Silicon CMOS FETs as Terahertz and Sub-Terahertz Detectors

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ABSTRACT

The terahertz portion of the electromagnetic spectrum is experiencing a substantial growth in interest, with new applications in security, medicine and communications, among others, emerging at a rapid pace. Limitations in source power place stringent requirements upon THz detector device performance in terms of responsivity, sensitivity and response speed. As well, many emerging applications require room temperature operation and the rigors of field deployment demand robust construction and alignment stability. Electronic devices such as Schottky diodes, HEMTs (high electron mobility transistors) and MOSFETs detect THz radiation at high rates, the latter due to rectification of plasma waves in the device channel. Silicon MOSFETs have the additional advantage of straightforward integration with signal processing circuit elements. The objective of our research is to study the response of silicon n-channel and p-channel MOSFETs to terahertz and sub-terahertz radiation towards understanding and predicting device behavior for application in THz detection and imaging systems.

In this thesis, we review the present state-of-the-art in terahertz sources and detectors, and discuss the operation of plasma wave terahertz devices. We evaluate response in devices with channel lengths in the range of 180 to 50 nm and widths of 1 to 10 μm, and present predictive models of terahertz response based upon the industry pervasive AIM Spice circuit simulator. We then demonstrate broadband response of silicon NFETs and PFETs from 0.2 to 1.6 THz, and evaluate these devices in terms of responsivity and Noise Equivalent Power. Exploring the implications of device dimensions and radiation coupling on device performance, we find that response in the region below the device threshold voltage is attenuated due to the division of voltage between the device channel and load resistances resulting in greater response roll-off, thus shorter, wider devices exhibit this effect. Channel resistance also directly influences device noise in the open drain configuration, and here wider, shorter devices are preferred also, but channel widths in the range of 10 μm may limit response above ~1 THz. We find that radiation coupling efficiency is crucial to device performance and properly optimized, we expect silicon CMOS FETs to equal the performance of presently available detectors.