Chapter 6

Conclusion and Future Scope

This chapter provides a summary of the research work conducted as part of this thesis, presenting the overall conclusion. This chapter also encompasses the discussion of the future scope and potential avenues for further work to be carried out.

6.1 Summary

This thesis describes, design and simulation of the refractive index detection surface plasmon resonance based optical fiber sensors. In this thesis, I have discussed the different types of optical fibers and light propagation principle through it. In chapter 1, I have given the information about the surface plasmons and surface plasmon resonance (SPR) phenomenon. I have designed the four different structure optical fiber sensors using the COMSOL Multiphysics software and analysed them by the finite element method. These all sensor sensing principle based on surface plasmon resonance phenomenon. By these sensors, I have detected different range of refractive indices of different analyte samples.

In chapter 2, I have designed a D-shaped structure optical fiber sensor and analysed the results by finite element method. Gold (Au), silver (Ag), and copper (Cu) metal layers have utilized separately to investigate the performance results of designed sensor using with SPR phenomenon. The sensor's average and maximal sensitivity increase as the thickness of the metal layer increases. I observe that the Au layer has a higher sensitivity compared to the Ag and Cu layers. A sensor with a 50-nm-thick Au layer demonstrates an average sensitivity of 5855 nm/RIU, a maximal sensitivity of 15,200 nm/RIU, and a resolution of 1.78×10^{-5} RIU. The figure of merit (FOM) and resolution have also obtained for all metal layers. This fiber sensor is highly effective in the chemical and biological areas for refractive index (RI)-based sample sensing.

Single gold (Au) nanowire utilized optical fiber sensor performance results explained in chapter 3. In this sensor, I have synthesized gold (Au) nanowire inside the fiber cladding hole. Sample analyte also placed inside the fiber cladding hole region. The finite element method (FEM) is utilized to optimize the structure parameters. My sensor model has demonstrated significant sensitivity, with an average wavelength sensitivity of 6700 nm/RIU and a maximum wavelength sensitivity of 14000 nm/RIU. In addition, the sensor achieved a high resolution and the maximum figure of merit (FOM) value of 7.14×10^{-6} RIU and 124.54 RIU^{-1}, respectively, for the analyte RI range of 1.33-1.43. The sensor's performance is unaffected by ± 5% of small fabrication errors. By positioning the analyte within the hole, it is shielded from the surrounding environment, thereby making the sensor more reliable and useful for detecting toxic or environmentally affected chemicals.

In chapter 4, I have proposed the Al-doped ZnO (AZO) coated refractive index detection optical fiber sensor. AZO plasmonic material is coated on the optical fiber flat D- surface. Sensor structure is easy to design as there is only single layer AZO coated on polished D-shape fiber. In my work, the thickness and width of the coated AZO layer were optimized to be 90 nm and 124.70 nm, respectively. The proposed infrared sensor demonstrated a RI sensitivity of 2000-16000 nm/RIU and resolution of 5.00×10^{-5}- 6.25×10^{-6} RIU for analyte refractive indices ranging from 1.23 to 1.37. My structure can withstand fabrication errors in the ± 5% range without affecting the sensor's performance. The designed sensor is useful for sensing of low refractive index organic chemical, biomedical, and liquid foods.

In chapter 5, I have considered the hollow-core optical fiber which is overcome the high refractive index analyte detection problem. The plasmonic gold (Au) thin layer is deposited on top of the unclad portion of the optical fiber. The analyte sample is filled inside the hollow-core. By analyzing loss peak position sifting, I examined sensor efficacy in the range of analyte RIs 1.45-1.52. At the optimized 30 nm thick Au layer, I determined a maximal sensitivity of 23,500 nm/RIU and resolution of 4.26×10^{-6} RIU. It is very useful in measuring the refractive index of many household oils like olive oil, kerosene, almond oil, soybean oil, and peppermint oil and other chemicals.

6.2 Future scope

In the near future, SPR phenomenon based optical fiber sensors are bound to find new peaks. The combination between SPR phenomenon and optical fiber has significant advancements in the sensing of different analytes related to refractive index. The SPR based fiber sensors hold significant potential for different applications due to their exceptional features, including real-time monitoring, level-free detection, and maximum sensitivity. Due to their ability to alter geometrical parameters, flexibility, compact structure, immunity to electromagnetic wave interference, and robustness, optical fiber sensors are poised to become a key tool in future sensing applications. Optical fiber sensors are poised to make a significant impact in various industries, including organic chemical sensing, biochemical sensing, biomedical sensing, and liquid food and beverage, due to the remarkable growth in the sensing applications. Additionally, it is imperative to optimize the critical factors and parameters in order to improve the necessary sensing capabilities.