A Novel InSb-Based Photo-Pixel with a Monolithically Integrated GaAs MESFET for Video Rate Sampling

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Abstract: We demonstrate the monolithic integration of an active photo-pixel made in InSb on a GaAs substrate. Video rate sampling of photo-generated signal can be provided by the co-integration of a GaAs MESFET with an InSb photodiode.

1. Introduction and summary

Imaging at medium wavelength infrared (MWIR) or mid-IR range has attracted sustained interest due to its wide range of applications in gas sensing, security, defense, medical diagnosis, environmental and astronomical observations [1]. In order to make an imaging device such as a focal plane array (FPA), it is required that the photodiodes, must be individually addressable using row and column decoding so that the photo-generated signal can be readout from each detector. For imaging at visible wavelengths, since both the photodiodes and the logic readout circuits are fabricated using complementary metal oxide semiconductor (CMOS) process, monolithic FPAs can be achieved [2]. Nevertheless, CMOS process on its own is not suitable for sensing at MWIR. As a result, the integration of the CMOS addressing chip known as a read-out integrated circuit (ROIC) with an array of isolated photodiodes made by small band gap semiconductors is required for FPAs working in MWIR. In this approach, since one-to-one connections between each photodiode and the addressing circuit on the ROIC must be realized, flip-chip bonding is used [3]. Although this hybridization method has successfully produced large format FPAs, the interconnections (indium bump bonds) and substrate alignment that used in flip-chip bonding become more challenging when larger arrays of smaller pixels are desired for high resolution cameras at lower cost.

We present a monolithically integrated switchable photo-pixel which hybridizes an InSb photodiode that is sensitive in the MWIR with a GaAs MESFET by heterogeneous growth of GaAs and InSb device layers on a semi-insulating (SI) GaAs substrate [4] (Fig. 1 and Fig. 2). The measurement results, as shown in Fig. 3 and Fig. 4, confirmed that the InSb-based photo-pixel was sensitive to mid-IR range at room temperature, and that the photo-response could be eliminated and isolated from its contacts by switching off the co-integrated MESFET. Moreover, the SI GaAs substrate method used in this work is suitable for the growth of a number of III-V materials with mid-IR detecting capabilities such as InAsSb and type-II InAs/GaSb superlattices [5][6], therefore alternative semiconductor layer structures could also be investigated. This heterogeneous technology creates great potential to realize a new type of monolithic focal plane array for imaging in the MWIR range without the need for flip-chip bonding to a ROIC.

In this paper, we will detail more electrical and optical measurement results of the photo-pixel such as typical transient response of the fabricated devices as shown in Fig. 5 and Fig. 6, and especially focus on the video rate sampling of the MWIR photoresponse generated in an InSb-based photodiode by the monolithically integrated GaAs MESFET.

2. Figures and tables

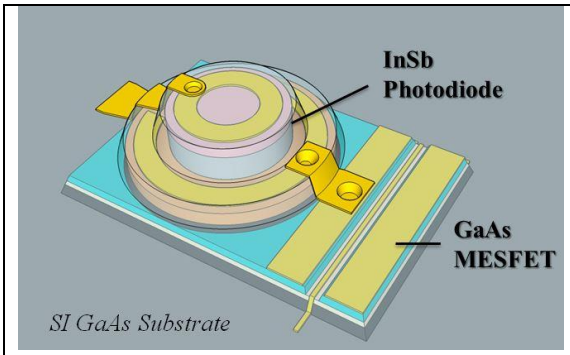

Fig.1. A 3D sketch of the monolithically fabricated GaAs MESFET and InSb MWIR detector (not to scale).

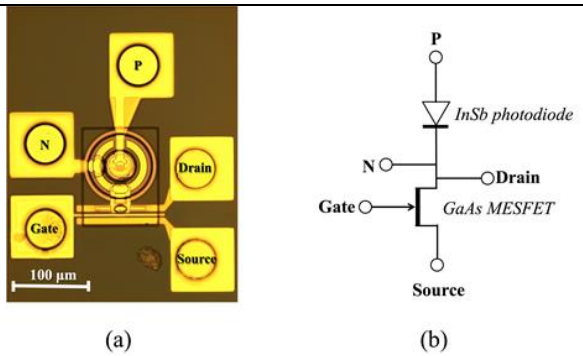

Fig. 2. (a) An optical micrograph and (b) equivalent circuit diagram of an integrated photo-pixel device.

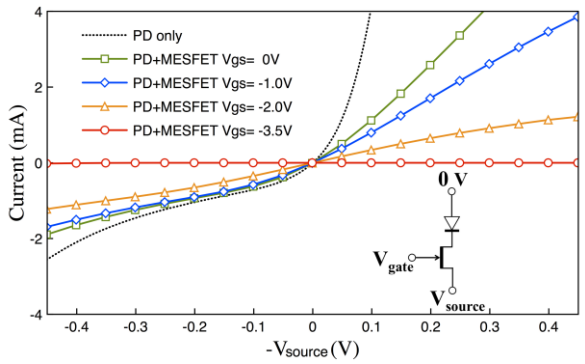

Fig. 3. The current–voltage characteristics of a photo-pixel device with a 45 µm diameter circular InSb photodiode.

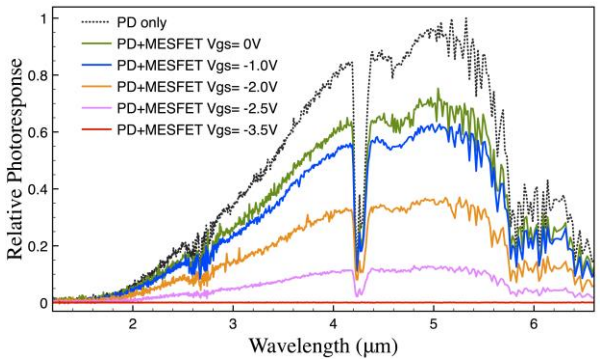

Fig. 4. The relative spectral response of the photo-pixel device under various gate bias conditions.

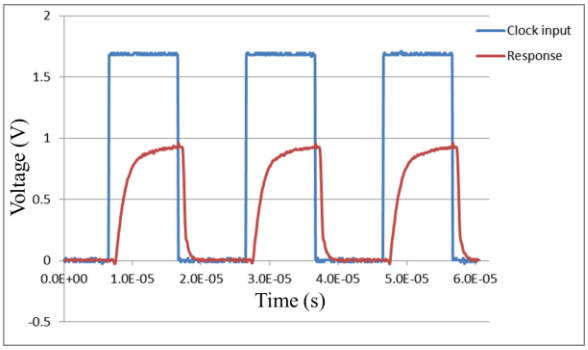

Fig. 5. The transient response of the fabricated MESFET.

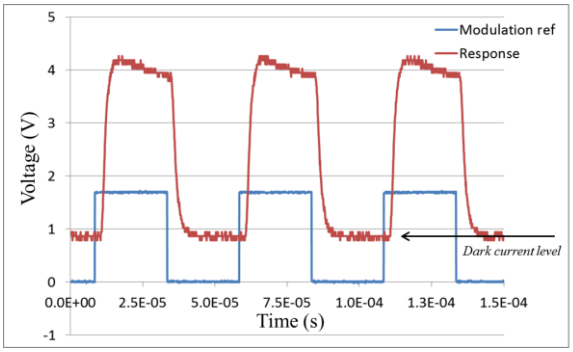

Fig. 6. The transient response of the fabricated InSb photodiode.

3. References

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