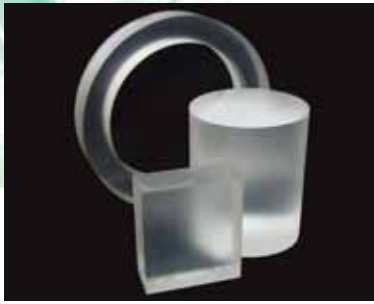


# Fused Silica Glass



## N Series



Tosoh N and NP materials are manufactured by fusing a high-purity silica powder using Tosoh's proprietary oxy-hydrogen flame fusion process. Thanks to its high purity, low aluminum content, and extremely low level of bubbles and inclusions, N has become the reference material for a broad range of applications, such as semiconductor manufacturing, metrology, optics, chemical processing, UV and high-temperature windows.

In particular, N is an enabling material for stringent plasma etch processes used in leading-edge semiconductor manufacturing.

NP is an enhanced version of N material, with further reduced alkali content for use in processes that require extreme contamination control.

Available in up to 1,200mm square and 580 mm round ingots, N and NP materials are 450mm wafer ready.

| Grades | Features                        |
|--------|---------------------------------|
| N      | Semiconductor standard grade    |
| NP     | Semiconductor high-purity grade |

## OP Series



Tosoh OP-1 and OP-3 materials are manufactured by fusing a high-purity silica powder using Tosoh's proprietary oxy-hydrogen flame fusion process and a method of generating uniformly dispersed small bubbles inside the material. Thanks to its high purity and excellent infrared blocking properties, OP-1 has become the material of choice as a heat-insulating material for semiconductor and solar manufacturing equipment, such as epi and RTP chambers, and oxidation, diffusion, and CVD batch furnaces.

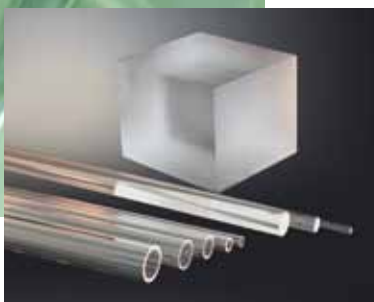
OP-3 is an enhanced version of OP-1 material, with further reduced alkali content for use in processes that require extreme contamination control.

OP-3HD is a high-density version of OP-3, with a smaller diameter bubble size distribution that provides enhanced sealing properties and lifetime for advanced batch furnace processes.

Available in up to 1,000mm round and square ingots, OP-1, OP-3, and OP-3HD materials are 450mm wafer ready.

| Grades | Features                        |
|--------|---------------------------------|
| OP-1   | Semiconductor standard grade    |
| OP-3   | Semiconductor high-purity grade |
| OP-3HD | High-density OP-3 grade         |

## S Series



Tosoh S material is manufactured by fusing a synthetic super high-purity silica powder using Tosoh's proprietary oxy-hydrogen flame fusion process. Tosoh SD material is fused from the same synthetic super high-purity powder using a plasma fusion process for reduced OH content. Thanks to their extreme purity and complete lack of inclusions, S and SD materials are the next generation of materials for semiconductor manufacturing.

Available in up to 1,200mm square ingots, S and SD materials are 450mm wafer ready.

### Available size

| Grades    | Ingots                     | Large tubes   |                | Narrow tubes  |                | Rods          |
|-----------|----------------------------|---------------|----------------|---------------|----------------|---------------|
|           | Diameter/Side (mm)         | Diameter (mm) | Thickness (mm) | Diameter (mm) | Thickness (mm) | Diameter (mm) |
| N Series  | □575~□1,200<br>○520~○580   | ~480          | ~6             | ~35           | 1~2            | ~35           |
| OP Series | □550~□1,000<br>○250~○1,000 | NA            | NA             | NA            | NA             | NA            |
| S Series  | ~□1,200                    | ~480          | ~6             | ~35           | 1~2            | ~35           |

\*For sizes other than those listed above, please inquire.

### Typical Impurity Level

Units: ppm

| Grades    | Al  | Ca  | Cu | Fe   | Na   | K    | Li   | Mg   | OH  |
|-----------|-----|-----|----|------|------|------|------|------|-----|
| N         | 9.1 | 0.9 | ND | 0.31 | 1.01 | 0.12 | 0.07 | 0.11 | 230 |
| NP        | 8.1 | 0.6 | ND | 0.12 | 0.14 | 0.05 | 0.05 | 0.04 | 270 |
| OP-1      | 9.1 | 1.0 | ND | 0.50 | 0.80 | 0.39 | 0.13 | 0.11 | 160 |
| OP-3, 3HD | 8.3 | 0.7 | ND | 0.21 | 0.15 | 0.06 | 0.13 | 0.05 | 160 |
| S         | 1.6 | 0.0 | ND | 0.05 | 0.18 | ND   | ND   | ND   | 350 |
| SD        | 0.2 | 0.0 | ND | 0.06 | 0.22 | ND   | ND   | ND   | 50  |

\*ND (Not Detectable): ≤ 0.01ppm

## Bubble and Inclusion levels

Units: Count/ft<sup>3</sup>

| Grades | Bubble diameter (mm) |          |        |       |
|--------|----------------------|----------|--------|-------|
|        | <φ0.3                | φ0.3~0.5 | φ0.5~1 | φ1.0< |
| N, NP  | n.sp.                | 3        | 2      | 0     |
| S, SD  | n.sp.                | 1        | 0      | 0     |

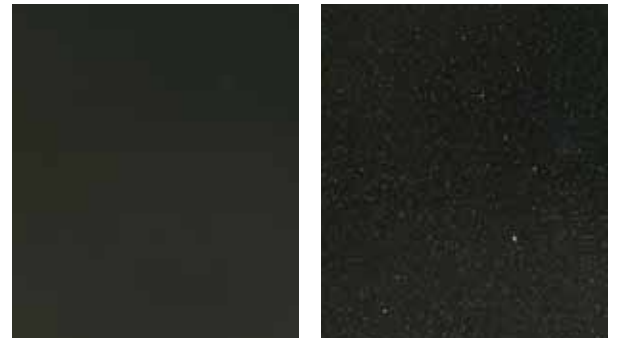
  

| Grades | Inclusion diameter (mm) |          |        |       |
|--------|-------------------------|----------|--------|-------|
|        | <φ0.3                   | φ0.3~0.5 | φ0.5~1 | φ1.0< |
| N, NP  | n.sp.                   | 2        | 1      | 1     |
| S, SD  | n.sp.                   | 1        | 0      | 0     |

※n.sp. : not specified

Tosoh N, NP, and S materials are fused in a Tosoh proprietary oxy-hydrogen flame fusion process that guarantees a significantly better level of bubbles and inclusions compared with traditional electrically fused quartz.

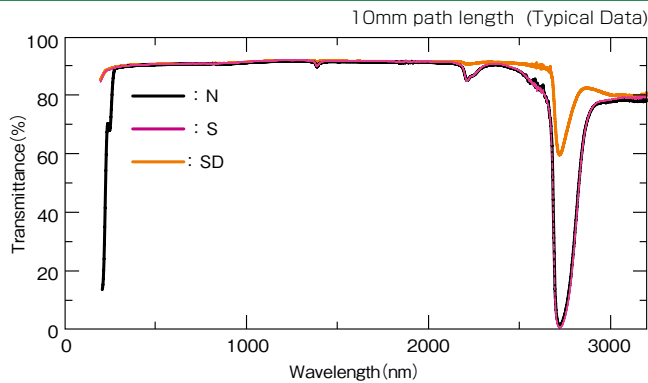
Microscopic image of bubbles and inclusions



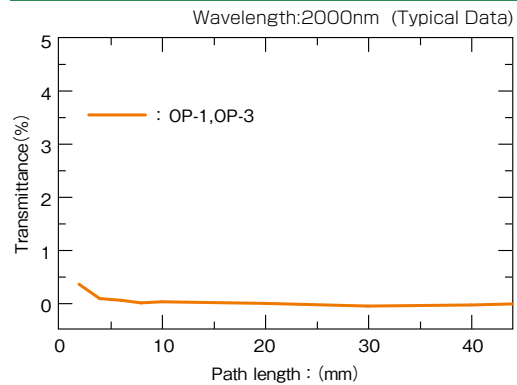
S, NP, N

Electrically fused quartz

## Spectral Transmission of N & S series



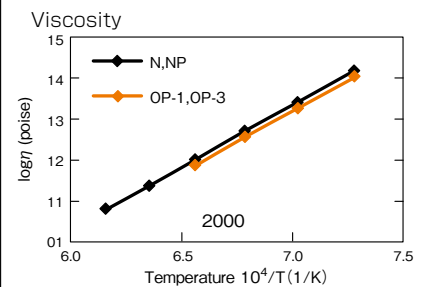
## Transmission of OP-1 & OP-3



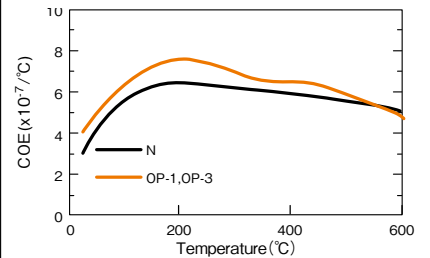
## Physical Properties

| Item                            |   | Unit                                | N,NP               | S                  | SD                 | OP-1,3 | OP-3HD |
|---------------------------------|---|-------------------------------------|--------------------|--------------------|--------------------|--------|--------|
| Mechanical properties           | Density                                 | g/cm <sup>3</sup>                   | 2.2                | 2.2                | 2.2                | 2.02   | 2.1    |
|                                 | Young's modulus                         | GPa                                 | 74                 | 74                 | 74                 | —      | —      |
|                                 | Shear modulus                           | GPa                                 | 31                 | 31                 | 31                 | —      | —      |
|                                 | Poisson's ratio                         |                                     | 0.17               | 0.17               | 0.17               | —      | —      |
|                                 | Bending strength *1                     | MPa                                 | 65~95              | 65~95              | 65~95              | 42~67  | 57~87  |
|                                 | Compressive strength                    | MPa                                 | 1,130              | 1,130              | 1,130              | —      | —      |
|                                 | Tensile strength *1                     | MPa                                 | 50                 | 50                 | 50                 | —      | —      |
|                                 | Torsion strength                        | MPa                                 | 29                 | 29                 | 29                 | —      | —      |
|                                 | Vickers hardness                        | MPa                                 | 8,900              | 8,900              | 8,900              | 8,900  | 8,900  |
| Thermal properties              | Strain point(η=10 <sup>14.5</sup> )     | °C                                  | 1,080              | 1,070              | 1,100              | 1,070  | 1,070  |
|                                 | Annealing point(η=10 <sup>13</sup> )    | °C                                  | 1,180              | 1,170              | 1,190              | 1,170  | 1,170  |
|                                 | Softening point(η=10 <sup>7.6</sup> )*2 | °C                                  | 1,720              | 1,720              | 1,720              | 1,720  | 1,720  |
|                                 | Coefficient of expansion 30~600°C       | x10 <sup>-7</sup> /°C               | 5.7                | 5.7                | 5.0                | 6.4    | 6.4    |
|                                 | Specific heat at 20°C                   | J/kg·K                              | 749                | 749                | 749                | 749    | 749    |
|                                 | Thermal diffusivity at 20°C             | x10 <sup>-7</sup> m <sup>2</sup> /s | 8.3                | 8.3                | 8.3                | 8.4    | 8.5    |
|                                 | Thermal conductivity at 20°C            | W/mK                                | 1.38               | 1.38               | 1.38               | 1.24   | 1.33   |
| Electric Prop.                  | Viscosity(logη) at 1200°C               | Poise                               | 12.7               | 12.5               | 13.0               | 12.6   | 12.6   |
|                                 | Dielectric constant 500MHz              |                                     | 3.9                | 3.9                | 3.9                | 3.7    | 3.8    |
|                                 | Dielectric loss factor 500MHz           | x10 <sup>-3</sup>                   | <1                 | <1                 | <1                 | <1     | <1     |
|                                 | Resistivity                             | Ω                                   | 3x10 <sup>15</sup> | 4x10 <sup>15</sup> | 1x10 <sup>16</sup> | —      | —      |
|                                 | Volume resistivity                      | Ω·cm                                | 5x10 <sup>16</sup> | 7x10 <sup>16</sup> | 2x10 <sup>17</sup> | —      | —      |
| Dielectric breakdown 50Hz, 20°C | V/mm                                    | 32,000                              | 32,000             | 32,000             | 25,500             | —      |        |

Thermal properties (Typical data)



Coefficient of Expansion



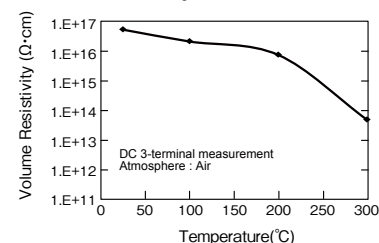
\*1 Bending and tensile strengths are affected by surface conditions.

\*2 Estimate from extrapolation

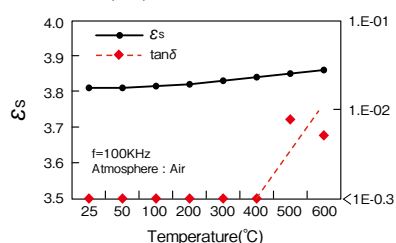
NOTE: Unless otherwise stated, all values represent typical data at 25°C

## Electrical properties (Typical data)

Volume Resistivity of N



Dielectric properties of N



Fused silica glass is a good electrical insulator, retaining high resistivity and excellent high-frequency characteristics at elevated temperatures.

\* tanδ Limit of measurement : 1x10<sup>-3</sup>

## Chemical Properties

Etching rate of fused silica glass by selected acids & alkali

| Grades | Unit: $\mu\text{m}/\text{min}$ . |                | Unit: $\mu\text{m}/\text{h}$   |                |
|--------|----------------------------------|----------------|--------------------------------|----------------|
|        | Solution : HF 10wt.%, 25°C *1    |                | Solution : KOH 10wt.%, 25°C *2 |                |
|        | F.p. surface*3                   | Ground surface | F.p. surface*3                 | Ground surface |
| N      | 0.07                             | 0.08           | 0.001                          | 0.003          |
| S      | 0.06                             | 0.08           | 0.001                          | 0.005          |
| OP-3   | 0.07                             | 0.1            | 0.002                          | 0.005          |

Etching rate is affected by solution concentration, temperature, materials, and surface condition.

\*1 Etching time : 3 hours

\*2 Etching time : 72 hours

\*3 F.p. = Fire polished

Chemical reactivity towards other materials

| Metals and nonmetals           |                              | Gases                           |   |
|--------------------------------|------------------------------|---------------------------------|---|
| Al, Ag                         | Rapid reaction at 700-800°C  | CO, SO <sub>2</sub>             | No reaction                                   |
| Au, Ag, Pt                     | No reaction                  | N <sub>2</sub> , O <sub>2</sub> | No reaction                                   |
| Zn, Sn, Pb                     | No reaction                  | Cl <sub>2</sub>                 | No reaction                                   |
| Si                             | Slight reaction when fused   | F <sub>2</sub>                  | No reaction with dried gases under 300°C      |
| Ge                             | No reaction at 900°C         | H <sub>2</sub>                  | No reaction                                   |
| Mo, W                          | No reaction                  | HCl                             | No reaction                                   |
| Oxides                         |                              | Salts                           |   |
| Al <sub>2</sub> O <sub>3</sub> | Gradual reaction over 900°C  | BaCl <sub>2</sub>               | Reaction when fused                           |
| CaO                            | Reaction over 900°C          | BaSO <sub>4</sub>               | Reaction over 700°C                           |
| CuO                            | Reaction over 800°C          | CaCl <sub>2</sub>               | Slight reaction when fused at 800°C           |
| Fe <sub>2</sub> O <sub>3</sub> | Reaction over 900°C          | KCl                             | Acceleration of devitrification at high temp. |
| PbO                            | Intense reaction with fusion | KF                              | Intense reaction when fused                   |
| MgO                            | Slight reaction at 900°C     | NaCl                            | Reaction visually recognized over 800°C       |
| ZnO                            | Reaction over 420°C          | Na <sub>2</sub> SO <sub>4</sub> | No reaction                                   |

## Devitrification

When silica glass is exposed to high temperatures, the pure SiO<sub>2</sub> structure changes from a glass state (amorphous) to a stable crystalline state called cristobalite. This structural change is known as devitrification and generally occurs at temperatures over 1,150°C for clean clear fused quartz. Devitrification may also occur at temperatures below 1,000°C in the presence of impurities such as metal. The relation between the devitrification rate of clear fused quartz and temperature in various atmospheres is indicated below.

| Gas composition   | Temp. (°C) | Time(h) | Degree of devitrification             | Devitrification thickness( $\mu\text{m}$ ) |
|---|------------|---------|---------------------------------------|--|
| Air   | 1,300      | 72      | Surface completely devitrified        | 250  |
| Dried oxygen  | 1,300      | 72      | Devitrification of 50% of the surface | 100~150                                    |
| Industrial nitrogen                                     | 1,300      | 72      | Surface devitrified                   | —  |
| Nitrogen (O <sub>2</sub> and H <sub>2</sub> O removed ) | 1,300      | 72      | No devitrification                    | —  |
| Hydrogen (O <sub>2</sub> and H <sub>2</sub> O removed ) | 1,300      | 72      | No devitrification                    | —  |

### Handling Precautions

Care must be taken to avoid direct hand contact with silica glass. The skin's natural salts contain alkali such as sodium, potassium, and other impurities that accelerate devitrification. All sources of metal contaminants should be avoided.

As a further precaution, fused silica should be washed in pure or distilled water, then either air dried in a clean area or wiped dry with an alcohol-soaked clean cloth. For more rigorous cleaning, a very thin surface layer of the glass can be removed by etching, prior to water washing, in a 5% - 10% hydrofluoric acid solution.

### Usage Precautions

- \* Always clean silica glass prior to use.
- \* Dry product completely before using at high temperature.
- \* Pay attention to devitrification due to atmospheric exposure.
- \* Please refer to the thermal properties for your application. Fused silica can resist sudden heating and quenching, but it does have its limits.
- \* Always consider fused silica's very low thermal expansion when the glass is used with other materials to avoid failure due to the differences in thermal expansion.
- \* Take caution during prolonged usage at temperatures approaching the annealing point.
- \* Be aware that slow sagging may occur under high temperature.



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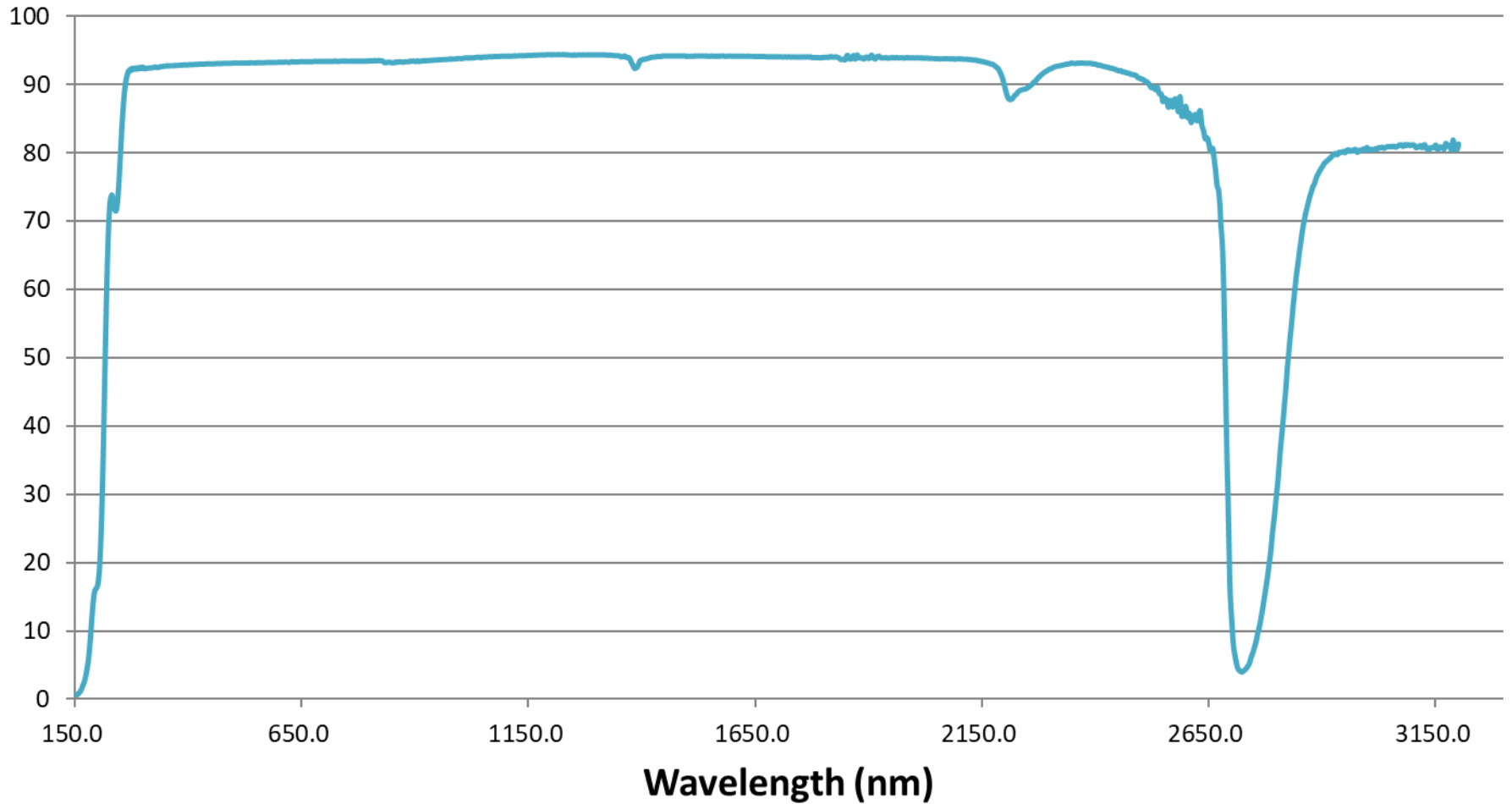


# Tosoh N-Material Transmission



# UV-Vis-IR (Typical)

External Transmission of N-Material (10 mm sample)

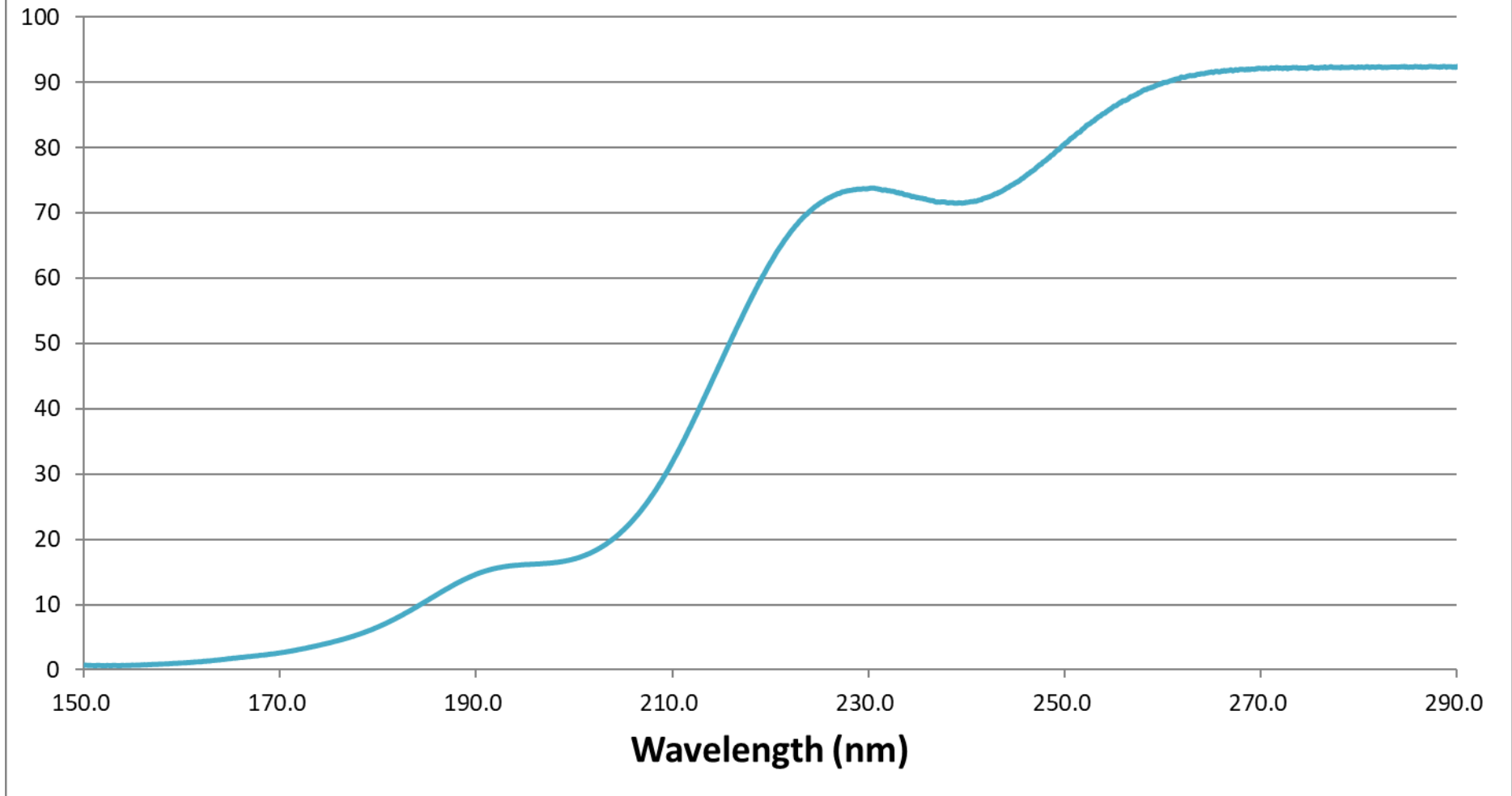




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# UV (Typical)

External Transmission of N-Material(10 mm sample)





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# IR (Typical)

External Transmission of N-Material(10 mm sample)

