Plasmonic and hybrid plasmo-photonic integrated waveguide technologies

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***Abstract*—We present different fabrication techniques we have developed for a range of plasmonic waveguide-based active or passive configurations implemented in data router, sensor or interconnect demonstrators. We have integrated active plasmonic waveguide structures into recesses etched into SOI or silicon nitride photonic chips using either e-beam or optical lithography. We also show the fabrication of flexible long-range plasmon waveguides and corner mirror chips, both technologies that could be used for passive interfacing of components.**

I. INTRODUCTION

This paper reviews some of the fabrication methods we have developed for a range of plasmonic-based technologies in the framework of three different European projects. These developments have been driven by the need for more energy-efficient and higher speed data communications applications but also for applications in ultra-sensitive biosensing. The introduction of plasmonic technologies in the Datacom filed is pretty disruptive. The high absorption of the plasmonic metal can be compensated by elaborated design combining photonic waveguides with plasmonics. We have worked on different active waveguide structures, e.g. switches, routers, or passive couplers or transmission lines. We have developed specific fabrication techniques that we summarize.

II. LITHOGRAPHY-IN-RECESS FOR HYBRID PLASMO-PHOTONIC CONFIGURATIONS

A. In-recess e-beam lithography and metal lift-off

The hybrid plasmo-photonic waveguide structure presented in Fig.1 is typical of those produced during project Plasmofab in which we demonstrated an ultrasensitive biosensing chip [1-3].

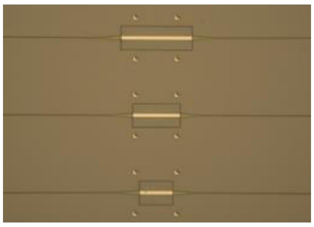

Figure 1. Hybrid plasmo-photonic waveguide strucuture. (fabrication by e-beam lithography)

The metal for plasmonics, usually Au or Al is deposited by e-beam-lithography, evaporation and lift-off inside a recess etched in the Si_3N_4-on-insulator chip. The lithography and lift-off had to be adapted to the placement of the metal into a 1 to 2-µm deep recessed cavity.

B. Recess Photomask Contact Lithography

In the former project PLATON, in which a dielectric-loaded plasmon waveguide structure was integrated in a SOI photonic waveguide platform, we have developed an original optical lithography technique to address the need for placing submicronic waveguide structures into relatively deep recesses (1 to 2 µm). This technique called Recess Photomask Contact Lithography is based on the use of an etched photomask with a relief following the topography of the photonic chip [4].

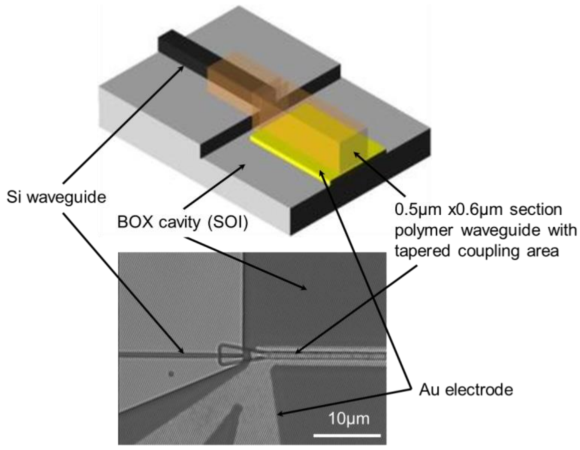

Figure 2. Hybrid plasmo-photonic waveguide strucuture (fabrication by Recess photomask Contact Lithograhphy RPCL).

III. LONG-RANGE PLASMONIC WAVEGUIDE WIRES FOR INTERCONNECTS

The large losses of plasmonic waveguides compared to photonic waveguides can be mitigated by the use of long-range plasmon waveguide structures, based on a thin (<20 nm) metal slab embedded into the dielectric. We deployed this waveguide structure in two interface demonstrators, one flexible based on elastomer, the other one rigid but integrated a corner mirror. Both are destined to serve as passive wiring for short-reach transmission of data between different cards or active chips.

A. *Bendable long-range plasmon waveguides*

To fabricate this polymer/gold waveguide, we start from a silicon substrate onto which the first cladding is deposited. The gold core of the waveguides is defined by evaporation, UV lithography and sputter etching, then the upper polymer cladding is deposited. In the end the stack is detached from the substrate to give a mechanically flexible waveguide array [5].

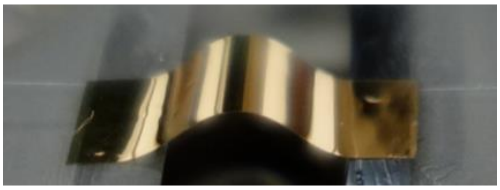

Figure 3. Flexible gold/polymer Long-range plasmonic waveguide array

The UV mask contains an array of waveguides (the gold core of the waveguide is typically 10 µm-wide) with a pitch of 100 µm. To achieve low loss we found that it was very important to enhace the metal/polymer adhesion by the use of a silane-thiol molecular linker [5].

B. *Plasmon waveguide corner mirror chip*

In this last demo, we deployed the long-range plasmon waveguide configuration in a rigid chip with an integrated mirror based on total internal reflection. The fabrication of such a chip is based on double UV-lithography of SU-8 photoresist acting as cladding. One of the difficulty is to obtain a perfectly flat vertical mirror across the double SU-8 layer. We developed an original technique using a self-alignment procedure and a single development for the two SU-8 exposures. In between the two exposures, the gold core is produced by another UV lithography step + etching [6].

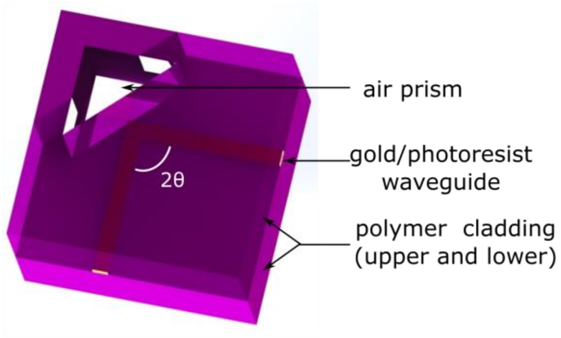

Figure 4. Long-range plasmonic waveguide chip equipped with corner mirror.

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