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CMOS based VIS-IR Tunable Multiband Imaging Sensors using Quantum Dots

Infrared imaging is used extensively in many fields of science, in defence and security applications, medical diagnostics and gas sensing. At present efforts in infrared (IR) research are directed towards making IR detectors cheaper and more convenient to use by integrating the sensing element on a silicon based read out integrated circuit (ROIC) and by increasing the temperature of operation so that Peltier coolers can be used instead of liquid nitrogen. Integration of IR cameras with complementary metal oxide semiconductor (CMOS) based ROIC would open the way to high resolution IR imaging and to multispectral devices where visible and IR radiation are simultaneously detected. Systems that collect data in multiple spectral bands are capable of discriminating both absolute temperature as well as unique signatures of objects in the scene. By providing this new dimension of contrast, multiband detection also offers advanced spectral processing algorithms to further improve sensitivity above that of single spectral devices.
IR are also a critical component in all astronomical research equipment for both space-based astronomy and earth observation. Yet the technology, based on hybridized HgCdTe/silicon, remains difficult and highly specialized and mostly based in the US. The possibility to extend to NIR and MIR spectra ranges large area CMOS sensor technology would allow to overcome such limitation and to develop a competitive EU based technology.
Quantum dot infrared photodetectors (QDIP) are III-V nanostructured semiconductor based sensors where intersubband transitions between electronic states confined within quantum dots (QD) are used for IR sensing. Being based on quantum confinement effects, the absorption wavelength can be tuned to the desired value by engineering the shape and dimension of the QD. QDIPs are expected to give superior performances at moderate cooling power due to their low noise. [1] Moreover QDIPs have high tolerance to crystal defects.
We are defining detailed procedures for the epitaxial deposition and monolithic integration of QDIP on silicon CMOS VIS sensors and related ROIC. This would allow for the use of state of the art CMOS imaging technology to be extended in the NIR and MIR regions. A Ge photodiode is used to integrate the GaAs/AlGaAs QDIP on CMOS, thus permitting to the detector to cover the NIR region, up to 1.7 um. Ge is already integrated with Silicon in CMOS foundries, as evidenced by its application in mainstream microelectronics and in Si-based photonics . Moreover due to its negligible lattice mismatch with GaAs (and AlGaAs), Ge is an excellent substrate for the deposition of QDIPs. The quantum efficiency of the device will be boosted both via the strain-free self-assembly of high density QDs, permitted by the droplet epitaxy growth technique [2]. The fabrication of vertically illuminated QDIP, monolithically integrated on Si by Ge on Si epilayers deposited by low-energy plasma enhanced CVD (LEPECVD) has been demonstrated. The realized QDIP pixel consists of an absorbing part made by a 30 nm thick AlGaAs barrier and GaAs QDs with an areal density around 1×1011 cm-2. The fabricated devices exhibit extremely low dark current densities at room temperature and a spectral response measured at 80K in the MIR range demonstrating the feasibility of QDIP integration on Si.
By extending the detecting spectrum of conventional CMOS image sensor, while retaining the simplicity of integration and use, the proposed sensor would enable new applications, for example in automotive, domotic, earth observation as well as scientific.

[1] P. Martyniuk and a Rogalski, "Quantum-dot infrared photodetectors: Status and outlook,"Progress in Quantum Electronics 32(3-4), 89–120 (2008) [doi:10.1016/j.pquantelec.2008.07.001].
[2] L. Cavigli, S. Bietti, N. Accanto, S. Minari, M. Abbarchi, G. Isella, C. Frigeri, A. Vinattieri, M. Gurioli, et al., "High temperature single photon emitter monolithically integrated on silicon,"Appl. Phys. Lett. 100(23), 231112 (2012) [doi:10.1063/1.4726189].

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