PlasMOS—Integration of Plasmonic Structures in Standard CMOS

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Today, the implementation of filters (e.g., polarization, pass-band etc.,) for image sensors and cameras requires additional and costly processing steps. This project investigates the feasibility of directly integrating plasmonic structures in or on a standard CMOS process; such a technology could allow for easy and cost-effective implementation of filters directly in our image sensors. An immediate application is the implementation of a multispectral imager at no extra cost compared to a conventional imager.

Since the extraordinary optical transmission measured through subwavelength holes in opaque metal sheets by Ebbesen in 1998 [1], there has been some speculation as to the possible benefits of tailoring metallic nanostructures to obtain optical effects beneficial for commercial devices. Recently, detailed investigations [2] have been performed regarding the potential to excite bounded surface waves between the metal-semiconductor interface, i.e. the so-called 'plasmons'. To obtain optical emission via excitation of these delocalized surface waves, it is necessary to structure the material at the scale of the wavelength of light, i.e. 400-700 nm for visible wavelengths. These resonant structures yield filtering functions that can be tailored by changing the properties of the metal structure e.g., size of the holes, shape of the holes, period of the holes, as well as, the type and thickness of the metal used.

The challenge in this work is finding a CMOS compatible structuration that provides the desired optical filtering function. Towards this end, the PlasMOS project investigates two different options for implementing filters based on plasmonic structures i.e. the use of:

- The existing metal stack of the CMOS process.
- A post-processing step on top of the existing CMOS wafer.

The filters are designed to exhibit a transmission band that is independent of the polarization. As the main goal is to obtain a plasmonic response at visible wavelengths, we are focusing on aluminum or aluminum alloy structures (copper is unsuitable for resonant plasmonic structures due to high losses at these wavelengths).

In the case of option 1, use of the existing CMOS metallization process to fabricate the plasmonic structures limits the choice to relatively older CMOS technologies, as more recent technologies have adopted copper for most of their metal layers. A thorough comparison of technology options and design rules was performed and we concluded that simple planar structures in the dimensions available with such older technologies are not suitable for plasmonic filters in the visible range. Given this, we are now investigating more complex 3D structures that could be implemented using consecutive metal layers.

With respect to the second option, fabrication of the plasmonic filters is performed in a post-processing step: UV nanoimprint lithography is used to replicate the nanostructure from a master onto the sensor. The master consists of periodic nanostructures arranged in pixels with a different pitch. It can be fabricated once with laser interference lithography or electron beam lithography and used numerous times, thus reducing the cost of manufacturing. After replication, an evaporation of the metal is performed on the nanostructure, thus generating an array of plasmonic nanostructures in two processing steps [3]. Each filter of the array transmits a different portion of the visible light. Specific marks are used on the corners of the sensor in order to ensure accurate alignment between the filters and the pixels.

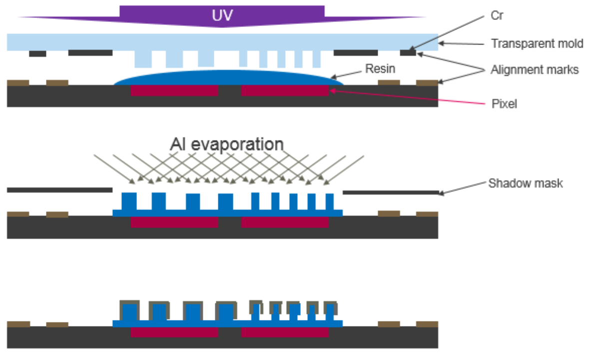

Figure 1: Fabrication of plasmonic filters in a post-processing step.

Simulations of the optical properties of the plasmonic filters fabricated via post-processing have been performed with the rigorous coupled wave analysis (Figure 2), taking into account the constraints of the process. In particular, the depth of the nanostructures and the thickness of the evaporated layer must be identical for all filters. Only the aperture dimensions and pitch can be varied.

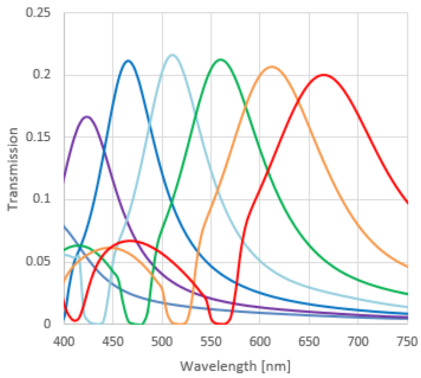

Figure 2: Simulated transmission spectrum for 6 different filters.

In a next step, the nanostructured pixels will be first fabricated in stand-alone form and their transmission characterized in order to assess the quality of the structures. In a second step, they will be replicated on top of an imager designed by CSEM.

[1] T. W. Ebbesen, *et al.*, "Extraordinary optical transmission through sub-wavelength hole arrays", Nature, 391 (1998) 667.

[2] F. J. Garcia-Vidal, *et al.*, "Light passing through subwavelength apertures", Rev. Mod. Phys., 82 (2010) 729.

[3] F. Lütolf, O. J. F. Martin, B. Gallinet, "Fano-resonant aluminum and gold nanostructures created with a tunable up-scalable process", Nanoscale, 7 (2015) 18179.