Laser-induced forward transfer of Au microstructure on a Si_3N_4 channel waveguide and its plasmonic effect

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Abstract

In this paper, we report laser-induced forward transfer (LIFT) of gold microstructures on top of a silicon nitride (Si_3N_4) channel optical waveguide and its surface plasmon effect. The excited surface plasmon polariton (SPP) was simulated through finite-difference time-domain (FDTD) technique, as TM fundamental mode propagates through the waveguide.

Keywords: Laser-induced forward transfer (LIFT), Au thin-film, Si_3N_4 waveguide, surface Plasmon polariton (SPP)

1. Introduction

Metallic micro- and nanostructures have interesting functionalities on a photonic chip, such as in plasmonic biosensing [1] and surface plasmon optical tweezing [2]. Currently fabrication of the metallic structures on waveguides requires two-steps - a) first defining metallic structure using ebeam lithography and etching, and b) defining waveguide around the metallic structure by second litho step followed by etching. This is a slow and complicated process. Therefore there is a demand for a process that enables to write/print metallic elements on top of already processed waveguides in a simpler, reproducible and faster manner. Laser induced forward transfer (LIFT) a laser-based direct writing method offers a solution to this problem. It has the ability to print high resolution features of a variety of materials on non-planar substrates. It is also inexpensive, maskless and single-step process [3].
In this paper LIFT printing of Au droplet on top of silicon nitride waveguide along with simulation results of SPP excitation via the guided TM mode of nitride waveguide underneath is discussed.

2. Experiments, simulation and results

A 100nm Au thin film evaporated onto a glass substrate was used as the donor. 1-2 µm gold microstructures were successfully and reproducibly printed on top of waveguides (Figure 1 a,b), using Gaussian pulses, generated by a 273 fs, 1030 nm laser (Satsuma Amplitude system) focused on Au thin film through an objective lens (20X with NA=0.4). The printing was achieved at a fluence of 443 mJ/cm^2, as seen in Table 1.

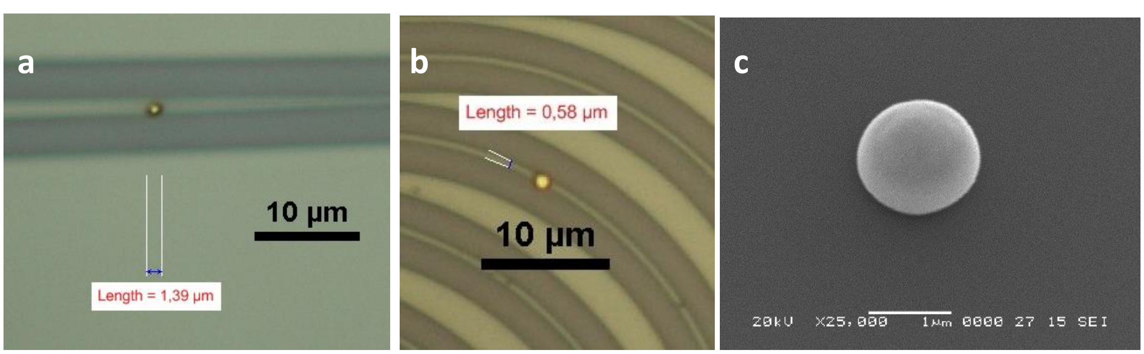
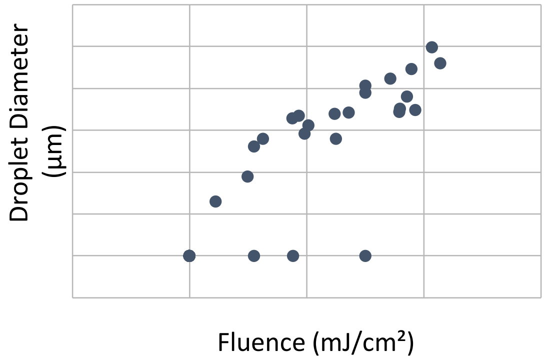
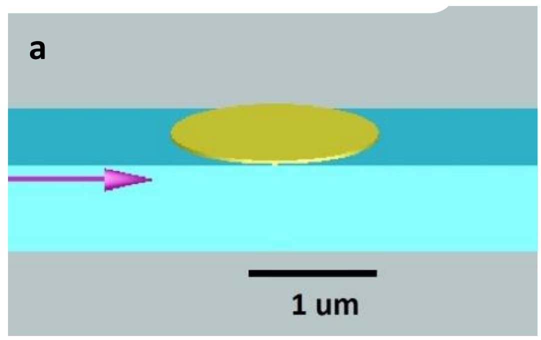


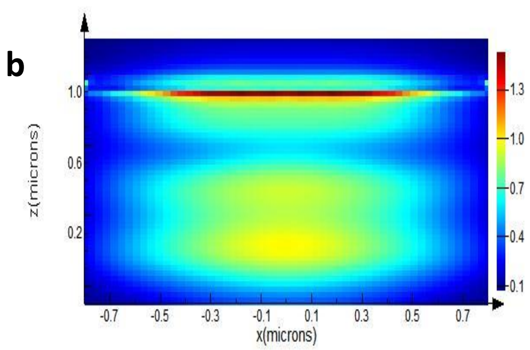
Fig. 1. (a) a LIFTed Au droplet on a Si_3N_4 waveguide (b) a LIFTed Au droplet on a Si_3N_4 bend waveguide (c) SEM image of on droplet under 45º tilt

Since the irradiated laser beam on the donor has a Gaussian profile, this results in printed structures with a rounded shape, of which the diameter is 1-2 µm.
Using FDTD analysis technique, we simulated the effect of Au droplet on transmission spectrum of a Si_3N_4 waveguide on silicon oxide (SiO_2) with 2.5 µm thickness, shown in Figure 2. a. Since we are interested in the surface interaction of the propagating mode and metal, TM fundamental mode was launched through a waveguide of 1.6 µm width and 1.2 µm height. The thickness of Au microstructure was assumed to be 50 nm. Figure 2 (b) shows the corresponding field enhancement at the boundaries of gold surface. The presence of this metallic layer results in excitation of surface Plasmon polariton (SPP) at certain wavelengths, one of which can be seen in Figure 2 (c) as a dip in transmission spectrum of the waveguide.

Tabel 1
Printed droplet diameter vs. fluence







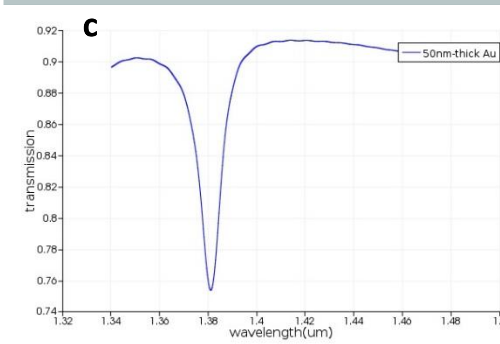


Fig. 2. (a) simulated Si_3N_4wavevguide/Au-droplet configuration (b) Field enhancement at Si_3N_4-Au interface

3. Conclusions

We present in this paper the fs-LIFT printing of Au microdroplets of 1-2 µm diameter on top of SiN waveguides. The structure (waveguide with Au droplet on top) was simulated using FDTD and results showed SPP excitation via TM guided mode. This can be used in SPP based biosensing applications

References

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