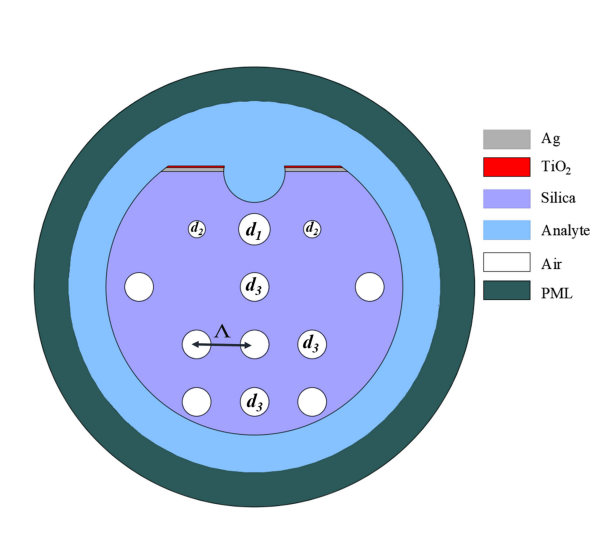
PROPOSED DESIGN 2 - A highly sensitive dual-core PCF plasmonic refractive index sensor designed for detecting small refractive indices is proposed. Plasmonic material Silver is placed at the edge of the fiber structure to detect changes in the surrounding medium refractive index. A thin layer of titanium dioxide is placed on top of silver to prevent oxidation. This study presents the design and numerical analysis of a dual-core Photonic crystal fiber(PCF), Surface plasmon resonance sensor specifically developed for detecting low refractive index. The integration of a microchannel and bimetallic configuration has enhanced the sensing performance in both wavelength and amplitude interrogation methods, resulting in the creation of a dual sensing channel. This occurs due to the generation of a significant quantity of electrons at the surface when TiO2 is positioned on top of silver. These electrons effectively attract the field emanating from the core, leading to a strong interaction with the plasmonic mode. Photonic crystal fibers are capable of supporting plasmonic modes. It involves the excitation of surface plasmons at the metal die electric interface within the PCF structure. The interaction between the guided modes within the fiber and the metal surface results in an increase in light-matter interactions and greater sensitivity to variations in the surrounding media.

The proposed photonic crystal fiber (PCF) is composed of a micro-structured optical fiber that contains a regular pattern of air holes running throughout its whole length. PCF characteristics can be adjusted to accommodate various modes, such as plasmonic modes, by integrating a metal layer or coating.

Photonic Crystal Fibres (PCFs) have the capability to accommodate several guided modes, including modes that are restricted within the core of the fibre. When light is directed through the central part of the photonic crystal fiber (PCF), it interacts with the metallic covering, resulting in the stimulation of surface plasmons.

Plasmon resonance occurs when the guided modes interact with the metal surface. Plasmon resonance is the phenomenon where the energy of the guided mode is linked to the collective oscillations of free electrons at the interface between a metal and a dielectric material. This leads to the amplification of electric fields close to the metal surface.

Plasmonic modes exhibit a high level of sensitivity to variations in the refractive index of the surrounding medium. The sensitivity of plasmonic resonance can be utilized in sensing applications to detect changes in the environment, such as the presence of analytes or fluctuations in temperature, by monitoring alterations in the plasmonic resonance condition.

  
Figure – Schematic diagram of the proposed sensor

A black circle with red and yellow lights

Description automatically generated  
  
Fig-Y polarization Core mode of PCF biosensor. Light is confined within the core.

A black circle with red dots

Description automatically generated  
Fig- SPP mode of the pcf biosensor. The entire field is confined to the plasmonic metal layer.

A black circle with red dots

Description automatically generated  
Fig- SPR mode of PCF biosensor(Resonance condition where the core mode and SPP mode intersects)

Optimized parameters for simulation

d1 =1.8[um] "diameter of circle 1"

d2= 1[um] "diameter of circle 2"

d3 =1.65[um] "diameter of circle 3"

A =3.3[um] pitch

Ts= 65[nm] "thickness of silver"

ti =10[nm] "thickness of titanium"

mc =1.75[um] microchannel

na =1.36 "RI of analyte layer"

b1 0.696166300 "Sellmeier equation constant"

b2 0.407942600 " Sellmeier equation constant "

b3 0.897479400 " Sellmeier equation constant "

c1 4.679148e-3[um^2] " Sellmeier equation constant "

c2 1.35120631e-2[um^2] " Sellmeier equation constant "

c3 97.9340025[um^2] " Sellmeier equation constant "

opw 1.72[um] "operating wavelength"

f c\_const/opw "Frequency"

nsilica =sqrt(1+((b1\*(opw^2))/(opw^2-c1))+((b2\*(opw^2))/(opw^2-c2))+((b3\*(opw^2))/(opw^2-c3))) "Sellmeier equation"

nti =sqrt(5.913+((2.441\*10^7)/(opw^2-(0.803\*10^7)))) "dielectric constant of TiO2"

Resonance happens when the frequency of the evanescent field aligns with the frequency of the electrons in the plasmonic material. The effective index of the core-guided mode and surface plasmon polariton (SPP) mode coincide at this specific frequency, resulting in a significant increase in confinement loss. The maximum energy is transferred from the core-guided mode to the SPP mode during this moment, which is called the phase-matching condition. The table below shows the confinement loss at wavelengths ranging from 1.5 to 1.76**. The phase matching condition occurs at wavelength 1.65um where the corresponding loss peaks at 263dB/cm.** The loss is calculated by using the formula

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Description automatically generated

For background material, SiO2 is used whose refractive index is calculated by the following Sellmeier equation-

A math equation with numbers and a plus

Description automatically generated

The dielectric constant of TiO2 can be defined by the given equation-

A math equation with numbers and symbols

Description automatically generated

|  |  |  |  |
| --- | --- | --- | --- |
| wavelength | confinement loss(dB/cm) | effective mode of core mode for x polarized light | effective mode index of SPP mode |
| 1.5 | 11.333 | 1.4358 |  |
| 1.51 | 12.871 | 1.4356 |  |
| 1.52 | 14.706 | 1.4353 |  |
| 1.53 | 17.014 | 1.4351 |  |
| 1.54 | 19.574 | 1.4349 |  |
| 1.55 | 22.83 | 1.4347 |  |
| 1.56 | 26.544 | 1.4344 |  |
| 1.57 | 31.671 | 1.4342 |  |
| 1.58 | 36.597 | 1.434 |  |
| 1.59 | 45.473 | 1.4337 |  |
| 1.6 | 55.272 | 1.4335 |  |
| 1.61 | 67.812 | 1.4333 |  |
| 1.62 | 84.043 | 1.4331 | 1.4347 |
| 1.63 | 105.96 | 1.4328 | 1.4342 |
| 1.64 | 135.63 | 1.4326 | 1.4337 |
| 1.65 | 179.69 | 1.4324 | 1.4321 |
| 1.66 | 263.05 | 1.4321 | 1.4324 |
| 1.67 | 234.56 | 1.4319 | 1.4312 |
| 1.68 | 176.98 | 1.4316 | 1.4306 |
| 1.69 | 142.16 | 1.4314 | 1.43 |
| 1.7 | 118.96 | 1.4312 | 1.4294 |
| 1.71 | 99.916 | 1.4309 | 1.4289 |
| 1.72 | 86.02 | 1.4307 |  |
| 1.73 | 75.061 | 1.4304 |  |
| 1.74 | 66.443 | 1.4302 |  |
| 1.75 | 59.339 | 1.43 |  |
| 1.76 | 53.589 | 1.4297 |  |
| 1.77 | 48.669 | 1.4295 |  |
| 1.78 | 44.751 | 1.4292 |  |
| 1.79 | 41.322 | 1.429 |  |
| 1.8 | 38.336 | 1.4288 |  |
| 1.81 | 36.228 | 1.4285 |  |
| 1.82 | 33.746 | 1.4283 |  |
| 1.83 | 31.953 | 1.428 |  |
| 1.84 | 30.301 | 1.4278 |  |
| 1.85 | 28.975 | 1.4275 |  |
| 1.86 | 27.723 | 1.4272 |  |
| 1.87 | 26.687 | 1.427 |  |
| 1.88 | 25.75 | 1.4267 |  |
| 1.89 | 24.887 | 1.4265 |  |
| 1.9 | 24.19 | 1.4262 |  |

Fig- Phase matching condition. As the phase matching condition is fulfilled, maximum power transfer can be observed from the core-guided fundamental mode to the plasmonic mode. As a result, a peak is observed at the point of intersection.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| wavelength | confinement loss at na=1.36 | confinement loss na= 1.37 | confinement loss at na=1.38 | confinment loss at na=1.39 |
| 1.5 | 11.333 | 16.472 | 7.0027 | 6.284 |
| 1.51 | 12.871 | 17.652 | 7.5664 | 6.6824 |
| 1.52 | 14.706 | 18.229 | 8.1977 | 7.1191 |
| 1.53 | 17.014 | 18.861 | 8.905 | 7.6006 |
| 1.54 | 19.574 | 19.527 | 9.6848 | 8.1203 |
| 1.55 | 22.83 | 20.235 | 10.572 | 8.6857 |
| 1.56 | 26.544 | 20.99 | 11.571 | 9.2962 |
| 1.57 | 31.671 | 21.797 | 12.693 | 9.9631 |
| 1.58 | 36.597 | 22.671 | 14.068 | 10.698 |
| 1.59 | 45.473 | 23.779 | 15.407 | 11.487 |
| 1.6 | 55.272 | 27.313 | |  | | --- | | 17.011 | | 12.34 |
| 1.61 | 67.812 | 31.611 | 19.014 | 13.347 |
| 1.62 | 84.043 | 35.195 | 21.188 | 14.502 |
| 1.63 | 105.96 | 43 | 23.743 | 15.819 |
| 1.64 | 135.63 | 50.442 | 26.609 | 17.27 |
| 1.65 | 179.69 | 59.659 | 29.964 | 18.865 |
| 1.66 | 263.05 | 70.946 | 33.843 | 20.644 |
| 1.67 | 234.56 | 84.892 | 38.297 | 22.609 |
| 1.68 | 176.98 | 102.09 | 43.506 | 24.773 |
| 1.69 | 142.16 | 124.2 | 49.508 | 27.139 |
| 1.7 | 118.96 | 150.57 | 56.224 | 29.616 |
| 1.71 | 99.916 | 185.76 | 64.667 | 32.727 |
| 1.72 | 86.02 | 224.48 | 73.717 | 36.007 |
| 1.73 | 75.061 | 244.31 | 84.619 | 39.568 |
| 1.74 | 66.443 | 202.83 | 97.06 | 43.574 |
| 1.75 | 59.339 | 170.36 | 111 | 47.954 |
| 1.76 | 53.589 | 145.24 | 126.25 | 52.749 |
| 1.77 | 48.669 | 125.7 | 143.18 | 57.953 |
| 1.78 | 44.751 | 110.31 | 160.64 | 63.717 |
| 1.79 | 41.322 | 97.47 | 178.62 | 69.961 |
| 1.8 | 38.336 | 87.24 | 194.85 | 76.522 |
| 1.81 | 36.228 | 78.777 | 209.3 | 83.447 |
| 1.82 | 33.746 | 71.442 | 222.11 | 91.02 |
| 1.83 | 31.953 | 65.873 | 232.45 | 98.527 |
| 1.84 | 30.301 | 60.722 | 240.21 | 106.25 |
| 1.85 | 28.975 | 49.799 | 245.74 | 113.9 |
| 1.86 | 27.723 | 49.799 | 118.98 | 121.7 |
| 1.87 | 26.687 | 49.437 | 109.16 | 129.05 |
| 1.88 | 25.75 | 46.697 | 101.01 | 136.16 |
| 1.89 | 24.887 | 44.213 | 93.588 | 142.75 |
| 1.9 | 24.19 | 42.11 | 87.285 | 148.99 |

Fig- Loss curves by varying the refractive index of analyte from 1.36 to 1.39

Fig- Amplitude sensitivity at different na (RI of analyte layer)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| wavelength | loss at d1=1.70 | d1=2[um] | d1=1.9 [um] | d1=2.3 |
| 1.5 | 11.434 | 11.093 | 11.225 | 10.463 |
| 1.51 | 13.005 | 12.587 | 12.75 | 11.8 |
| 1.52 | 14.848 | 14.35 | 14.559 | 13.365 |
| 1.53 | 17.093 | 16.701 | 16.724 | 15.29 |
| 1.54 | 19.765 | 19.033 | 19.322 | 17.638 |
| 1.55 | 23.059 | 22.173 | 25.403 | 20.645 |
| 1.56 | 27.114 | 26.057 | 26.431 | 24.412 |
| 1.57 | 32.078 | 30.836 | 31.314 | 29.116 |
| 1.58 | 38.33 | 36.759 | 37.274 | 34.897 |
| 1.59 | 46.1 | 44.121 | 44.835 | 41.937 |
| 1.6 | 55.978 | 53.45 | 54.332 | 50.959 |
| 1.61 | 68.865 | 65.709 | 66.674 | 62.62 |
| 1.62 | 85.355 | 81.414 | 82.592 | 77.231 |
| 1.63 | 107.91 | 102.13 | 103.93 | 96.759 |
| 1.64 | 138.44 | 130.11 | 132.71 | 123 |
| 1.65 | 184.07 | 171.48 | 175.39 | 161.07 |
| 1.66 | 273.43 | 245.12 | 253.44 | 224.39 |
| 1.67 | 382.89 | 244.48 | 239.21 | 260.56 |
| 1.68 | 174.07 | 182.19 | 179.5 | 407.52 |
| 1.69 | 141.02 | 145.45 | 144.4 | 431.3 |
| 1.7 | 117.78 | 121.05 | 119.74 | 124.89 |
| 1.71 | 99.255 | 101.63 | 100.87 | 103.97 |
| 1.72 | 85.447 | 87.099 |  | 88.977 |
| 1.73 | 74.65 | 75.862 |  | 77.196 |
| 1.74 | 66.04 | 66.993 |  | 67.94 |

Fig- Loss curve for variation of d1(Diameter of circle 1)

|  |  |  |  |
| --- | --- | --- | --- |
| wavelength | d2=0.8 x polarization loss core mode | d2=1 | d2=1.4 |
| 1.5 | 16.385 | 11.434 | 5.351 |
| 1.51 | 18.708 | 13.005 | 6.0733 |
| 1.52 | 21.479 | 14.848 | 6.9317 |
| 1.53 | 24.82 | 17.093 | 7.9799 |
| 1.54 | 28.769 | 19.765 | 9.2219 |
| 1.55 | 33.627 | 23.059 | 10.77 |
| 1.56 | 39.492 | 27.114 | 12.678 |
| 1.57 | 46.686 | 32.078 | 15.027 |
| 1.58 | 55.535 | 38.33 | 17.975 |
| 1.59 | 66.656 | 46.1 | 21.719 |
| 1.6 | 80.51 | 55.978 | 26.465 |
| 1.61 | 98.58 | 68.865 | 32.7 |
| 1.62 | 121.41 | 85.355 | 40.645 |
| 1.63 | 152.14 | 107.91 | 51.178 |
| 1.64 | 193.29 | 138.44 | 64.387 |
| 1.65 | 248.48 | 184.07 | 80.366 |
| 1.66 | 310.51 | 273.43 | 96.425 |
| 1.67 | 360.07 | 382.89 | 102.62 |
| 1.68 | 192.14 | 174.07 | 94.141 |
| 1.69 | 160.64 | 141.02 | 81 |
| 1.7 | 137 | 117.78 | 68.835 |
| 1.71 | 117.69 | 99.255 | 58.097 |
| 1.72 | 102.77 | 85.447 | 49.635 |
| 1.73 | 91.025 | 74.65 | 42.96 |
| 1.74 | 81.484 | 66.04 | 37.575 |
| 1.75 | 73.601 | 59.037 | 33.254 |
| 1.76 | 67.223 | 53.302 | 29.772 |
| 1.77 | 61.729 | 48.668 | 26.836 |
| 1.78 | 57.137 | 44.667 | 24.449 |
| 1.79 | 53.237 | 41.328 | 22.439 |
| 1.8 | 49.729 | 38.351 | 20.69 |
| 1.81 | 46.907 | 35.964 | 19.27 |
| 1.82 | 44.309 | 33.794 | 18.015 |
| 1.83 | 42.143 | 32.007 | 16.967 |
| 1.84 | 40.234 | 30.426 | 16.063 |
| 1.85 | 38.559 | 29.048 | 15.293 |
| 1.86 | 37.075 | 27.82 | 14.593 |
| 1.87 | 35.796 | 26.788 | 13.999 |
| 1.88 | 34.662 | 25.857 | 13.495 |
| 1.89 | 33.644 | 25.041 | 13.039 |
| 1.9 | 32.746 | 24.323 | 12.652 |

Fig- Loss curves for variation of d2(diameter of circle 2)

|  |  |  |  |
| --- | --- | --- | --- |
| wavelength | d3=1.55 | confinement loss d3=1.65 | d3=1.75 |
| 1.5 | 10.679 | 11.333 | 11.719 |
| 1.51 | 12.221 | 12.871 | 13.175 |
| 1.52 | 14.055 | 14.706 | 14.913 |
| 1.53 | 16.307 | 17.014 | 17.05 |
| 1.54 | 19.036 | 19.574 | 19.623 |
| 1.55 | 22.383 | 22.83 | 22.82 |
| 1.56 | 25.967 | 26.544 | 26.634 |
| 1.57 | 31.821 | 31.671 | 31.25 |
| 1.58 | 38.587 | 36.597 | 37.021 |
| 1.59 | 47.173 | 45.473 | 44.001 |
| 1.6 | 57.933 | 55.272 | 52.672 |
| 1.61 | 72.564 | 67.812 | 63.623 |
| 1.62 | 91.578 | 84.043 | 77.895 |
| 1.63 | 118.05 | 105.96 | 95.721 |
| 1.64 | 156.55 | 135.63 | 119.16 |
| 1.65 | 223.06 | 179.69 | 151.46 |
| 1.66 | 201.34 | 263.05 | 198 |
| 1.67 | 154.79 | 234.56 | 345.82 |
| 1.68 | 124.27 | 176.98 | 346.88 |
| 1.69 | 103.26 | 142.16 | 198.85 |
| 1.7 | 87.307 | 118.96 | 162.23 |
| 1.71 | 74.791 | 99.916 | 134.07 |
| 1.72 | 64.712 | 86.02 | 114.52 |
| 1.73 | 57.015 | 75.061 | 98.665 |
| 1.74 | 50.762 | 66.443 | 86.625 |
| 1.75 | 45.667 | 59.339 | 77.047 |
| 1.76 | 41.507 | 53.589 | 69.112 |
| 1.77 | 37.932 | 48.669 | 62.452 |
| 1.78 | 35.001 | 44.751 | 55.86 |
| 1.79 | 32.501 | 41.322 | 52.264 |
| 1.8 | 30.372 | 38.336 | 48.471 |
| 1.81 | 28.564 | 36.228 | 45.139 |
| 1.82 | 26.943 | 33.746 | 42.227 |
| 1.83 | 25.603 | 31.953 | 39.692 |
| 1.84 | 24.413 | 30.301 | 37.596 |
| 1.85 | 23.392 | 28.975 | 35.783 |
| 1.86 | 22.562 | 27.723 | 34.169 |
| 1.87 | 21.723 | 26.687 | 32.726 |
| 1.88 | 21.038 | 25.75 | 31.463 |
| 1.89 | 20.458 | 24.887 | 30.355 |
| 1.9 | 19.888 | 24.19 | 29.426 |

Fig- Loss curves for variation of d3

|  |  |  |  |
| --- | --- | --- | --- |
| wavelength | pitch 3.0 | confinement loss pitch 3.2 | pitch 3.4 |
| 1.5 | 101.9 | 11.333 | 7.4199 |
| 1.51 | 130.72 | 12.871 | 8.1834 |
| 1.52 | 175.18 | 14.706 | 9.2032 |
| 1.53 | 390.88 | 17.014 | 10.246 |
| 1.54 | 313.04 | 19.574 | 11.635 |
| 1.55 | 223.7 | 22.83 | 13.194 |
| 1.56 | 174.26 | 26.544 | 14.961 |
| 1.57 | 140.23 | 31.671 | 17.311 |
| 1.58 | 115.94 | 36.597 | 19.865 |
| 1.59 | 98.126 | 45.473 | 19.808 |
| 1.6 | 84.243 | 55.272 | 27.295 |
| 1.61 | 72.985 | 67.812 | 32.008 |
| 1.62 | 64.771 | 84.043 | 38.499 |
| 1.63 | 57.672 | 105.96 | 46.295 |
| 1.64 | 51.986 | 135.63 | 55.593 |
| 1.65 | 47.446 | 179.69 | 68.561 |
| 1.66 | 43.758 | 263.05 | 84.673 |
| 1.67 | 40.411 | 234.56 | 105.09 |
| 1.68 | 37.708 | 176.98 | 135.61 |
| 1.69 | 35.354 | 142.16 | 176.47 |
| 1.7 | 33.463 | 118.96 | 270.42 |
| 1.71 | 31.719 | 99.916 | 393.01 |
| 1.72 | 30.171 | 86.02 | 428.29 |
| 1.73 | 28.897 | 75.061 | 134.51 |
| 1.74 | 27.749 | 66.443 | 112.03 |
| 1.75 | 26.789 | 59.339 | 95.688 |
| 1.76 | 25.956 | 53.589 | 82.435 |
| 1.77 | 25.224 | 48.669 | 72.625 |
| 1.78 | 24.558 | 44.751 | 64.656 |

Fig- Loss curves for variation of pitch (distance between air holes)

|  |  |  |  |
| --- | --- | --- | --- |
| wavelength | thickness of Ag=65 | Ag=75 | Ag= 85 |
| 1.5 | 11.333 | 14.309 | 18.733 |
| 1.51 | 12.871 | 16.491 | 16.491 |
| 1.52 | 14.706 | 19.466 | 26.854 |
| 1.53 | 17.014 | 22.699 | 32.646 |
| 1.54 | 19.574 | 27.156 | 39.792 |
| 1.55 | 22.83 | 32.739 | 49.134 |
| 1.56 | 26.544 | 39.627 | 61.435 |
| 1.57 | 31.671 | 48.706 | 78.002 |
| 1.58 | 36.597 | 60.085 | 99.628 |
| 1.59 | 45.473 | 74.075 | 129.24 |
| 1.6 | 55.272 | 94.403 | 169.11 |
| 1.61 | 67.812 | 120.18 | 480.7 |
| 1.62 | 84.043 | 160.31 | 150.38 |
| 1.63 | 105.96 | 233.65 | 120.95 |
| 1.64 | 135.63 | 203.11 | 99.987 |
| 1.65 | 179.69 | 157.71 | 83.736 |
| 1.66 | 263.05 | 127.51 | 71.323 |
| 1.67 | 234.56 | 105.76 | 61.79 |
| 1.68 | 176.98 | 88.846 | 54.06 |
| 1.69 | 142.16 | 77.374 | 47.885 |
| 1.7 | 118.96 | 66.156 | 42.982 |
| 1.71 | 99.916 | 58.622 | 38.899 |
| 1.72 | 86.02 | 52.678 | 35.572 |
| 1.73 | 75.061 | 47.18 | 32.756 |
| 1.74 | 66.443 | 42.582 | 30.335 |
| 1.75 | 59.339 | 39.223 | 28.285 |
| 1.76 | 53.589 | 36.281 | 26.592 |

Fig- Loss curves for variation of thickness of silver

|  |  |  |  |
| --- | --- | --- | --- |
| wavelength | TiO2=5nm | TiO2=10nm | TiO2=15nm |
| 1.5 | 12.766 | 11.333 | 10.069 |
| 1.51 | 14.633 | 12.871 | 11.319 |
| 1.52 | 16.923 | 14.706 | 12.821 |
| 1.53 | 19.689 | 17.014 | 14.554 |
| 1.54 | 23.058 | 19.574 | 16.638 |
| 1.55 | 27.215 | 22.83 | 19.147 |
| 1.56 | 32.466 | 26.544 | 22.346 |
| 1.57 | 38.979 | 31.671 | 25.919 |
| 1.58 | 47.348 | 36.597 | 30.379 |
| 1.59 | 57.814 | 45.473 | 36.007 |
| 1.6 | 71.324 | 55.272 | 42.986 |
| 1.61 | 89.658 | 67.812 | 51.721 |
| 1.62 | 113.8 | 84.043 | 62.732 |
| 1.63 | 148.33 | 105.96 | 77.027 |
| 1.64 | 203.7 | 135.63 | 95.602 |
| 1.65 | 260.93 | 179.69 | 120.34 |
| 1.66 | 187.26 | 263.05 | 154.99 |
| 1.67 | 148.14 | 234.56 | 206.5 |
| 1.68 | 121.81 | 176.98 | 290.73 |
| 1.69 | 101.94 | 142.16 | 362.8 |
| 1.7 | 87.146 | 118.96 | 174.54 |
| 1.71 | 74.896 | 99.916 | 141.82 |
| 1.72 | 66.18 | 86.02 | 118.57 |
| 1.73 | 58.731 | 75.061 | 100.67 |
| 1.74 | 52.69 | 66.443 | 87.723 |
| 1.75 | 47.716 | 59.339 | 76.92 |
| 1.76 | 43.709 | 53.589 | 68.176 |
| 1.77 | 40.21 | 48.669 | 61.08 |
| 1.78 | 37.219 | 44.751 | 55.271 |
| 1.79 | 34.759 | 41.322 | 50.414 |
| 1.8 | 32.65 | 38.336 | 46.425 |
| 1.81 | 30.766 | 36.228 | 42.82 |
| 1.82 | 29.137 | 33.746 | 40.048 |
| 1.83 | 27.778 | 31.953 | 37.636 |
| 1.84 | 26.553 | 30.301 | 35.257 |
| 1.85 | 25.52 | 28.975 | 33.393 |
| 1.86 | 24.585 | 27.723 | 31.821 |
| 1.87 | 23.779 | 26.687 | 30.436 |
| 1.88 | 23.104 | 25.75 | 29.184 |
| 1.89 | 22.469 | 24.887 | 28.091 |
| 1.9 | 21.924 | 24.19 | 27.151 |

**Fig- Loss curves for variation of TiO2 Layer**