Nano Scale Disruptive Silicon-Plasmonic Platform for Chip-to-Chip Interconnection

Fabrication of plasmonic waveguide couplers with less than 3 dB coupling loss

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Executive Summary

This document shall incorporate (all) rules procedures concerning the technical and administrative management of the project and is therefore to be updated on a regular basis. Please look at www.navolchi.eu regularly for the latest version.

Change Records

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Introduction

It has been shown in the Milestones 9 and in the Deliverable 3.2 that the figure of merits of the plasmonic modulators are dramatically increasing while reducing the size of the plasmonic slot below 100nm. However, the excitation of the surface plasmon polariton in the metallic nanoslots with these dimensions is challenging and requires special care in the design of the coupling structure. We employ metallic tapered coupling structure which we have optimized for its highest transmission in in the case of given geometrical and material properties. Less than 1dB coupling losses are theoretically estimated for the optimized couplers.

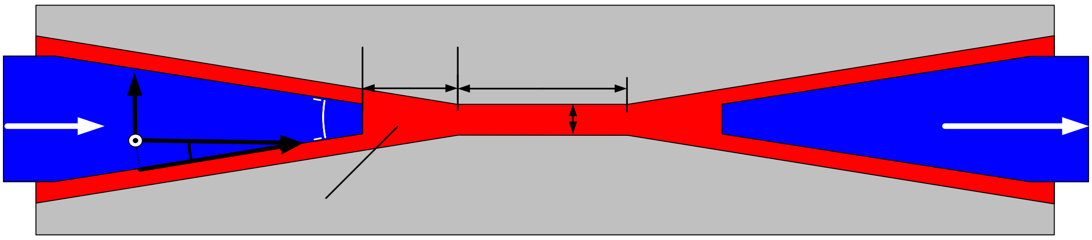

Figure 1 Top view of the SPP coupling structure. Light guided through silicon nanowire is adiabatically squeezed and launched into metallic nano-slot.

In this milestone, we discuss the work progress in developing efficient couplers for the excitation of surface plasmon polaritons in the metallic nanoslots. We describe the process flows employed and the initial characterization results of the couplers

Methods and Results

Silicon part of the entire coupler first has been design by KIT based on the previous optimized geometry discussed in Milestone 25. IMEC has processed an entire SOI wafer with a top silicon device thickness of 220nm using the design layout provided by KIT. The wafer has been diced at IMEC and shipped to KIT, where the post processing of the diced samples has been carried out to design the metallic part of the couplers. The entire process flow for the fabrication of metallic tapered couplers as well as of the modulators is depicted in Fig. 2. The silicon waveguide first

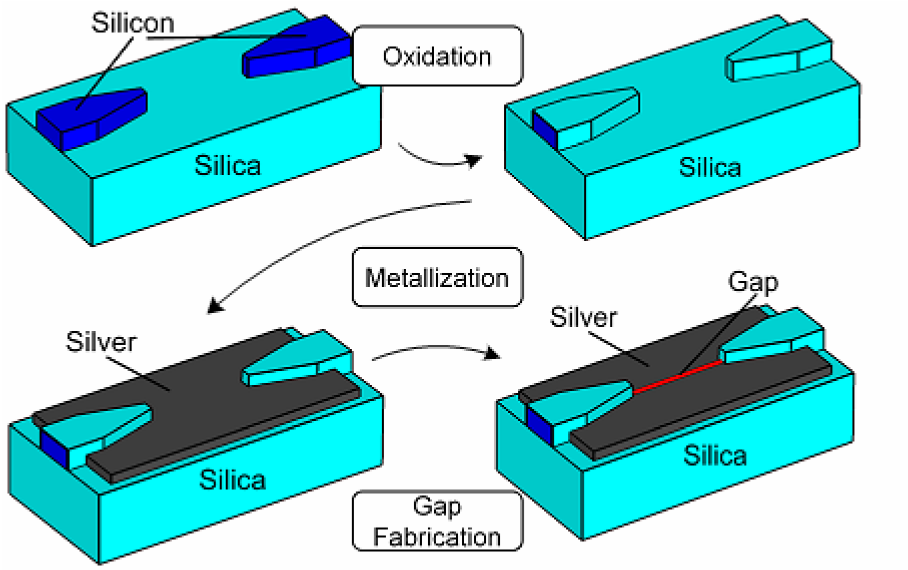

Figure 2 Process flow for fabrication of the plasmonic phase modulator

have been dry thermally oxidized and 15-20nm of silicon oxide has been grown around the waveguides, see Fig. 2(b). The metallization of the samples has been done by conventional e-beam lithography and lift off processes. The slot in the metal is design either in the previous lift-off step or by focused ion beam milling technique right after the metallization.

Focused Ion Beam Milling

First, we discuss the results obtained by the focused ion beam milling technique. In Fig. 3(a) we show the configuration of the silicon passive waveguides on the chip and the area on the PMMA which has been opened with e-beam lithography. For the coupling loss estimation with cut back method, the distance between the tips of the silicon tapers has been varied from 5µm to 15µm with 5µm increments, see Fig. 3(a). The technique has an advantage that milling of the ultra-small slots with relatively low sidewall roughness is possible. The samples treated with focused ion beam usually resulted in metallic slots with 40-70nm width, as can be seen in Fig. 5. However, the slot widths resulting from the milling process varies from device to device which makes coupling loss estimation challenging. Moreover, the alignment of the slot relative to silicon tip, which plays a major roll and has significant influence on the coupling efficiency, was not possible to achieve with the required accuracy, see Fig. 3(b). Therefore, the difficulties have arisen during characterization of the devices, because of the not reproducibility of the results from device to device, see Fig. 4.

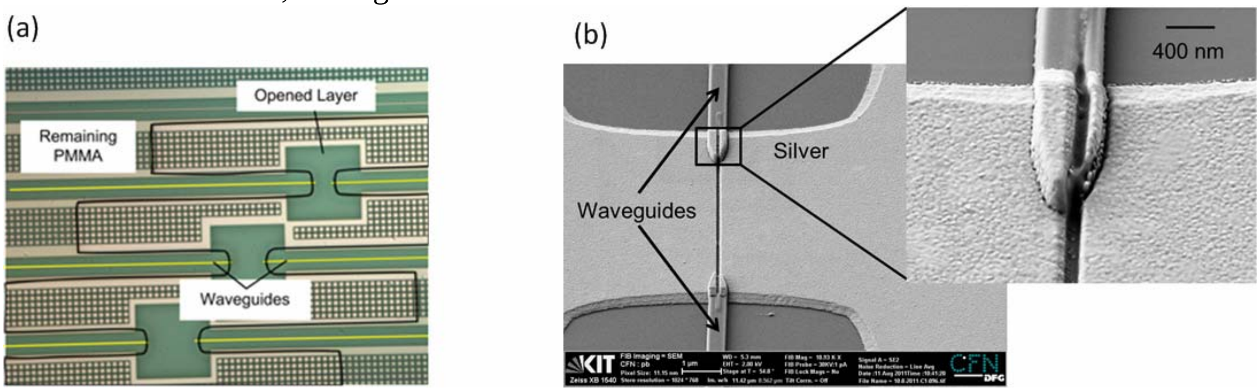

Figure 3 Process flow for fabrication of the plasmonic phase modulator

In Figure 4, we show the transmission spectra of the devices with 5µm, 10µm and 15µm long slots from two identical samples. It can be seen that the results are not reproducible.

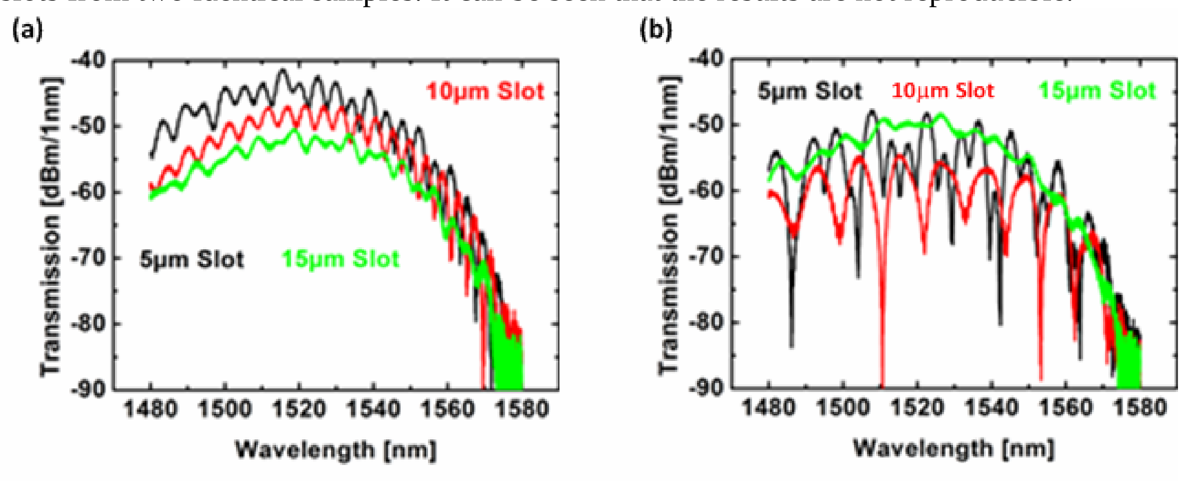

Figure 4 Transmission spectra of the devices with various plasmonic slot lengths are given for two identical samples (a) and (b). The slot has been fabricated with focused ion beam.

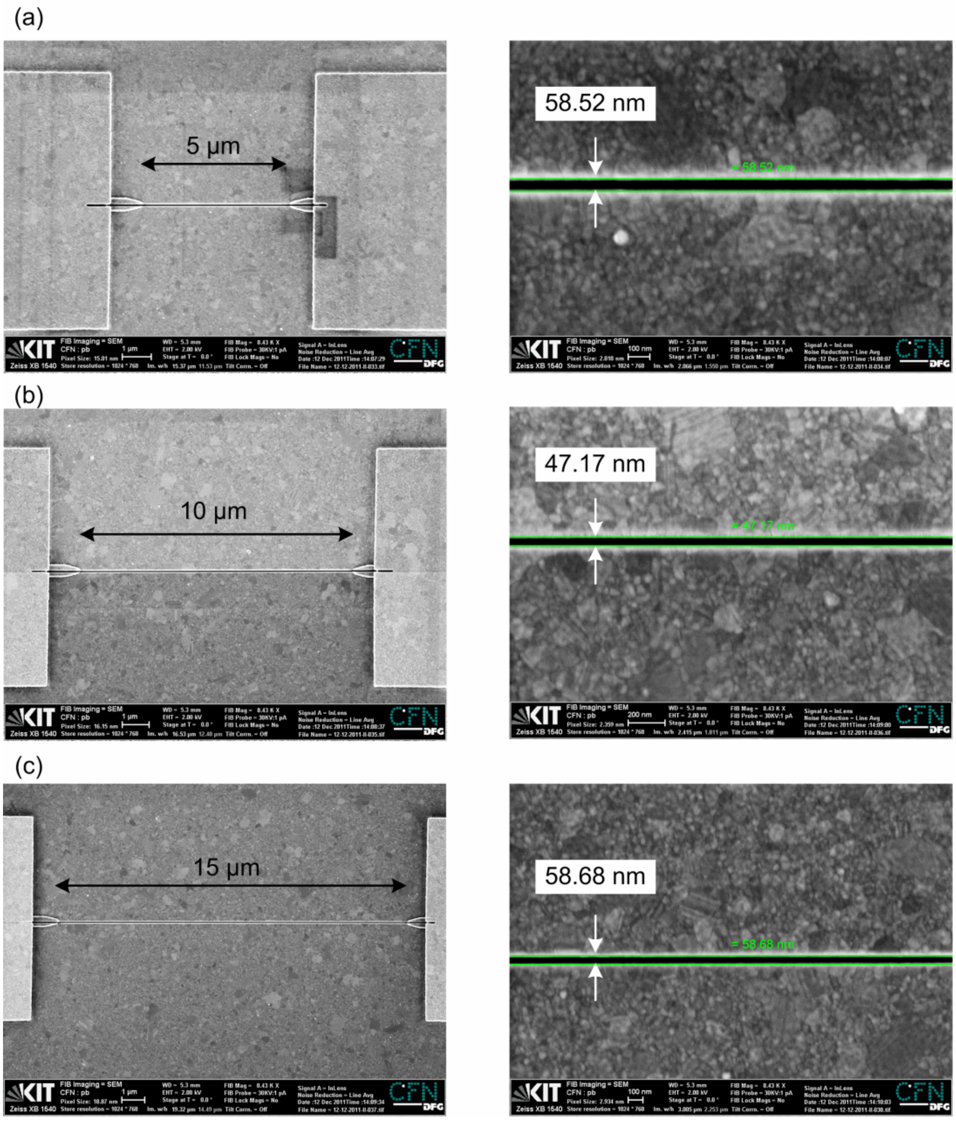

Figure 5 SEM images of fabricated couplers before stripping. All milled slots are perfectly hit in the middle of the tips with narrow slots of 47 nm and 58 nm. Images in the same row correspond to each other.

Lift-off process

In the second fabrication run, the metallic slots are designed through the lift off process. This process is more reproducible, therefore resulted in better results. In the Fig. 6 we show the metallic slots and tapers fabricated with this approach. Much better alignment accuracy is achieved with lift off process than for the FIB milling approach.

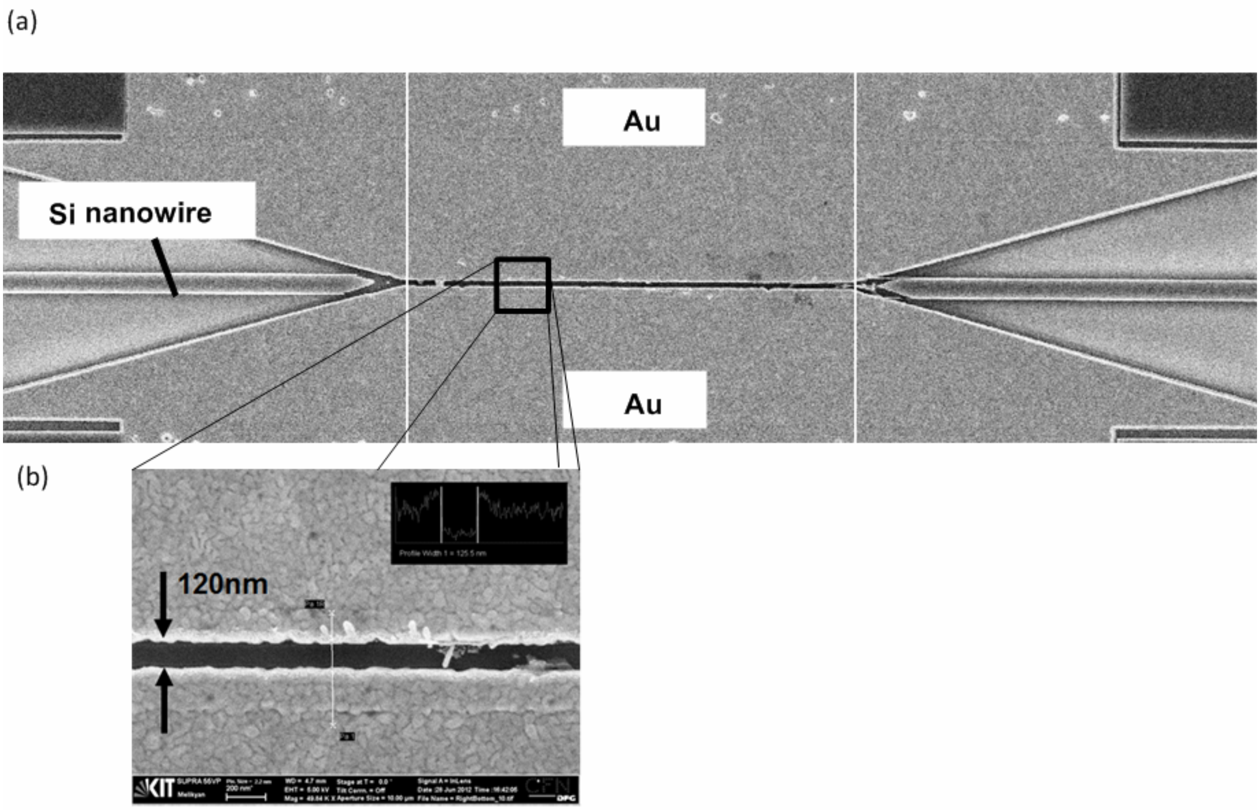

Figure 6 Metallic slots and the tapered fabricated by lift off process.

Using the cut-back method we have estimated the coupling losses in our plasmonic couplers. We have fabricated plasmonic couplers with different separations, i.e. different plasmonic waveguide lengths. Measuring the insertion loss of each individual device we are able to make our first estimation about the coupling losses of the plasmonic couplers, see Fig. 7. The coupling loss per tapered coupler is measured to be 1dB. However, taking into account the difference in the plasmonic slot widths, which is a result of the fabrication uncertainties, we can say that the coupling losses should be in the range of 2dB per taper coupler.

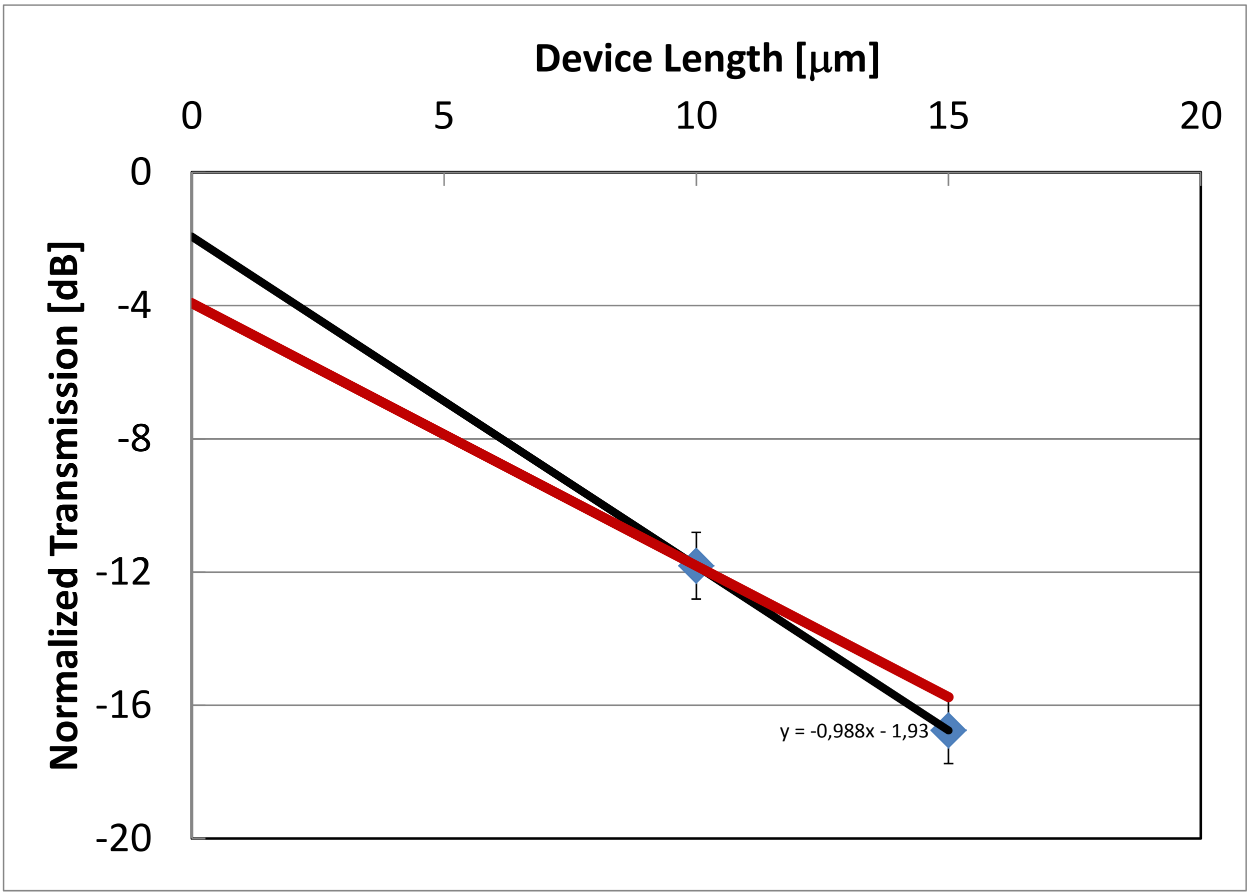

Figure 7 The insertion loss of the couplers with different separations of 10μm and 15μm. The coupling loss can be calculated by linear interpolation towards zero separation. Linear interpolation from the measurement points obtained from 120nm and 167nm slot widths (black line). Linear interpolation from the points taking into the different propagation lengths of the plasmonic waveguides with 120nm and 167nm slot widths (red line).

In conclusion, KIT with the help of IMEC has completed the first run of the fabrication and characterization of the plasmonic couplers. About 2dB coupling loss is measured for the plasmonic couplers fabricated with the lift off approach. The second fabrication run for the plasmonic modulator various length is in progress.