CWR2 **5:15 pm**

1.3 μm GaAs based resonant cavity enhanced Schottky barrier internal photoemission photodetector

Necmi Biyikli, Ibrahim Kimukin,
Ekmel Ozbay, Gary Tuttle,* *Dept. of Physics, Bilkent Univ., Bilkent, Ankara 06533 Turkey; E-mail: biyikli@fen.bilkent.edu.tr*

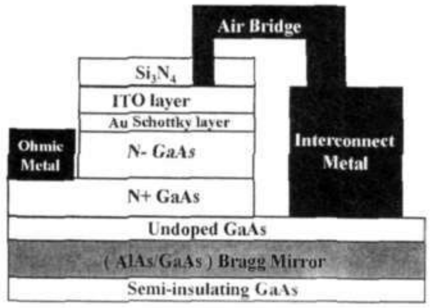
High-speed photodetectors operating at 1.3 and 1.55 um are important for long distance fiber optic based telecommunication applications. Different materials such as InGaAs, InSb have been used at these wavelengths. But, the functionality of these photodetectors based on such materials have been limited as they can not be defect-free grown on GaAs based substrates. We fabricated GaAs based photodetectors operating at 1.3 um that depend on internal photoemission as the absorption mechanism. Detectors using internal photoemission have usually very low quantum efficiency (QE).[1,2] We increased the QE using resonant cavity enhancement (RCE) effect.[3] RCE effect also introduced wavelength selectivity which is very important for wavelength division multiplexing (WDM) based communication systems. In this paper, we report our work on Schottky barrier internal photoemission photodiodes.

In Schottky barrier internal photoemission detectors, internal quantum efficiency, in the vicinity of the cutoff wavelength, is given by Fowler relation.[4]

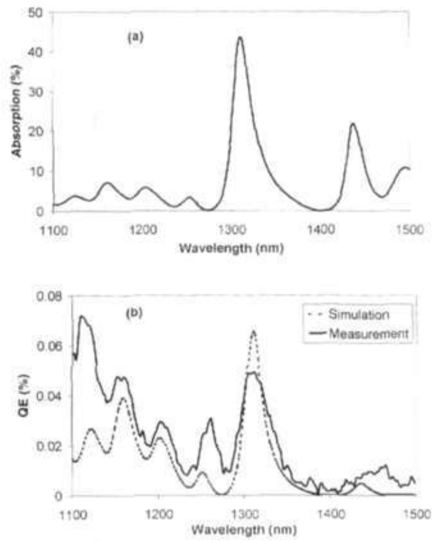
$$\eta_1 \propto \left\{ \begin{matrix} (h\upsilon - \varphi_B)^2 & , & (h\upsilon \geq \varphi_B) \\ 0 & , & (h\upsilon < \varphi_B) \end{matrix} \right\} \qquad (1)$$

Here φ_B is the Schottky barrier height. The external quantum efficiency can be found by multiplying the absorption in the Schottky layer and the internal quantum efficiency. The thickness of the Schottky layer should be kept small to get a higher internal quantum efficiency, on the other hand the absorption decreases as the thickness gets smaller. We can get over this trade-off by placing the Schottky layer inside of a Fabry-Perot cavity.

The top-illuminated Schottky photodiodes were fabricated by a microwave-compatible monolithic microfabrication process. Figure 1 shows the schematics of the fabricated devices. Fabrication started with formation of ohmic contact to N^+ layer. Mesa isolation was followed by a Ti-Au interconnect metallization. A 10 nm Au-Schottky layer, a 100 nm transparent-conductor indium tin oxide (ITO) layer, and silicon nitride were deposited.



CWR2 Fig. 1. Diagram showing the cross section of a fabricated photodiode.

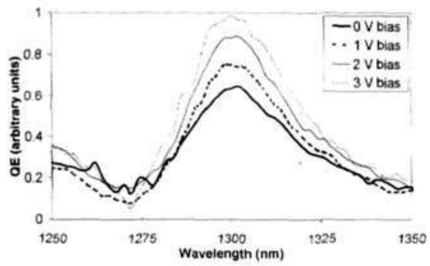


CWR2 Fig. 2. (a) Absorption in the gold Schottky layer; (b) quantum efficiency measurement and simulation.

Finally, a thick Ti-Au was deposited to form an air-bridge connection between the interconnect and the ITO layer.

In Au-based RCE photodiodes, the top metal layer serves as the top mirror of the Fabry-Perot cavity. Bottom mirror is composed of 15 pair AlAs/GaAs distributed Bragg reflector (DBR). In our structure, the thickness of the ITO and Si_3N_4 were chosen to act as an antireflection coating. We have used transfer matrix method (TMM) to simulate the optical properties of the photodiodes. Figure 2(a) shows the absorption in the Schottky layer calculated by using TMM. Photospectral measurements were carried out by using a tungsten-halogen light source and a monochromator. In Fig. 2(b), we present the room temperature QE measurement and simulation of our photodiodes at zero bias.

Our simulations show that, we have achieved 9 fold enhancement in the QE, with respect to a similar photodetector without a cavity. We also investigated the effect of reverse bias on QE. Figure 2 shows the QE of a photodiode under different reverse bias voltages. Applying reverse bias decreases the barrier height, which in turn results in a higher QE. Due to the relatively thin N^- layer, our devices are RC time constant limited with a predicted 3-dB bandwidth of 70 GHz. The



CWR2 Fig. 3. Quantum efficiency measurements under different reverse bias voltages.

high speed performance of our photodiodes will be measured by using an OPO based 1.3 micron picosecond light source.

This work is supported by NATO Grant No. SfP971970.

Microelectronics Res. Ctr., Iowa State Univ., USA

1. Bor-Yeu Tsaur, Melanie M. Weeks, R. Trubiano, Paul W. Pellegrini, T.-R. Yew, "IrSi Schottky-Barrier Infrared Detectors with 10-μm Cutoff Wavelength," IEEE Electron. Dev. Lett. **9,** 650–653 (1988).
2. T.L. Nin, J. Meserjian, "Novel $Si_{1-x}Ge_x$/Si heterojunction internal photoemission long-wavelength infrared detectors," Appl. Phys. Lett. **57,** 1422–1424 (1990).
3. M. Selim Unlu, Samual Strite, "Resonant cavity enhanced photonic devices," J. Appl. Phys. **78,** 607–638 (1995).
4. R.H. Fowler, "The Analysis of Photoelectrical Sensitivity Curves for Clean Metals at Various Temperatures," Phys. Rev. **38,** 45–56 (1931).