Azimuth and Elevation Angle Dependence of Light Sensitivity in SOI Photodiode with Gold Grating

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The angle sensitive pixel (ASP) is the key component to accomplish the new generation of computational imaging [1]. Although ASPs are essential to add two-dimensional (2D) angle information in the plenoptic function, most of commercial cameras capture only the intensity of incoming light even in the recent years. As one candidate of ASPs, we have already developed a silicon-on-insulator photodiode (SOI PD) with one-dimensional (1D) metallic line and space (L/S) grating, and the unique selectivities of light detection to wavelength, polarization, and incident angle have been shown [2, 3].

In this study, the light sensitivity of our proposed device on azimuth and elevation angle at the fixed incident angle and polarization is investigated. Figure 1 shows the bird's eye view of SOI PD with 2D hole array grating type gold SP antenna, and the definition of azimuth (ϕ), elevation (θ) and polarization (ϕ_{pol}) angles. The electromagnetic simulations based on finite difference time domain (FDTD) method are applied to evaluate the absorption efficiency in SOI layer for different incident angles ϕ and θ at fixed wavelength of 685 nm. Since the hole array type SP antenna has 2D periodicity, the periodic boundary conditions to *x* and *y* directions are adopted to FDTD calculation for efficient computations. When the phase matching condition between the diffracted light from grating and the waveguide mode in SOI layer is satisfied, higher absorption efficiency can be obtained at a specific incident angle [2, 3]. The angle dependence is represented as a spatial pattern which simultaneously indicates the azimuth and elevation angle dependences as shown in Fig. 2. In the result, the absorption efficiency for $\phi_{pol} = 45°$ is evaluated. A four-fold symmetry similar to the theoretical prediction based on the phase matching condition (data not shown) was confirmed. Compared to the conventional ASP, our proposed device captures a rich collection of angular information in 2D direction. This unique feature of the 2D angle sensitive response could be realized by using a single ASP. Our device is compatible with complementary metal-oxide-semiconductor (CMOS) integrated circuit technology, thus an array of ASPs could be incorporated in a single chip and offer potential applications, for example, depth mapping, lensless imaging, and light detection and ranging (LiDAR).

References:

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3. Anitharaj Nagarajan, et al., *Silicon Nanoelectronics Workshop (SNW). IEEE,* **2019**, 1-2.

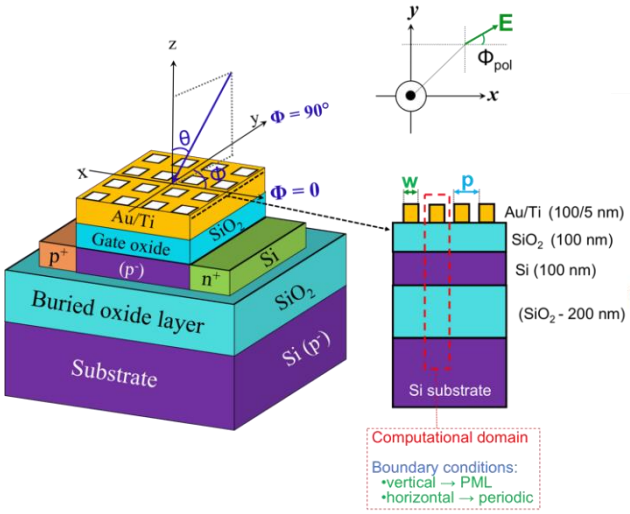

Fig. 1: Bird's eye view of SOI PD with 2D gold hole array grating with the definition of azimuth (ϕ), elevation (θ) and polarization (ϕ_{pol}) angles.

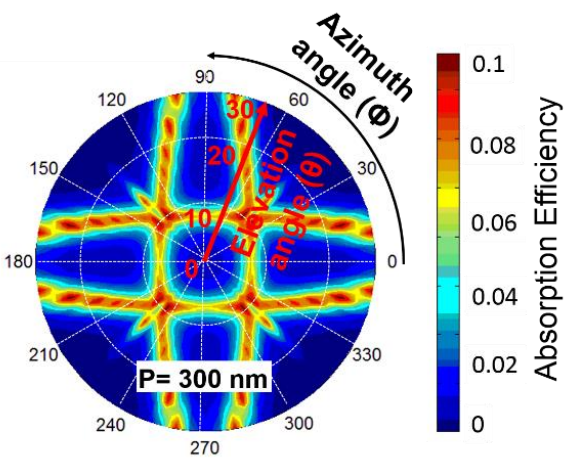

Fig. 2: Spatial pattern (azimuth and elevation angle dependences) of absorption efficiency for $\phi_{pol} = 45°$.