FABRICATION AND ANALYSIS OF GaAs SCHOTTKY BARRIER DIODES FABRICATED ON THIN MEMBRANES FOR TERAHERTZ APPLICATIONS†

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ABSTRACT

The GaAs Schottky diode is predominantly used as the critical mixer element in heterodyne receivers in the frequency range from 300 GHz to several THz[1]. At operating frequencies above one THz the skin effect adds significant parasitic resistance to the diode which degrades the receiver sensitivity. A novel diode structure called the Schottky barrier membrane diode is proposed to decrease the skin effect resistance by reducing the current path between the Schottky and ohmic contacts. This is accomplished by fabricating the diode on a very thin membrane of GaAs (about 1 μm thickness). A theoretical analysis has shown that this will reduce the substrate resistance by 60% at 3THz. This reduction in resistance corresponds to a better frequency response which will improve the device’s performance as a mixer element.

INTRODUCTION

The cross section of a standard Schottky barrier diode chip is illustrated in Figure 1[2]. The Schottky contact (anode) is a micron-size dot of Pt on GaAs with an overlayer of Au. A single chip is approximately 250 x250 μm and 125 μm thick. The top surface is an array of thousands of Schottky contacts. The ohmic contact, located on the back surface, serves as the cathode and facilitates soldering the chip to a small metal post. The GaAs substrate is highly doped to minimize parasitic resistance and supports a lower doped epitaxial layer (10^{16} – 5x10^{17} cm^{-3}) which controls the electrical characteristics of the metal-semiconductor junction. The fabrication process involves first, pyrolitically depositing silicon dioxide (SiO_{2}) and defining the anode wells by

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photolithographic techniques. The wafer is then lapped to a thickness of 125 μm and ohmic contact metals (SnNi/Ni/Au) are electroplated and alloyed onto the back surface. The wafer is then diced into chips and the anodes are plated with Pt and an overlayer of Au. A sharply pointed whisker is used to contact one anode.

To design Schottky diodes which will operate in the submillimeter wavelength range it is necessary to minimize the parasitic series resistance, $R_s$, and zero bias junction capacitance, $C_{jo}$[3]. The $R_sC_{jo}$ product is inversely proportional to the cutoff frequency, a quality parameter for the diode. Very high frequency diodes are typically small (<1 μm diameter) to minimize $C_{jo}$ and have a highly doped epitaxial layer to minimize $R_s$ (on the order of 1-4 x10$^{17}$). Diode noise is also a very important parameter, however at submillimeter wavelengths the cutoff frequency is presently the limiting factor[3].

The series resistance is a function of the high frequency current path, which is illustrated in Figure 2. The skin effect forces most of the electrons to flow within a skin depth of the surface of the chip. The skin depth depends on the frequency and conductivity and is approximately 1 μm at 3 THz for a typical highly doped substrate. This crowding of the current along the edges of the chip adds significant resistance to the diode. The total series resistance can be considered the sum of four components: the resistance of the epilayer, the spreading resistance in the substrate, the skin effect resistance, and the ohmic contact resistance[4].

$$R_s = \frac{t_{epi}}{\sigma_{epi} A} + \frac{1}{2 \sigma_{sub} d} + \frac{1}{2 \pi \delta_s \sigma_{sub}} \ln \left[ \frac{b}{d} \right] + R_{oc}$$ (1)