Optics Communications 335 (2015) 86–89

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Hybrid plasmonic waveguide crossing based on the multimode interference effect

Yan Li [a], Chao Xu [a], Cheng Zeng [b], Wanjun Wang [c], Jianyi Yang [a], Hui Yu [a,*], Xiaoqing Jiang [a,*]

[a] Department of Information Science and Electronics Engineering, Zhejiang University, Hangzhou 310027, China
[b] Wuhan National Laboratory for Optoelectronics, School of Optoelectronics Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, China
[c] The 38th Research Institute of China Electronics Technology Group Corporation, Hefei 230088, China

ARTICLE INFO

Article history:
Received 16 July 2014
Received in revised form
2 September 2014
Accepted 5 September 2014
Available online 22 September 2014

Keywords:
Hybrid plasmonic waveguides
Multimode interferometer
Waveguide crossings

ABSTRACT

The waveguide crossings based on the hybrid plasmonic waveguides (HPW) are demonstrated by using the self-imaging effect of the multimode interferometer. The single self-imaging formed at the crossing center mitigates the wavefront expansion due to the light diffraction at the crossing area. The plasmonic waveguide comprises a 30 nm hydrogen silesquixsane layer sandwiched between a 220 nm silicon layer and a 100 nm silver layer. The total length of the crossing is 4870 nm. Its insertion loss and crosstalk at 1550 nm are 4.9 ± 0.3 dB and -22 dB. The optical bandwidth is more than 40 nm. This device could be a fundamental building block in future HPW based optical circuits.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Plasmonic waveguides can spatially confine light beyond the diffraction limit, and therefore enable optical devices with nanoscale dimensions. However, there is a fundamental trade-off between localization and loss occuring in plasmonic guiding geometries [1]. Plasmonic modes are damped modes due to the metal absorption. Among various plasmonic waveguides, hybrid plasmonic waveguides (HPW) have been attracting more and more attention. The HPW, which consists of a high index dielectric layer, a thin metal layer and a low index dielectric layer between them, exhibits not only good light confinement ability in nanoscale, but also low propagation loss and potential compatibility with CMOS technology [2,3]. In order to implement high-density and fully operational HPW optical circuits, passive devices like the optical crossing are essential. Due to optical crossings can work as building blocks for cross-grid arrays, and flexible optical crossings are important for significantly decreasing fabrication complexity in dense circuits [4]. The conventional silicon based crossings have been demonstrated with negligible insertion loss and crosstalk [5]. Nevertheless, a silicon crossing is indispensable used to cross two HPWs, which means that transitions between two HPWs need to pass through these crossed silicon waveguides. So far this kind of transitions gives a loss as high as 1.3 dB [6]. The coupling problem between silicon waveguides with HPWs impedes its application in HPW based optical circuits. Therefore, it is more economical to accomplish the crossing within the regime of HPW.

Since a direct waveguide crossing has very poor performance due to the light diffraction at the crossing area, various structures have been demonstrated for low loss and low crosstalk crossings on different material systems over the past decade, which include the crossings based on broadened waveguides [7], multimode interferometer (MMI) [8,9], subwavelength gratings [10], photonic crystals [11], and so on. Considering the simplicity and tolerance of the design and processing, we think that the multimode interferometer based crossing is favorable for the HPW waveguide.

In this letter, we demonstrate a HPW based crossing which comprises two orthogonal MMIs [12]. It exhibits high transmission efficiency and low crosstalk over a broad wavelength band. By comparing the theoretical with the experimental results, we prove the viability of the HPW crossing structure.

2. Geometry and fabrication

Fig. 1(a) and (b) show the schematic layout and the SEM image of the HPW based crossing, respectively. The dimension of the single mode HPW is $350\,\text{nm} \times 300\,\text{nm}$ as shown in Fig. 1(c), where the thicknesses of the high index silicon layer (silicon), the low index layer (hydrogen silsesquioxane, HSQ) and the top metal layer (silver) are 220 nm, 30 nm and 100 nm, respectively. The complex permittivity of silver is characterized by Drude model, $\varepsilon_{ag} = \varepsilon_{\infty} - \omega_p^2/\omega(\omega - i\gamma)$. Here

* Corresponding authors.
E-mail addresses: huiyu@zju.edu.cn (H. Yu), iseejxq@zju.edu.cn (X. Jiang).

http://dx.doi.org/10.1016/j.optcom.2014.09.016
0030-4018/© 2014 Elsevier B.V. All rights reserved.

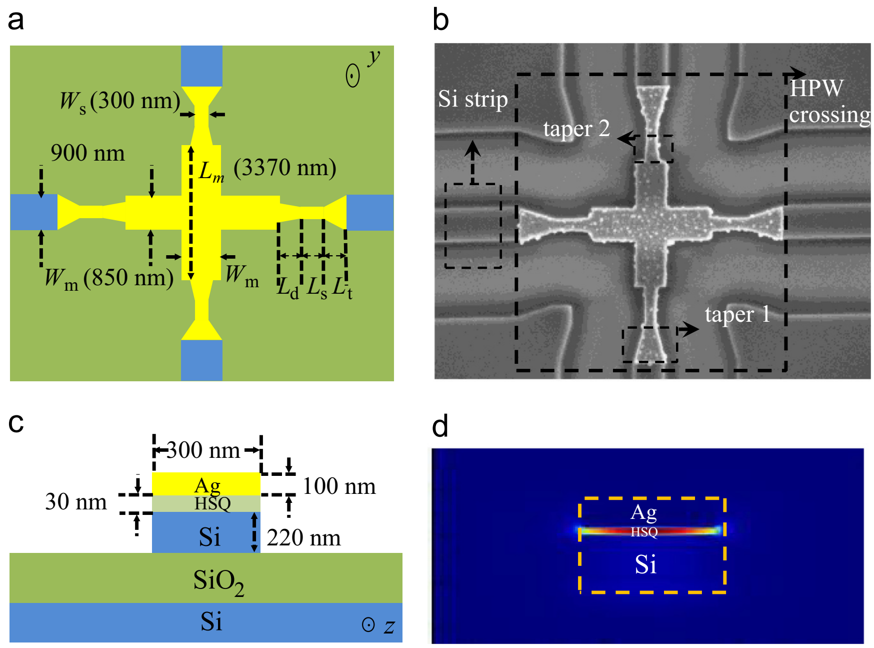

Fig. 1. (a) Layout of HPW based crossing inserted in the 900 nm wide Si strip waveguides, $L_d = L_s = L_t = 500$ nm. (b) Top view SEM picture of the crossing. (c) Schematic cross sectional view of the single mode HPW. (d) Distribution of the horizontal electrical field component *Ey* of the fundamental quasi TM mode in the HPW at 1550 nm.

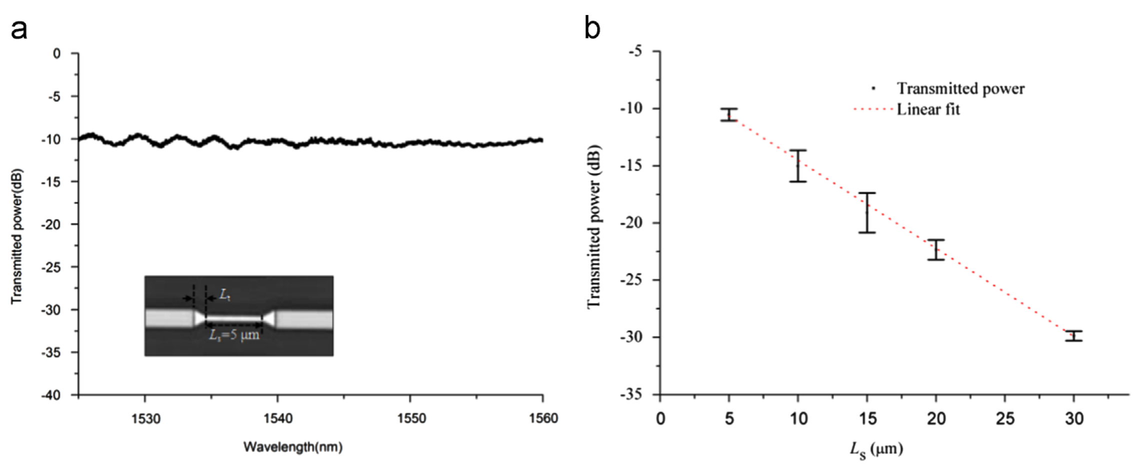

Fig. 2. (a) The normalized transmission of the 5 μm long single mode HPW with $W_s = 300$ nm, inset is the optical microscopy picture for the top view. (b) Fitting loss with different L_s at 1550 nm.

the constant ε_∞, the plasma frequency ω_p, and the collision frequency γ are: $\varepsilon_\infty = 3.3651$, $\omega_p = 2.193 \times 10^3$ THz, and $\gamma = 4.972$ THz [13], respectively. The refractive index of HSQ and silicon are set as 1.4 [14] and 3.445, respectively. The simulated field distribution of the fundamental quasi-TM mode is displayed in Fig. 1(d). The mode exhibits an effective index of 2.04 and a propagation loss 0.12 dB/μm. As expected, the modal power is mostly confined inside the low index layer between the silicon and the metal.

To excite the plasmonic mode in the HPW with the single mode fiber, the fiber output is at first converted into the fundamental TM mode of a silicon strip waveguides of 220 nm × 900 nm by a TM polarized grating couplers [15]. Subsequently a tapered coupler is utilized to facilitate an efficient coupling between the TM mode in the silicon strip and the hybrid plasmonic mode in the 300 nm HPW [5]. As shown in Fig. 1(b), the linear taper which is denoted as taper 1 has a length of 500 nm ($L_t = 500$ nm) for optimal coupling efficiency. The same tapers are used to couple the light out.

The devices were fabricated on a silicon–oxide–insulator (SOI) substrate with a 220 nm thick top Si layer on a 2 μm buried oxide layer. Firstly, the waveguides were defined by electron beam lithography (EBL) and inductive coupling plasma reactive ion etching (ICP RIE). Then the sample was spin coated with a HSQ layer of 30 nm thick. After that the 100 nm thick metal (Ag) layer was patterned by lift-off technique.

3. Design and measurement

First of all, we characterized the coupling loss of taper 1 and the propagation loss of HPW by measuring a set of the HPWs with different length. Fig. 2(a) shows the normalized transmission spectra of a 5 μm long single mode HPW. Fig. 2(b) plots the insertion loss of the single mode HPW at 1550 nm as a function of the length.

As the loss, due to the grating couplers and the access silicon strip waveguides, has been normalized by a reference silicon waveguide. The total insertion loss consists of two parts, i.e., the coupling loss of the two tapered couplers, and the propagation loss of the hybrid mode itself. The linear fit in Fig. 2 indicates that their values are 6.8 ± 0.6 dB

Download English Version:

https://daneshyari.com/en/article/1534148

Download Persian Version:

https://daneshyari.com/article/1534148

Daneshyari.com