Numerical Investigation on Microfluidic Integrated Side Polished Fiber to Detect Biological Analytes

1st M.Valliammai
Department of ECE
Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology
Chennai,India
drvalliammaim@veltech.edu.in

2nd J.Mohanraj
Department of ECE
Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology
Chennai, India
jmohanraj@veltech.edu.in

3rd Balasubramanian Esakki
Department of Mechanical Engineering
National Institute of Technical Teachers Training and Research
Chennai, India
esak.bala@gmail.com

4th Lung – Jieh Yang
Department of Mechanical Engineering
Tamkang University
Taiwan
ljyang@mail.tku.edu.tw

5th Chua-Chin Wang
Department of Electrical Engineering
National Sun Yat-Sen University
Taiwan
ccwang@ee.nsysu.edu.tw

6th Ranjan Rishav
Department of ECE
Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology
Tamilnadu, India
ranjanrishav007@gmail.com

***Abstract*—To improve the integration and sensitivity of surface plasmonic resonance (SPR) detection systems, we have numerically inversigate the SPR microfluidic integrated side polished fiber (SPF) sensor to detect the biological analytes. The proposed device consists of PDMS microfluidic channel and few layer MoS_2 nano coated SPF. Finally, the integrated microfluidic channel with SPF bio sensor evaluated by flow velocity of micro fluidic channel and SPR occurring wavelength.**

***Index Terms*—Microfluidic Channel, Side polished fiber, Surface plasmonic resonance, MoS_2 nanosheets**

I. Introduction

The surface plasmon resonance (SPR) technique is fundamentally based on the evanacent field interaction at a metal-dielectric interface. These metallic structures possess a highly localized electromagnetic field, making them highly sensitive to the refractive indices changes of the surrounding medium [1]. This techniques can be extensively utilized for various biocomponent detection such as biomarkers, toxins, pathogens and allergens. Microfluidic technology enables the analysis and manipulation of substances inside a microchannels with a requirement of minimum volume of samples [2]. The Properly designed microfluidic chips can improve the efficiency of substance detection. The hybrid system of optical fiber with microfluidics results in rapid detection, high sensitivity, good reproducibility and high integration. As a result, numerous researchers have combined fiber-based SERS technology with microfluidics to create various microfluidic fiber-based SERS probes. Recently, Fan et al. integrated end-face fiber SERS probes into a microfluidic chip, achieving a detection sensitivity of 10 mol/L for R6G [3]. In this work, We have integrated the microfluidics channel with SPF in order to improve resonance effect through controlled flow assistance.

This research was funded by the Department of Science and Technology (DST) - Global Innovation and Technology Alliance (GITA), Government of India, under the 2021 India-Taiwan S & T Cooperation call for proposals (GITA/DST/TWN/P-99/2022).

II. Design

In section.II, we illustrate about the design of the microfluidic integrated MoS_2 nanocoated SPF to detect the bioanalytes which is shown in Fig.1(a). The proposed design

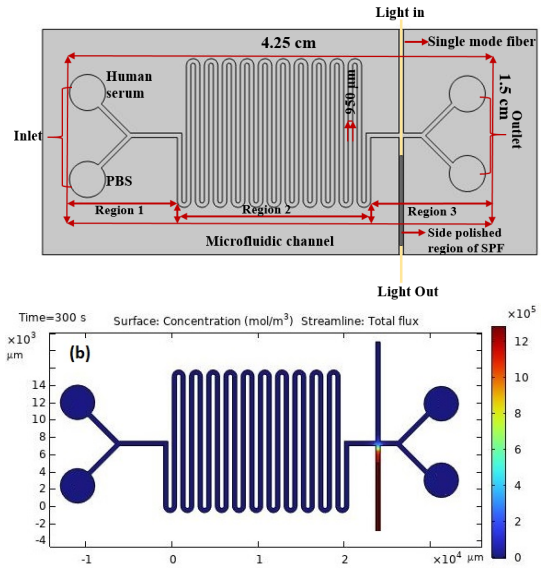

Fig. 1. (a) Schematic view of microfluidic integrated SPF Sensor. (b) Field profile of SPF sensor integrated with microfluidic channel.

consists of two major sections as microfludic channel and MoS_2 nanocoated SPF. Firstly, we have design the microfludic channel to utilize advantages of compact size, effecient flow control, requirement of low sample volume in order to improve the bio-substance detection of SPF. The proposed microfluidic channel has a length and height of 4.25 and 1.5 cm, respectively. The channel width of microfluidic channel is varied ranges from 1 to 1000 μm. The proposed PDMS microfluidic channel comprises three regions. Region 1 and Region 3 has called as entrance and exit region, respectively, which consists of two inlets and outlets with a diameter of 0.5 mm. Inlets and outlets are used to insertion of human serum as well as PBS sloution and collection wastes, respectively. Region 2 is a middle region or mixing region of human serum and PBS solution. Further, the Region 2 supplies the mixed solution to the side polished MoS_2 coated sensing region. Further, MoS_2 nano coating is varied from monolayer to fewlayers(1 to 10) with a fixed single layer thickness as 0.625 nm. The considered SPF is regarded as a single-mode fiber, featuring core and clad diameters of 8 μm and 125 μm, respectively. The upper and above the core polished length of SPF is about 26 and 17 mm, respectively. The polished depth of SPF is about 58 μm. Further, Fig.1(b) shows the field profile associated with SPF. In real time integration aspects, the microfluidic channel can be integrate with SPF by plasma bonding.

III. Results and Discussion

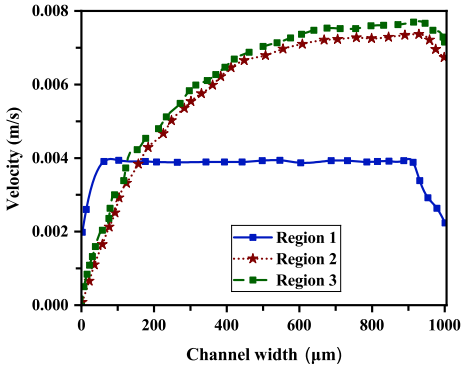

Fig. 2. Variation in velocity profile of microfludic channel with respect to the variation in channel width.

Fig.2 depicts the velocity profile of proposed microfluidic channel with respect to the various channel width. Here, Region 1,2 and 3 represents the entrance,middle and exit region of microfluidic channel, respectively. one can see in Velocity profile that that the velocity of region 1 is same as 3.9×10^{-3} ms^{-1} of region 2 and 3 at a channel with of 125 and 150 μm, respectively. Initially,the velocity is set at 2.5×10^{-3} ms^{-1} at the inlet of the microfluiudic. The maximum velocity of region 2 (middle) and region 3 (exit) is attained $7.3 \times 10^{-3} ms^{-1}$ and 7.7×10^{-3} ms^{-1}, respectively, at a channel width of 950 μm. Further, Fig.2 indicates that the exit velocity get slightly exceeds the middle region velocity due to the reduction of cross sectional area of microfluidic channel in the exit region. Hence, one can infer from the figure that constant velocity and enhanced velocity of entrance region and middle, exit region can be at microfluidic channel width of 950 μm. Thus, we fix the channel width as 950 μm through out studies.

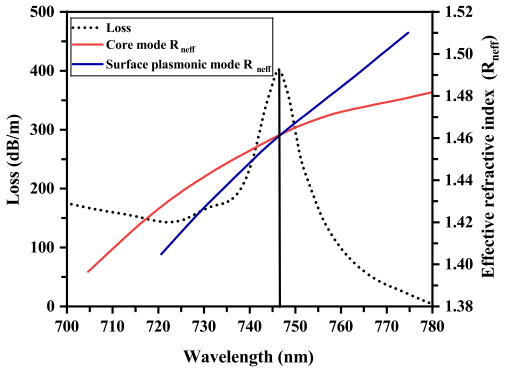

Fig. 3. Variation of loss as well as effective refractive index of core and SPR mode with repect to the wavelengths.

SPR is generally identified when the real effective indices and losses of the core and SPR mode indices match [4]. Resonance between core and evanescent field mode occurred only when the loss and real effective indices value of both modes gets matched. Fig.3 illustrates the real parts of the effective index and loss of both the core and the evanescent field mode as functions of wavelength. From Fig.3, it is clear that the real part of the both the mode indices of SPF match at 745 nm wavelength. On the same hand, the peak of the loss can also observed at 745 nm wavelength. Hence, the proposed SPF exhibits the SPR effect around the wavelength range of 745 nm.

IV. Conclusion

In this work, the microfluidic channel integrated SPF has been proposed to improve the performance of SPR based bio analytes detection system. The proposed design exhibits the maximum velocity of $7.3 \times 10^{-3} ms^{-1}$ at 950 μm of microfluidic channel width. Further, The SPF sensor exhibits the SPR at a wavelength of 745 nm for bio analytes detection.

References

[1] "Numerical study of a d-shaped optical fiber spr biosensor for monitoring refractive index variations in biological tissue via a thin layer of gold coated with titanium dioxide," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, vol. 304, p. 123358, Jan 2024.

[2] A.-G. Niculescu, D. E. Mihaiescu, and A. M. Grumezescu, "A review of microfluidic experimental designs for nanoparticle synthesis," *International Journal of Molecular Sciences*, vol. 23, pp. 1–32, July 2022.

[3] M. Fan, P. Wang, C. Escobedo, D. Sinton, and A. G. Brolo, "Surface-enhanced raman scattering (sers) optrodes for multiplexed on-chip sensing of nile blue a and oxazine 720," *Lab Chip*, vol. 12, pp. 1554–1560, March 2012.

[4] M. Valliammai, K. Senthilnathan, P. Ramesh Babu, and S. Sivabalan, "Influence of quasi-periodic cladding on single mode behavior in a leakage channel fiber: Towards the enhancement of modal discrimination and low bending loss of the lp01 mode," *Optics Communications*, vol. 389, pp. 239–246, April 2017.