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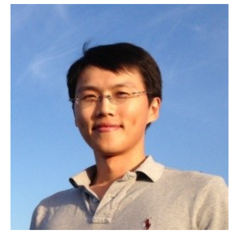


Multiband charge-coupled device

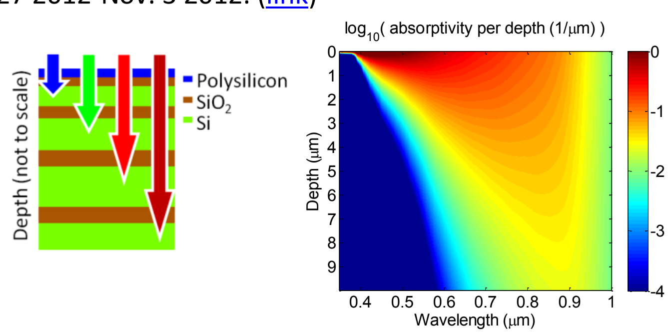
The multiband charge-coupled device (CCD) is designed to generate color images of extremely faint objects, primarily for astronomical applications. Fabricated on a silicon-on-insulator (SOI) wafer with multiple silicon device layers, the multiband CCD is similar to the conventional CCD in many senses, except that different layers are designed to interact primarily with photons in different wavelength bands, as shown in Fig. 1(a). This concept is inspired by the fact that the absorptivity and penetration depth of silicon vary greatly with wavelength, as shown in Fig. 1(b). By using the SOI wafer, electron-hole pairs generated at different depths by photons of different wavelengths can be collected by gate potential but still be physically separated in different horizontal active layers by buried silicon dioxide layers, forming vertically stacked charge packets. Subsequently, the stacked packets are transferred together by the same gate voltage but detected at separate sense nodes. The charge from different active layers then forms images in different colors.

We are working on a proof-of-concept three-layer implementation. The scattering-matrix method is used to model and optimize the optical response of the three-layer version of Fig. 1(a). Fig. 2 shows the absorptivity spectra of an optimized stack. The absorptivity of different active layers is separated into three separate wavelength bands. The overall absorptivity is on par with that of a conventional CCD.

The implementation above is superior to an *ideal* conventional CCD with three color filters, because every pixel in the former collects photons across the useful bandwidth (400nm-1000nm), retaining information for three colors after each exposure, whereas each pixel of the conventional CCD can only collect roughly a third of the incident photons due to the use of band-pass filters. As a result, our implementation is twice as fast as the conventional system, as depicted in Fig. 2.

For more information, please refer to

C.-E. Chang, J. D. Segal, A. J. Roodman, R. T. Howe and C. J. Kenney, "Multiband charge-coupled device," Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2012 IEEE , pp.743-746, Oct. 27 2012-Nov. 3 2012. (link)



(a) (b)

Fig. 1. (a) Multiband CCD implemented with a multi-layer silicon-on-insulator wafer. Different layers are designed to interact primarily with photons in different wavelength bands, as shown by the arrows. (b) The absorptivity of silicon versus wavelength and depth into the substrate.

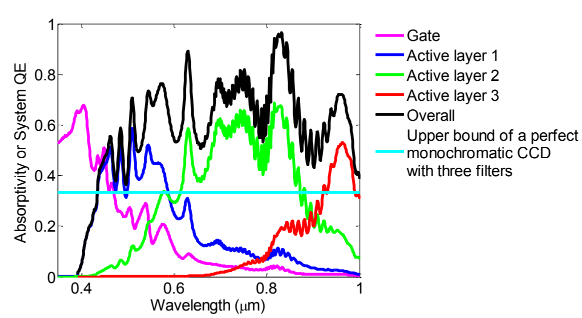


Fig. 2. Optical performance of the prototype device calculated with the scattering-matrix method.