

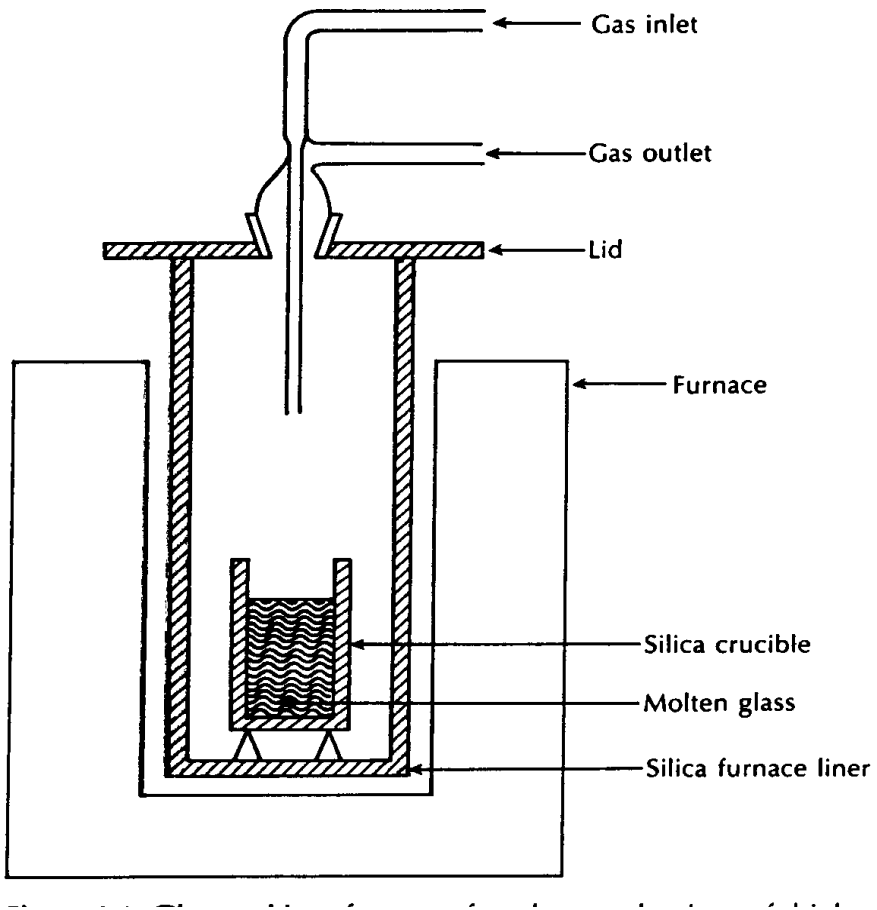
- Flame Hydrolysis (VAD, OVPO)

- Chemical Vapour Deposition (MCVD, PCVD)

Purification of Fiber Materials

- Preparation of ***Ultra pure material*** powders; Usually Oxides or Carbonates
  - SiO_2, GeO_2, B_2O_3 ,Al_2O_3 and F - Silica glass fibers
  - Na_2CO_3, K_2CO_3, $CaCO_3$ and $BaCO_3$ – Decomposes to Oxides
    - MC Glass fibers
- Very High initial purity essential (~ PPB) ; lesser for transition metal (Cr, Cu, Fe, Ni, Mn, V) impurities.
- Involves combined techniques of ***fine filtration and coprecipitation***, followed by ***solvent extraction*** before ***recrystallization*** and final ***drying in a vacuum*** to remove any residual OH ions.
- Purification accounts for large proportion of material cost; Commercially available.

Melting Processes



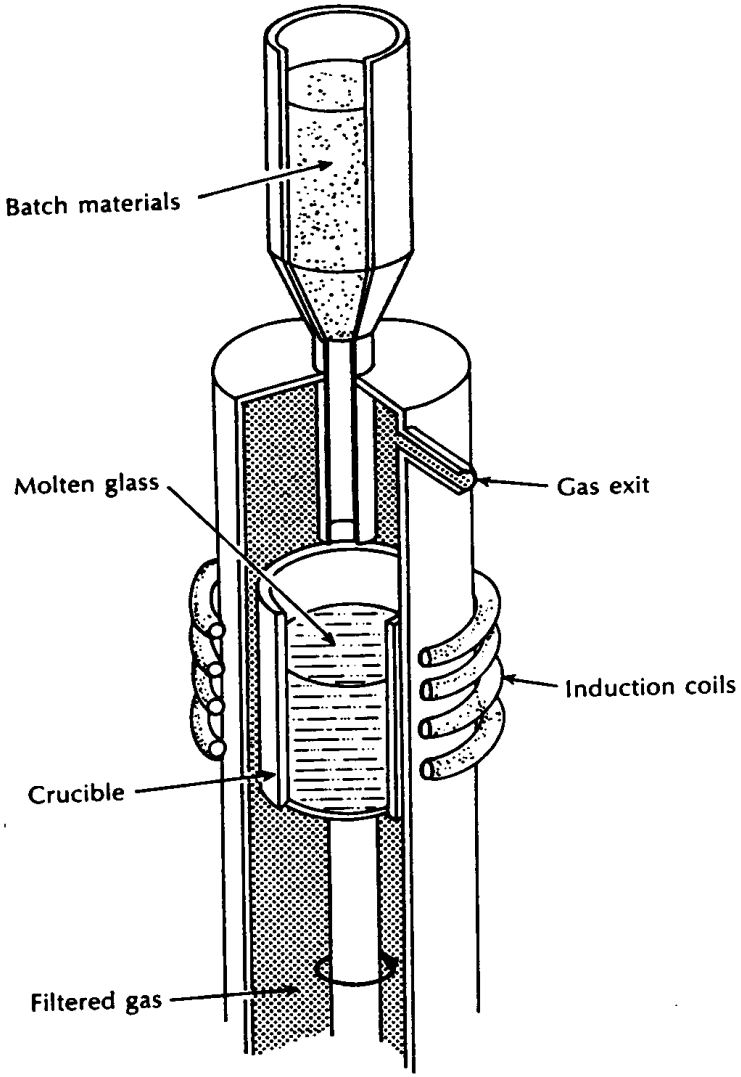
Glassmaking furnace for the production of high purity glasses.

- Melting high purity powder to **homogeneous**, **bubble free** glass melt
- Change in R.I. in molten state by change in composition of various constitutents
- Temp: 900 – 1400 ^{O}C

✓ **Silica or Platinum Crucibles**

- Contamination
- Inhomoginities

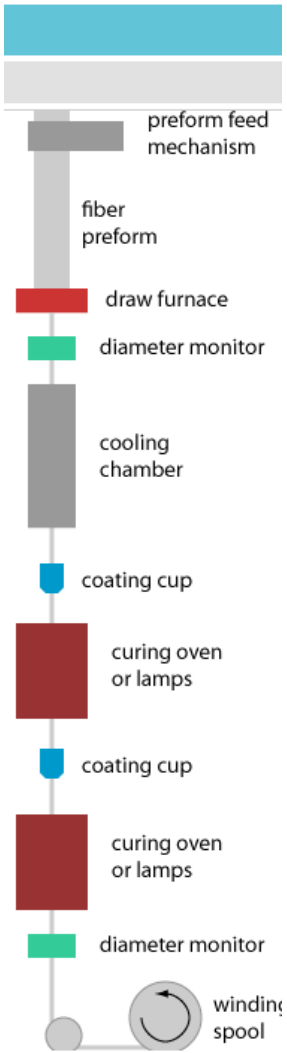
RF Induction Furnace



- Radio Frequency of ~ 5MHz
- Heated to 1000 ^{O}C
- Form a thin layer of solidified pure glass between melt and crucible – ***avoid contamination***

High-purity melting using a RF induction furnace.

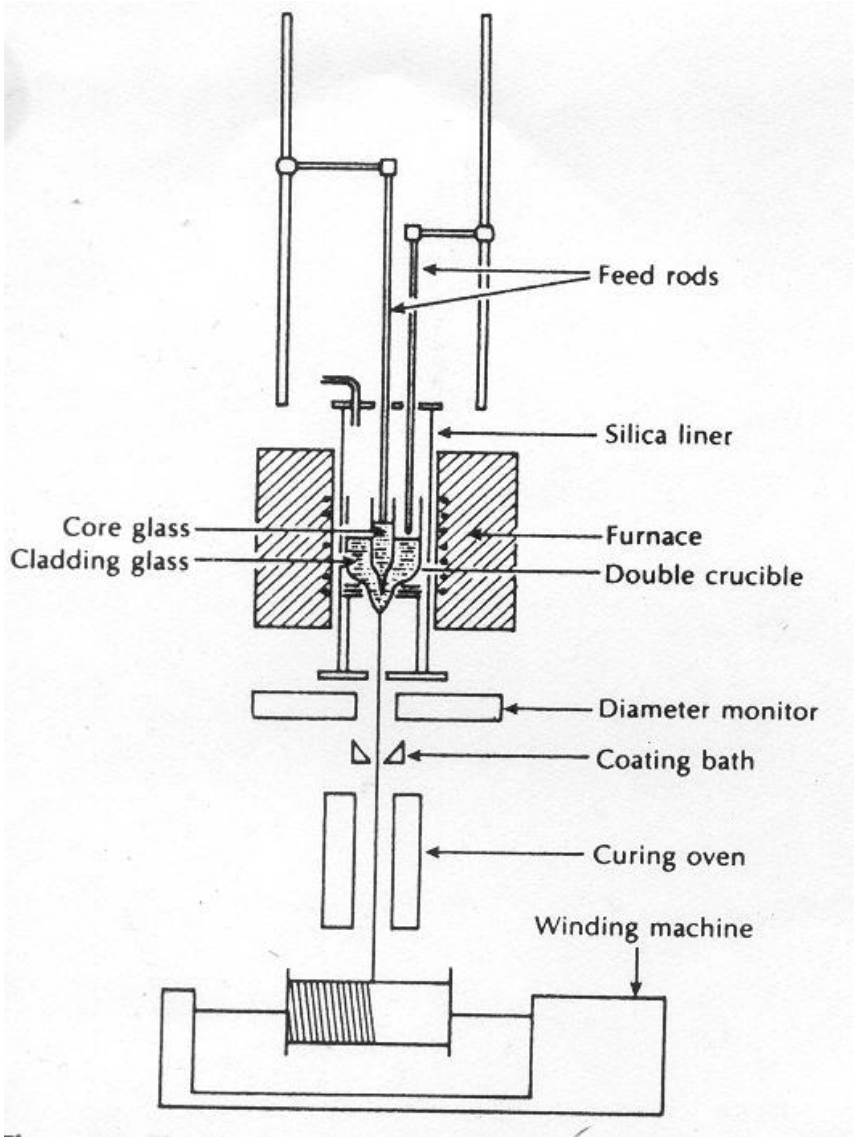
Fiber Drawing



Optical Fiber from a Preform.

- **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

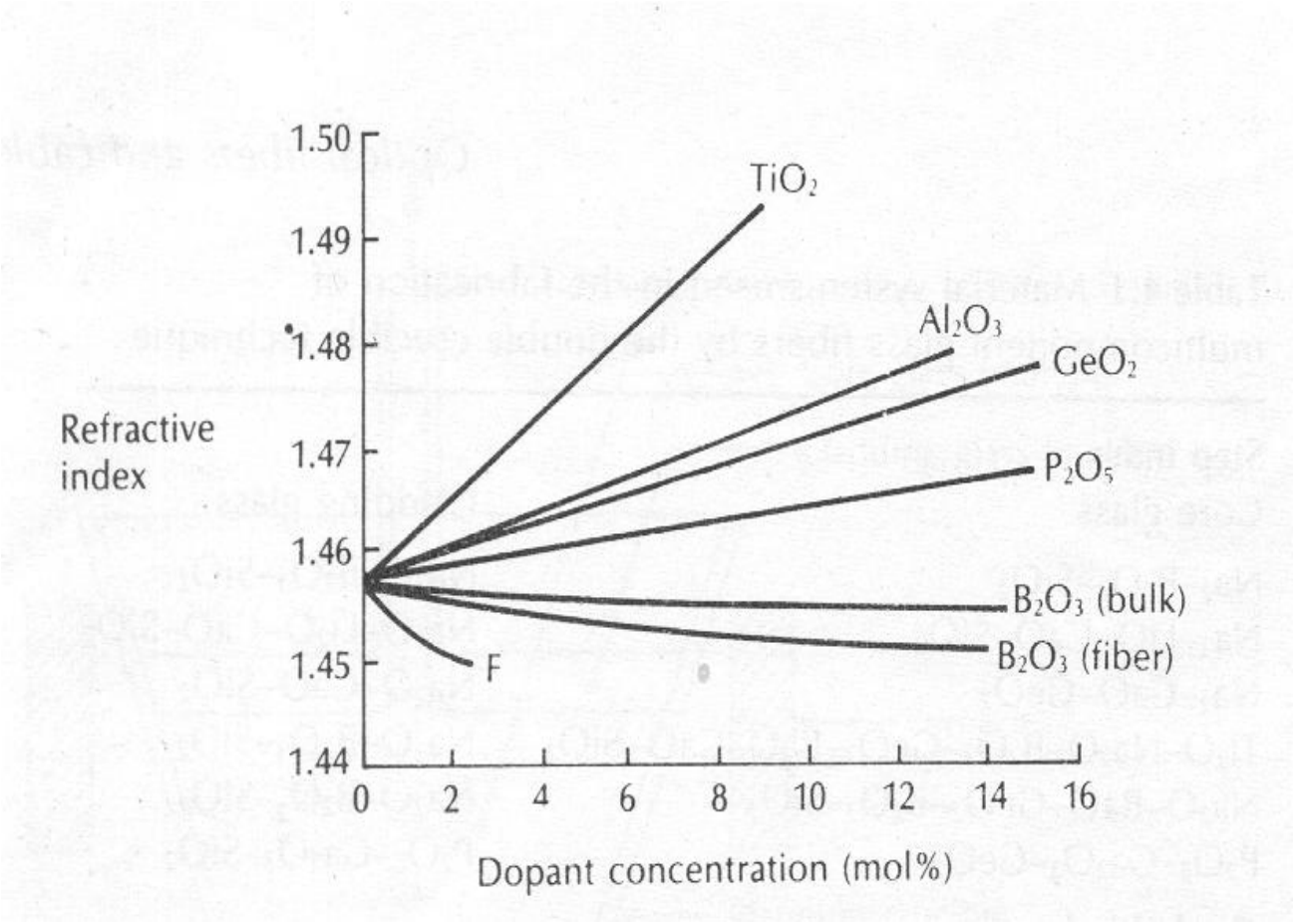
Double Crucible Approach



Double Crucible Method for Fiber Drawing

- Core and cladding in form of separate rods fed into two concentric platinum crucibles
- Temp. between 800 to 1200 ^{O}C
- Technique for SI & GI Fibers
- Diffusion of mobile ion across core-cladding interface witihin molten glass
- Reasonable graded index profile
- Typical losses between 3 –5 dB/km
- Possibility of continuous production
- Lack of precise control-

Doping Materials



The variation in the refractive index of silica using various dopants.

THANK YOU