An Extremely Miniaturized and Highly-Efficient High-Pass Wavelength Plasmonic Filter at Near-Infrared

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Abstract: This letter describes design and numerical simulation of an extremely-compact and efficient high-pass plasmonic filter based on MIM waveguides. Numerical results shown that by tuning structural parameters, desired cut-off wavelengths can be chosen.
OCIS codes: (240.6680) Surface plasmon; (130.7408) Wavelength filtering devices.

1. Introduction

Miniaturization has been considered to be the main source of innovation in the microelectronic industry. Exceptional developments in machinery, materials, and manufacturing methods enabled to reduce the size of the transistor, the primary active component in modern electronics. Besides, energy efficiency is not only beneficial from a sustainability viewpoint, but also for consumer devices, less power-hungry electronics means greater time between charges and incentives for a smaller onboard energy storage network. As a result, the industry is looking to incorporate current CMOS-based technology with modern and innovative alternatives such as plasmonics, where their integration could greatly contribute to minimizing the size and power consumption, with exceptional improvement in speed, specifically for wireless communication systems [1, 2]. Surface plasmon polaritons (SPPs) emerge from the coupling of surface electromagnetic waves with free electrons of plasma gas at high frequencies, giving rise to extraordinary light confinement at an interface of a metal and a dielectric [1, 3]. Plasmonics unique contribution may be defined as the capability to circumvent the diffraction limit of light, to carry both optical and electrical signal, and the ability of controlling the electromagnetic response of the structure at subwavelength scales. This makes them a promising platform for integration not only with current electronics industry, but to play a major role in photonic integrated circuits (PICs), providing an alternative solution where integration of highly-compact and efficient optical circuits may become possible. In general, plasmonic waveguides are categorized as insulator-metal-insulator (IMI), which provides low propagation loss with low mode confinement, and metal-insulator-metal (MIM), possessing strong light confinement characteristics with almost accepted level of propagation loss, thus making MIM-based structures favoured in utilization in PICs. Thus, miscellaneous optical circuits based on MIM plasmonic waveguides including sensors [4], absorber [5] and so on were suggested, and some of them have been experimentally realized. Among various components, optical filters play an important role in, for example, wavelength-division multiplexing (WDM) in communication systems, fluorescent microscopy, dispersion compensation, and machine vision systems. Nevertheless, the development of novel optical filters might have been overlooked, despite their key role in numerous applications, for instance, in point-of-care (POC) diagnostic instruments that offer the possibility of achieving prompt results, either near or in proximity of a patient, as well as in lidar laser sensors. Therefore, we have proposed a miniaturized and highly efficient plasmonic high-pass filter based on MIM waveguides, operating at near-infrared (NIR) of the electromagnetic spectrum. Furthermore, we have realized that by tuning its structural parameters, the desired cut-off wavelength can be easily attained.

2. Design and Simulation Results of proposed High-Pass Plasmonic Filter

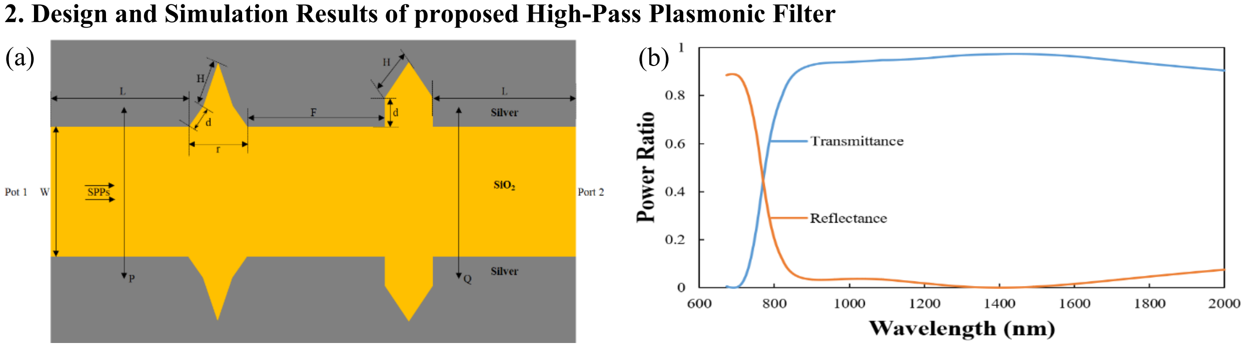

Fig. 1. (a) Schematic configuration of proposed high-pass wavelength plasmonic structure. (b) Transmission spectra of the high-pass plasmonic filter.

Figure 1(a) displays the schematic configuration of the suggested plasmonic high-pass wavelength filter. The structure is formed by two layers of silver, whose complex permittivity has been taken from tabulated data of Johnson and Christy [6], and an insulator layer, set to be Silicon dioxide, sandwiched between the two metallic layers. In order to ensure only the propagation of fundamental TM mode within the structure, the width of the waveguide, W, is chosen remarkably smaller than that of the incident light wavelength. We have chosen the grid sizes to be 5 nm × 5 nm along the x and y directions, respectively. In order to capture and detect the incident and transmitted power from the structure, two power monitors P and Q, respectively, are positioned at an equal distance from the central waveguide, which led to the definition of the transmission in the device as T=Pout/Pin. An EM software tool, CST MWS, is employed to obtain the numerical results of the proposed filter. Figure 1 (b) demonstrates the transmission and reflection spectra as a function of wavelength for W=60 nm, denoting the width of the waveguide, L=100nm shows the distance between the port and the first triangle, d=10 nm is defined as the length of the first side of the triangle, H= 15 nm indicates the length of the second side of the triangle, F=L/2= 50 nm, connecting the left triangle with the right one, and r=40 nm, as the length between the two edges of the triangle. It should be mentioned that we have made extra effort to design a symmetric structure with several degrees of freedom in order to tune its transmission spectrum. As seen in Fig. 1(b), the cut-off wavelength for a high-pass wavelength filter is specified as where the transmittance goes to 1% [7], and is here found to be 711 nm. The transmission efficiency is more than 90%, for a wide range of wavelengths, for instance, from 850 nm up to 2 μm. Figure 2 shows the transmission profile of the proposed high-pass wavelength filter for different values of the distance between the left and right triangles for F= 30 nm, 40 nm, 50 nm and 60 nm. One can see that a reduction in the distance, causes cut-off wavelength shifts towards the shorter wavelengths. For F= 30 nm, the cut-off wavelength is found to be 665 nm, whereas by increasing F, the cut-off wavelength moves to longer wavelength, for instance to 785 nm for F= 60 nm. Thus, through tuning the distance between the triangles, the transmission of the high-pass wavelength filter may be easily adjusted.

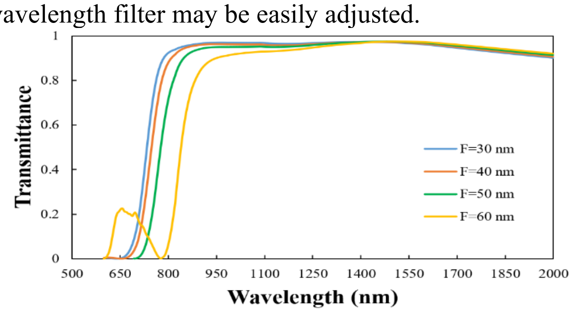

Fig. 2. Transmission spectra as a function of wavelength for the suggested high-pass filter for various values of F.

3. Conclusion

In summary, we have proposed an extremely compact and efficient high-pass wavelength filter at near-infrared (NIR) range. The plasmonic filter is significantly smaller and more efficient than recent research works [8, 9], and may find applications in high density photonic integrated circuits and facilitate the development of miniaturized and compact optical circuits for on-chip applications.

4. References

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