Journal of Materials Science and Engineering B 13 (4-6) (2023) 70-71
doi: 10.17265/2161-6221/2023.4-6.001

Photodiodes from Hetero Junctions of Intrinsic 4H-SiC and Si Semiconductor Materials

Ravi Kumar Chanana

Retired Professor, Self-Employed Independent Researcher, Gr. Noida-201310, India

Abstract: In this research article, it is proposed that photodiodes can be made with hetero junctions formed out of intrinsic 4H-SiC and intrinsic silicon in the form of UV (ultraviolet) light activated switch, a very sensitive UV photo detector, or an UV solar cell. Other semiconductors can be tried for other longer wavelength devices.

Key words: Hetero junctions, intrinsic semiconductors, 4H-SiC, silicon.

A Short Communication

It has been shown that the universal mass-energy equivalence relation $dE/E = dm/m$ applicable to semiconductors can lead to the determination of their intrinsic Fermi energy levels E_i below the semiconductor conduction bands. Here, dE is the differential potential energy of electrons from the intrinsic Fermi energy level E_i to the semiconductor conduction band, E is the semiconductor bandgap as the total potential energy of electrons, dm is the differential mass as the longitudinal electron effective mass in the semiconductor, and m is the free electron mass [1, 2]. The relative longitudinal electron effective mass in 4H-SiC oriented in the (0001) direction and Si-terminated as dm/m is 0.297 and the bandgap of intrinsic 4H-SiC is 3.26 eV. Substituting these in the universal mass-energy relation will give dE in 4H-SiC as $0.297 \times 3.26 = 0.97$ eV as the position of E_i below the conduction band of 4H-SiC. Similarly for intrinsic silicon, the relative longitudinal electron effective mass in the Si (100) direction is 0.49 for one conduction valley and the bandgap of Si at 300 K is 1.12 eV. These when substituted in the universal mass-energy relation give $dE = 0.49 \times 1.12 = 0.55$ eV below the Si conduction band. The hetero junction formed out of intrinsic 4H-SiC and silicon will align the intrinsic Fermi energy levels due to charge neutrality giving depletion of electrons in silicon having a built-in voltage of 0.97 - 0.55 = 0.42 V, with silicon being positive. Since the semiconductor materials are intrinsic, their intrinsic carrier densities are very small with about $10^{-8}/cm^3$ in 4H-SiC and $10^{10}/cm^3$ in silicon at 300 K temperature. The dark current with these carrier densities will be very small. When the UV (ultraviolet) light impinges on 4H-SiC, it will generate EHP (electron-hole pairs) in 4H-SiC. Due to the existing electric field from Si to 4H-SiC the electrons generated in 4H-SiC will flow towards silicon forming a current in the junction device with the conventional current direction from silicon to 4H-SiC. The photodiode can thus act as a UV light activated switch, or an UV solar cell if placed in the sun, or it can act as a sensitive UV photo detector with UV impinging on the SiC. Other semiconductor materials such as GaAs can replace SiC for photodiodes that work with longer wavelength radiations.

Corresponding author: Ravi Kumar Chanana, Ph.D., retired professor, self-employed independent researcher, research fields: MIS characterization, device physics, power electronics.

References

[1] Chanana, R. K. 2022. "Theoretical Finding of the Properties of a Si (100) MOS Device." *IOSR-J. Applied Physics* 14 (3): 5-6.

[2] Chanana, R. K. 2022. "N-Channel 4H-SiC MOSFET Device on (11$\bar{2}$0) Oriented Epitaxial Surface." *IOSR-J. Electrical and Electronics Engineering* 17 (3): 20-2.