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Analysis of Subwavelength Metal Hole Array Structure for the Enhancement of Quantum Dot Infrared Photodetectors

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In the past decade, the infrared detectors based on intersubband transition in quantum dots (QDs) have attracted much attention due to lower dark currents and increased lifetimes, which are in turn due a three-dimensional confinement and a reduction of scattering, respectively. In parallel, focal plane array development for infrared imaging has proceeded from the first to third generations (linear arrays, 2D arrays for staring systems, and large format with enhanced capabilities, respectively). For a step further towards the next generation of FPAs, it is envisioned that a two-dimensional metal hole array (2D-MHA) structures will improve the FPA structure by enhancing the coupling to photodetectors via local field engineering, and will enable wavelength filtering. In regard to the improved performance at certain wavelengths, it is worth pointing out the structural difference between previous 2D-MHA integrated front-illuminated single pixel devices and back-illuminated devices. Apart from the pixel linear dimension, it is a distinct difference that there is a metal cladding (composed of a number of metals for ohmic contact and the read-out integrated circuit hybridization) in the FPA between the heavily doped gallium arsenide used as the contact layer and the ROIC; on the contrary, the front-illuminated single pixel device consists of two heavily doped contact layers separated by the QD-absorber on a semi-infinite GaAs substrate. This paper is focused on analyzing the impact of a two dimensional metal hole array structure integrated to the back-illuminated quantum dots-in-a-well (DWELL) infrared photodetectors. The metal hole array consisting of subwavelength-circular holes penetrating gold layer (2DAu-CHA) provides the enhanced responsivity of DWELL infrared photodetector at certain wavelengths. The performance of 2D-Au-CHA is investigated by calculating the absorption of active layer in the DWELL structure using a finite integration technique. Simulation results show the enhanced electric fields (thereby increasing the absorption in the active layer) resulting from a surface plasmon, a guided mode, and Fabry-Perot resonances. Simulation method accomplished in this paper provides a generalized approach to optimize the design of any type of couplers integrated to infrared photodetectors.

Keywords: Surface plasmon sresonance, Infrared photo detector, Quantum dot, Metal hole array, Focal plane array