Analysis of v-groove surface plasmon polaritión waveguide

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***Abstract* - We proposed the dielectric filling in a v- groove on GaAs wafer. In order to fabricate easily, the channel plasmon polaritons waveguide is proposed and analyzed, compared to conventional optical waveguide based on multi-epitaxial layer. The propagation loss is analyzed using 3-dimensional finite-difference time-domain method. We obtained the propagation loss of 1.02 dB / 30 μm.**

I. INTRODUCTION

Plasmonic have recently been demonstrated to be one of the best available options for the design of effective subwavelength waveguides and interconnectors for highly integrated nanooptics and new optical sensors [1]. This is because they offer a unique opportunity for breaking the diffraction limit of light which does not allow localization of electromagnetic waves in dielectric media into a region that is much smaller than the wavelength. Guided waves in such metallic structures are surface plasmons which are collective oscillations of electron plasma in the metal, coupled to electromagnetic waves. A number of different types of guiding the optical signal with the metal nano-structures have been proposed and described [2]. However, it seems that the two best options for the design of effective plasmonic waveguides are the groove waveguide on a metal surface [3], and gap plasmon waveguides in the form of a nanogap in a thin metal film. Both these types of subwavelength plasmonic waveguides demonstrate several superior features compared to other possible guiding metallic nanostructures.

Both numerical and analytical methods of analysis were developed and used for the inverstigation of plasmonic waveguides and device. These methods include the finite-difference time domain (FDTD) method, finite element analysis, effective medium approach, geometrical optics approximation, and etc.

In this paper, we proposed and analyzed v-groove plasmonic waveguide based on semiconductor wet-etching process for enhanced low-loss optical interconnection by using FDTD method.

II. THEORY

Surface plasmon polaritons (SPPs) are quasi-two-dimensional electromagnetic excitations, propagating along a dielectric-metal interface and having the field components decaying exponentially into both neighboring media. SPPs are tightly bound to the metal surface penetrating on ~100 nm in dielectric and ~10 nm in metal, a feature that implies the possibility of using SPPs for miniature photonic circuits and interconnects. It has been shown using numerical simulations that nanometer-sized metal layer can support extremely confined SPP modes propagating though only over hundreds.

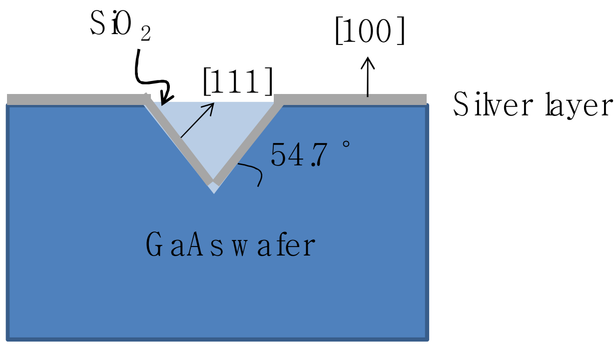

Figure 1. Cross sectional schmetic view of the v-groove

Figure 1 shows the semiconductor v-groove with thin metal layer. The process begins with a [100] GaAs substrate which is patterned with a v-shaped groove oriented along the [111] direction employing photolithography and a wet chemical etch. The [111] plane has the slowest etch rate than other direction. Therefore, the v-groove of 50.6 ° is formed. A thin-silver layer is evaporated on the etched GaAs wafer. Then, SiO_2 is filled in v-groove.

The analysis of channel plasmon polaritons (CPP) propagation in the considered structure and the effect of thin-metal layer on the groove are conducted using the three-dimensional (3D) FDTD method. We used the frequency dependent dielectric permittivity for silver obtained from P.B. Johnson and R. W. Christy's experimental results [4]. The complex dielectric permittivity of silver using the Drude model [5] was fitted with a plasma frequency of 9.15 eV, a collision rate of 0.018 eV, and a static permittivity (ε_∞) of 3.7. These fitted results by the Drude model agreed well with the experimental data obtained at a wavelength of 850 nm. The GaAs wafer refractive index is 3.644 + i0.0479 at a wavelength of 850 nm.

III. RESULTS

Figure 2 shows the field intensity as a function of propagation length in the v-groove waveguide with non-metal layer. It shows the 5.4 dB / 30 µm propagation loss.

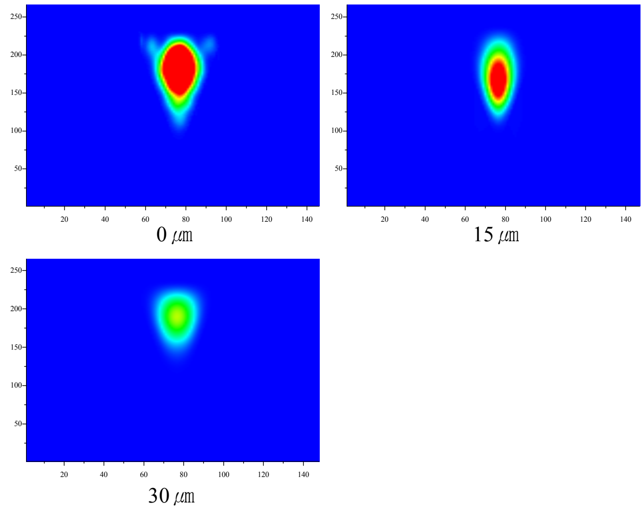

Figure 2. Normalized propagation field intensity profile in the groove with non-metal layer

Figure 3 shows the field intensity in the groove with 50 nm silver layer. It shows larger loss than non-metal layer.

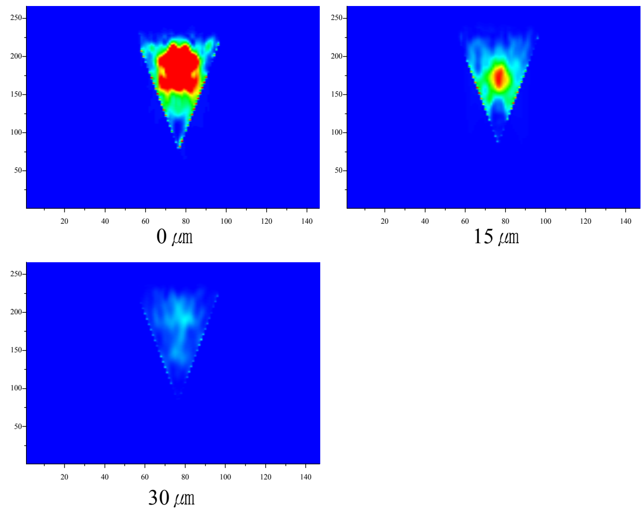

Figure 3. Normalized propagation field intensity profile in the groove with 50 nm silver layer

Figure 4 shows the field intensity in the v-groove waveguide with 100 nm silver layer. It shows the 1.02 dB / 30 µm propagation loss, because the CPP mode has been made within the groove.

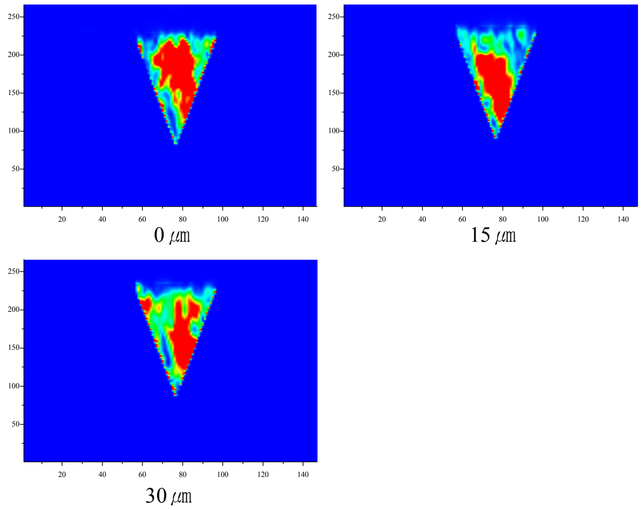

Figure 4. Normalized propagation field intensity profile in the groove with 100 nm silver layer

IV. CONCLUSION

An etched v-groove CPP waveguide based on GaAs wafer to reduce the loss has been designed and analyzed. We obtained the loss of 1.02 dB / 30 µm. The propagation loss can be reduced than this study. The CPP waveguide can be fabricated easily, compared to conventional optical waveguide based on multi-epitaxial layer.

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