ABSTRACT

High quality mobile, fibre and satellite communications are an essential part of modern life and vital to industries related to telecommunications. RF is the most widely used communication medium, however optical systems have an advantage of extremely broad bandwidth, high data rate, low losses, and immunity to noise. Faithful reconstruction of transmitted signal is the main expectation of any communication system which is fulfilled with detectors at the receiver section. In optical communication link, photodetectors are used to detect optical signal i.e. to convert into its original form (voltage or current). Semiconductors devices are used as photo detectors which determines overall performance of an optical communication system. Sensitivity of FET devices have opened up the possibility of its use for photo detection purposes. Further, device behavior can be well understood with the help of mathematical modeling approach. It predicts device performance prior to actual fabrication.

In the present work, optical modeling of two devices namely, Si MOSFET and InGaAs MIS-FET is carried out to study their behavior as photodetectors. Mathematical model is developed which describes optical phenomenon that takes place inside the device. The model is physics based and takes care of all short channel effects. For modeling purpose, the channel is assumed to be uniformly doped. Conductivity of the device depends on the W/L ratio of the device i.e. either by decreasing length of the device or by increasing device width. For MOSFET, the length of the device is miniaturizing to nano scale, thereby increasing short channel effects in the device. With increasing width device becomes bulky. To improve the conductivity of device, multi finger structure is used with 10 number of fingers. It increases the effective width of the device. Width of individual finger is taken as 12 $\mu$m and length of 0.36 $\mu$m. Gate is of polysilicon material which is transparent to the incident light (having energy greater than band gap energy of device material) and 90 percent of the light is absorbed by the device. To investigate the sensitivity of the device, light intensity is varied by varying optical flux density of incident radiation from $10^{15}\text{wb/m}^3$ to $10^{17}\text{wb/m}^3$ which in turn varies generated optical power. The source of light with these flux densities, is focused on the gate of the device by means of the lens, in Y-direction. Optical power (Pop) is generated in proportion to the intensity or flux density of incident light. Perfect detection of the received signal depends on the output current of the detector. DC analysis is carried out under dark (Pop = 0) and illuminated (varying Pop from 0.25 mW to 25 mW) conditions. It is observed that drain current and transconductance of both devices increases under illumination due to photo effect. Under illumination, at constant gate bias of 1 V, drain current of MOSFET increases by 4.5 mA at 0.25 mW optical power and increases by 2.6 mA with gradual increase in optical power from 0.25mW to 25mW. Drain current of MISFET increases by 2 mA as that of dark and by 2.5 mA for increasing optical power. When compared at the same bias, threshold voltage, doping concentrations, device dimensions and optical condition, it is seen that photo current of MISFET is more than that of the MOSFET by 0.7 mA. This analysis is carried out at 1GHz. Further, it is seen that MISFET photodetectors are more sensitive to light compared to MOSFET as output current of MISFET is more(on an average 1.3mA) than that of MOS-
FET current. It is due to high mobility of compound III/V material of MISFET. As the device is expected to be used at RF (Radio Frequency), its frequency dependance is studied at 1-10 GHz frequency range. Frequency dependency of device characteristics shows that after 4GHz the drain current of the device decreases due to decay in carrier life time.

At high frequencies, the device becomes capacitive in nature. A small signal model for both devices is developed and the optical effect on different capacitances is investigated at 1GHz. Gate to source capacitance (Cgs) and Gate to Drain capacitances (Cgd) are main capacitances which affect RF performance of the device. Cgs decreases whereas Cgd increases with light, which reduces the overall capacitive effect of the device. Frequency dependence of capacitance shows that it decreases with increasing frequency, which is an additional controlling parameter of the device. This characteristic accounts a lot at RF.

\( Y \) parameters are computed from small signal model which predicts that the device can be used as a transconductance amplifier. It is necessary to understand noise behavior of the device.

Sources of noise are internal to the device itself as it is immune to external noises. Noise model of OGMOSFET, operating at high frequency is developed. Channel thermal noise is the main contributor of noise as excess carriers are generated in the channel. Noise figure (NF) is the figure of merit to measure the noise. Analysis shows that there is significant reduction in noise figure of the device, under illumination, due to decrease in noise resistance.

At RF, device characteristics can be well understood with S parameters. Gap is left by the researchers to describe optical behavior of the MOSFET with the help of S-parameters. OGMOSFET is represented as a two port network with 50\( \Omega \) terminations. S parameters are computed at 1 to 10 GHz frequency band and stability of the device is tested. It is seen that device is potentially unstable. The device can be conditionally stable with appropriate matching network. The amplifier is designed using ADS CAD tool with matching network and gain analysis of the device is carried out. With low noise and amplified gain, the device can be used as low noise amplifier (LNA), a first building lock of any receiver system. Modeling of the device, as a LNA, is carried out at 2.5 GHz which can be used for personnel network application.

It is essential to investigate photodetector characteristics such as responsivity and quantum efficiency. MISFET Detector characteristics are investigated up to terahertz for wavelength of 1.33 nm which shows significant rise for increasing optical power and is good agreement with reported one. With this characteristics, the device can be used as a photodetector or MISFET based light sensor, operating at terahertz.

Finally, various methods used for modeling of optical effect are reviewed with the help of different mathematical models. Models are then simulated and tested to verify the detection principal. To carry out further research in this field, researchers can choose appropriate modeling technique as per the requirement of the application.

To validate the results of theoretical analysis, computer aided simulation have been carried out in the MATLAB simulation tool. Simulation results are validated by comparing with reported results under dark (Pop=0) conditions. Optical results are verified with the standard CAD tool.
used for design and simulation of device and circuits i.e. TCAD. Results agree in principle with MATLAB simulation results.

**Key words:** LNA, MISFET, MOSFET, Modeling, Optical, Photo detector, Quantum Efficiency, RF, Responsivity, Simulation.