Light detection enhancement in Near Infra-red by 2-dimensional Silver nanograting integrated by Electron Beam Lithography

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Photon detecting devices have been extensively investigated over the last years to improve detection efficiency and timing resolution. In this study we focused on thin silicon photodiodes and exploited the effects of Surface Plasmon Polaritons (SSP), which can transform light into highly confined modes, boosting NIR photon absorption near the active depth of the devices. The goal of this contribution is to enhance the detection of a silicon photodiode by integrating a silver plasmonic nanoarray directly on the active area of the devices using Electron Beam Lithography (EBL) and Ag evaporation/ lift-off.

In Figure 1, a not-in-scale cross-section of the suggested detector is depicted. The designed silicon photodiode is made of a 3 μm thick silicon slab and a thin dielectric coating (silicon nitride) protecting the top detector surface, serving two purposes: to passivate the detector reducing surface recombination; to operate as an optical coupling layer between the detector and the 2D nanograting [1]. The metallic nanograting is precisely fabricated directly on top of the detector by EBL, followed by silver evaporation and a lift-off procedure [2].

The ideal geometrical parameters of the 2-dimensional nanograting (grating periodicity, slit, and Ag thickness) were investigated with time-domain finite-elements (FDTD) simulations under TM polarized light illumination [3]. Two nanograting pitches resulted promising to increase NIR absorption, i.e. 260 and 535 nm (P260 and P535 samples, respectively). In figures 2, SEM pictures of the actual devices are reported.

A custom setup was used to conduct electro-optical characterizations of the samples operating in the visible and near-infrared light range. We measured the quantum efficiency [4] and its enhancement (with respect to reference devices without Ag grating) for the different geometries, as shown in Fig. 3. A QE enhancement of 45% was achieved without compromising the correct functionality of the device.

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[1] P. Berini et al., Laser and Photonics Reviews 8.2 (2014) 197-220.
[2] A. Hessel et al., Applied Optics 4.10 (1965) 1275-1297.
[3] Lumerical Inc. https://www.lumerical.com/products/.
[4] A. Filippi, Improving Silicon Photodetectors NIR Responsivity via Hybrid Opto-Plasmonic Resonances, PhD Thesis, Università degli Studi di Padova, 2020.

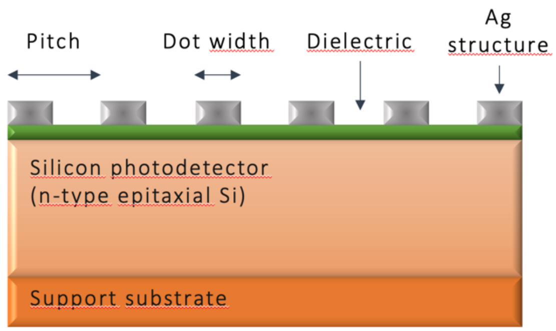

Figure 1: Cross section of the proposed structure

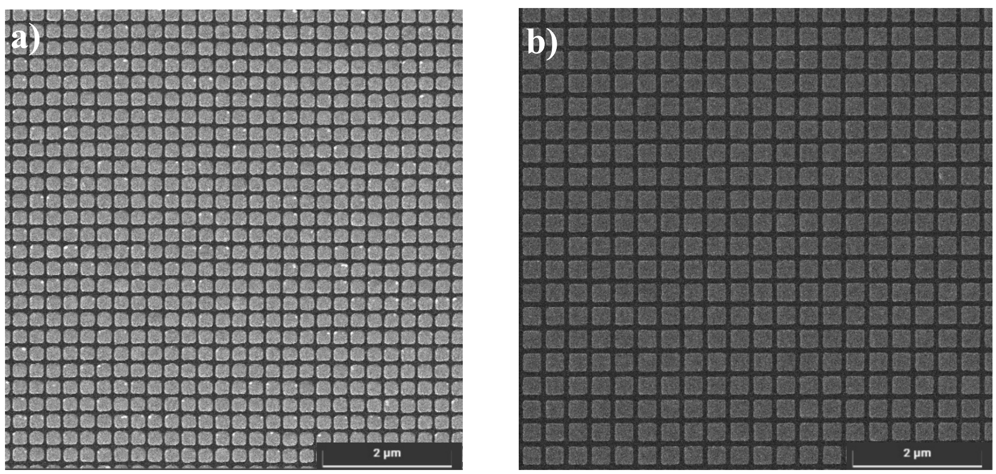

Figure 2: SEM plan view of 2D silver nanograting: a) sample P260: grating periodicity 260 nm, and b) sample P535: grating periodicity 535 nm

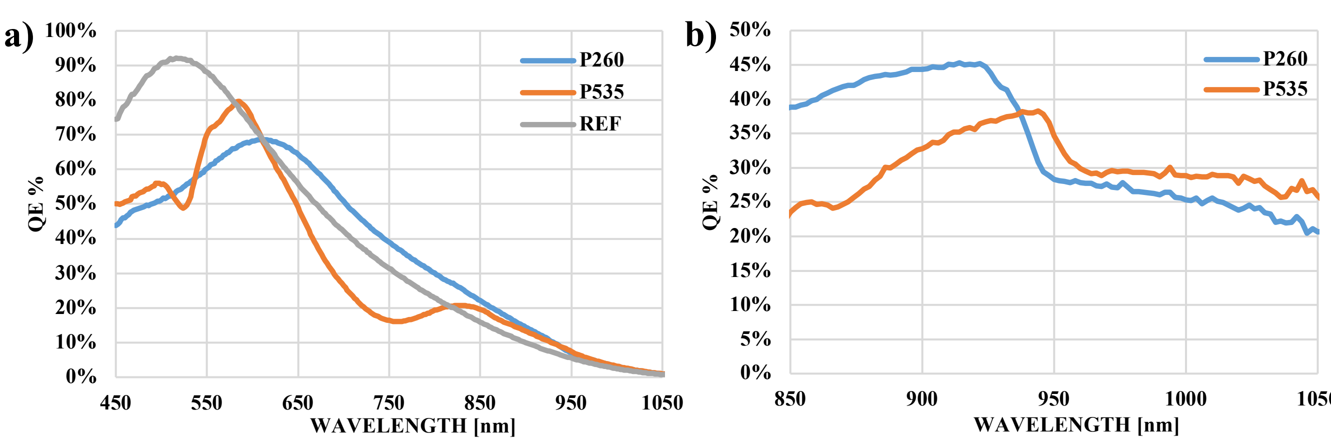

Figure 3: a) QE as a function of wavelength of P260 (blue lines), P535 (orange line) and of the reference without nanograting (grey line), b) QE enhancement of the two samples compare to the reference as a function of wavelength.