Plasmon confinement in V-groove waveguides fabricated by NanoImprint Lithography

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Outlook

- Plasmons: definition, confinement in V-gr., simulations, state of the art
- V-grooves fabrication process: design, description and results
  - Stamp
  - Nanoimprint and post processing
- Optical characterization
  - Far field
  - Near Field
- Conclusions
• PLASMON (SPP): Quasi-particles resulting from the coupling of free electrons in a metal and the electromagnetic field of the light.

• SPPs are evanescent waves, propagating along the dielectric/metal interface.

Propagation length ~10 - 400 µm (depending on the wavelength of the incident light).

-> Plasmons: suitable for guiding light in sub-λ structures -> nanostructures (waveguides)

Surface Plasmon Polariton in sub-λ structures:

Channel-Plasmon-Polaritons (CPPs)

V-Groove: SPPs propagating in each side couple at the bottom of the groove.

V-GROOVE

Propagation Lenght is reduced for decreasing V angle

State of the art: First experimental results in v-grooves

SNOM measurements in v-shape structures

RING RESONATORS
MACH ZENDER
INTERFEROMETER
Y-SPLITTER
Silver V-Groove made by FIB

It is possible to confine and guide light in sub-λ structures

Disadvantage: FIB fabrication is suitable just for demonstrators

- Sharp grooves, but it is difficult to control the angle
- Rough sidewalls
- Slow, process in serie
- A bigger area has to be milled, for light coupling

Not suitable for fabrication of devices, or "real" applications

Our proposal: v-grooves fabrication process based in NanoImprint lithography

Fabrication: Nanoimprint + postprocessing

- Process in parallel: up to 180 grooves in one single wafer!!
- The smoothness is improved
- Can be used to fabricate devices
Design and NIL-based fabrication process

V-groove device design

Wafer scale fabrication: different lengths and sizes in the same sample.

V-Groove: variable length (100-500 µm) and width (3-12 µm), angle = 70°, (fix by the fabrication process)

NIL allows multilevel fabrication in the same step:

Integration of v-groove and deep channels

Channels: deep (300 µm) and wide (200 µm), to approach the fibers to the groove

Light source

Optical fiber

Gold on transparent substrate
Nanoinprinting

1. Hard stamp
2. Substrate with a polymer layer
3. Heat,
4. Pressure
5. Cool down (with the pressure)
6. Separate

Main advantages:

√ Unlimited resolution (given by the stamp fabrication)
√ Parallel fabrication process: 1 sample processing at a time, containing several single chips
√ Simple and cheap process, suitable for large scale fabrication of devices

A. Stamp

B. Nanoimprint and postprocessing

1. Imprint in PMMA
2. Gold deposition
3. Ormocomp deposition (UV curing)
4. Removing PMMA

C. Final Structures
**Silicon Stamp**

1. RIE

Channels

2. KOH

V-Grooves

3. Oxidation

\[ W = 5 \mu m \]

6h, 1150ºC

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**A. Stamp**

Gold (200 nm)

Ormocomp (transparent polymer, from Silicon)

**B. Nanoimprint and postprocessing**

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2. Gold deposition
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**C. Final Structures**
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Gold Grooves on transparent substrate

40 µm

5 µm
OPTICAL CHARACTERIZATIONS

I. Far field images

II. Near field: SNOM characterization

Far field characterization

There is a clear output mode for TM polarization
Optical Near Field characterization (SNOM)

Light couples and propagates inside the grooves

Evaluation of the performance for light guidding

V-groove geometry:
- width = 3.8 µm
- depth = 4 µm
- apex angle = 50°

SNOM measurements (at \( \lambda \approx 1525 \text{ nm} \)):
- Propagation length = 120 µm
- Confinement: FWHM = 1.33 µm

- CPPs are less confined than in previous works (FIB), due to the large apex angle.
- This results in larger propagation lengths -> good compromise between confinement and losses.
**Use for (bio)sensing:** Fiber-to-fiber measurements

Change in the output signal as a function of the media inside the V-waveguide.

![Diagram of fiber-to-fiber measurements](image)

**Conclusions**

- Plasmon confinement in v-grooves has been demonstrated recently.
- A method for parallel fabrication of v-grooves integrated with deep channels, in wafer scale, has been presented.
- Optical characterization in far field show an output mode for TM polarization.
- SNOM measurements show plasmon confinement and light guiding in the waveguides.