Direct write and nanoprinting for plasmon resonance color filters

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The field of nanoplasmonics has undergone rapid expansion in recent years due to advancements in fabrication and characterization of nanostructured devices that demonstrate surface plasmon resonance (SPR). Surface plasmons (SP) have been exploited to make devices such as biosensors and have potential in areas such as subwavelength optics[1]. Here we present the fabrication methods for optical plasmonic filters and their integration with complementary metal oxide semiconductor (CMOS) image sensors for digital imaging.

We have fabricated plasmonic filter sets using a glass substrate with a 150nm aluminum film and a 200nm SiO_2 cap layer. The aluminum layer was patterned with a series of triangular hole arrays using electron beam lithography (EBL) and dry etch[2]. Using this method we have recreated a microscopic, color image of the University of Glasgow logo, as is shown in Figure 1.

Color filtering is often provided by dye films in CMOS imaging chips, however as pixel pitch is scaled to smaller sizes, dye films demonstrate undesirable cross talk properties due to the large gap between each filter and corresponding photodiode. Plasmonic filters can be fabricated in a metal layer as part of the CMOS process, therefore closer to the photodiodes, ultimately resulting in diminished crosstalk. In our work we have fabricated plasmonic filters on top of single pixel and multi-pixel CMOS image sensors using EBL and dry etch[3,4]. Our plasmonic filter integrated CMOS chips are shown in Figure 2.

An alternative fabrication technique that we have developed for fabrication of plasmonic filters and polarizers uses a silicon stamp to transfer aluminum nanostructures on to a flexible polycarbonate substrate. This method is both faster and cheaper than the conventional EBL and focused ion beam (FIB) lithography fabrication techniques. The silicon stamp was fabricated using EBL and dry etch, with ZEP520A acting as the etch mask. A low-adhesion layer was formed on the silicon surface to facilitate the transfer of the aluminum on to the polycarbonate sheet. Aluminum was then evaporated on to the silicon stamp and the coated silicon stamp was used to print the patterned aluminum film on to the polymer. The process flow is shown in Figure 3. A polycarbonate sheet was placed on top of the aluminum to meet the index matching condition required to optimize plasmonic filter performance. The transfer printing technique yields similar nanohole quality to that observed using EBL and dry etch processes[5].

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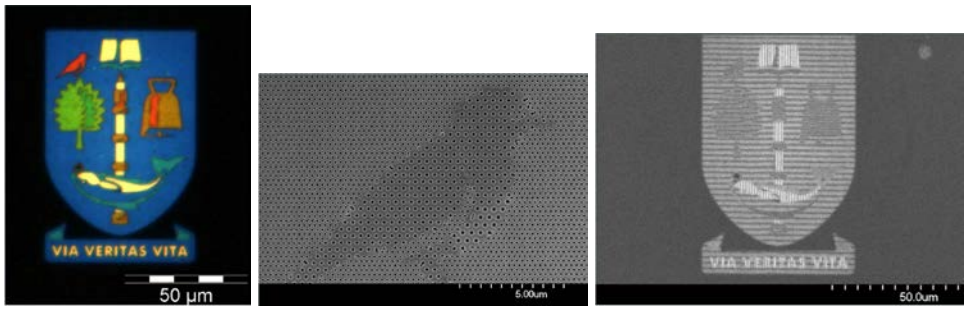
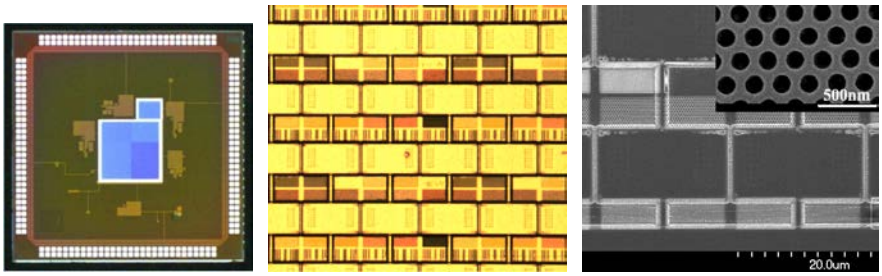


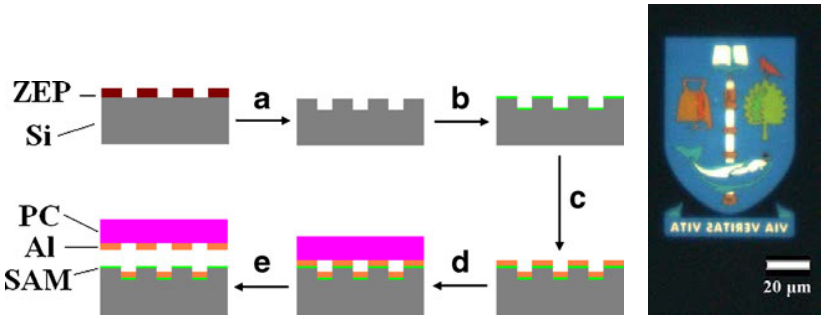
(a) (b) (c)

Figure 1: University of Glasgow logo made using plasmonic filters: (a) Transmission microscope image. (b) SEM image of the bird of the University of Glasgow crest. (c) SEM image of the crest.



(a) (b) (c)

Figure 2: Images of single pixel and multi-pixel CMOS image sensors integrated with plasmonic filters: (a) Reflection microscope image of single pixel image sensor with integrated plasmonic filter. (b) Reflection microscope image of multi-pixel image sensor with integrated plasmonic filters on top. (c) SEM image of plasmonic filters fabricated on top of the multi-pixel array.



(f)

Figure 3: Imprint process: (a) Silicon stamp is fabricated using EBL and dry etch; (b) the surface is treated with an anti-adhesion coating; (c) aluminum is evaporated on to the stamp; (d) the silicon stamp is used to print aluminum on to polycarbonate sheet; (e) the polycarbonate sheet is peeled off the stamp. (f) The University of Glasgow logo fabricated on a polycarbonate substrate with polycarbonate cap layer. The logo has been fabricated using the nano transfer printing technique.