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A Simple Method to Measure the Depletion Capacitance of a Schottky Junction Diode

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ABSTRACT

A simple laboratory method to measure junction capacitance of a Schottky barrier diode has been proposed from the measurement of cut off frequency of a high pass filter. Existence of series and shunt resistances associated with depletion capacitance may be ignored in some special conditions. Theoretical analysis for the measurement of junction capacitance has been carried out. Junction capacitance of a Schottky diode is evaluated from the filter circuit at different applied reverse bias and a good capacitance voltage characteristic has been found from the experimental result.

Keywords: Depletion capacitance, Schottky diode, High pass filter

1. Introduction

The measurement of junction capacitance is generally important to study the frequency response of a Schottky diode. The junction capacitance may be used to measure doping concentration in the semiconductor side of a schottky diode [1]. It is also used to determine built in potential and junction area of a device [2].To measure the barrier height and interface properties of a metal semiconductor diode the junction capacitance has been used by earlier workers [3].However, the Junction capacitance of a diode is generally determined from the measurement of peak to peak voltage of a diode circuit and at the output of the operational amplifier at two different frequency [4].The junction capacitance of a metal-semiconductor diode can be measured using S parameter measurement and also by using LCR meter [5]. Recently the junction capacitance of a carbon nano-tube Schottky diode was measured from rectification of ac signals at high frequency range and from the measurement of cut off frequency [6]. In our work ,we have proposed a comparatively simple technique to compute junction capacitance of Schottky diode using a high pass filter circuit and its cut off frequency measurement. The complex mathematical expression of the transfer function of the proposed circuit may be simplified at some special cases and the method is applied to determine the junction capacitance in laboratory and a good variation of C-V plot has been noticed from experimental data.

2. Calculation

Let us consider a filter circuit as shown in figure 1 where a Schottky diode is replaced by its equivalent circuit [7] shown by a dashed box, here R_s and R_j represents the series and shunt resistances respectively of a Schottky diode equivalent circuit and C_j is the junction capacitances. The parasitic inductance and geometric capacitance may be neglected at low frequency condition and in case of unpackaged junction. V_{in} is the input applied signal, R_L is the load resistance and C is the decoupling capacitor, that protect DC voltage to influence the biasing condition of the diode.

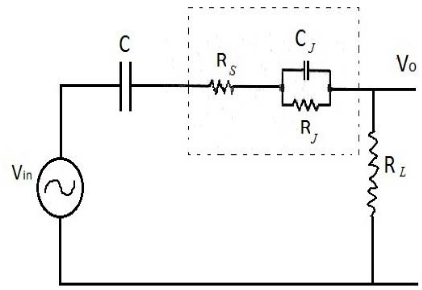

Figure 1: A high pass filter using a Schottky diode and a decoupling capacitor

The gain of the circuit as shown in figure 1 is given by $A_v = V_0 / V_{in}$

This gain is a function of frequency ω and it's modulus value can be written as

$$|A_v(\omega)| = \frac{R_L \Big/ \left(R_s + R_L + \dfrac{R_J}{1+\omega^2 C_J^2 R_J^2}\right)}{\sqrt{1+\left[\dfrac{\left(\dfrac{1}{\omega C} + \dfrac{\omega C_J R_J^2}{1+\omega^2 C_J^2 R_J^2}\right)}{\left(R_s + R_L + \dfrac{R_J}{1+\omega^2 R_J^2 C_J^2}\right)}\right]^2}} \tag{1}$$

The circuit shown in figure 1 is a high pass filter and its gain will be maximum at ω→∞. So the gain of the circuit as in equation (1) may be reduced to

$$|Av(\omega)| \text{ at } \omega\to\infty .= R_L/(R_s + R_L) \tag{2}$$

The expression of gain in equation (2) shows the maximum gain of the circuit. Using equation (1) and (2) one can write

$$\frac{0.707 R_L}{R_s + R_L} = \frac{R_L \Big/ \left(R_s + R_L + \dfrac{R_J}{1+\omega_0{}^2 C_J^2 R_J^2}\right)}{\sqrt{1+\left[\dfrac{\left(\dfrac{1}{\omega_0 C} + \dfrac{\omega C_J R_J^2}{1+\omega_0{}^2 C_J^2 R_J^2}\right)}{\left(R_s + R_L + \dfrac{R_J}{1+\omega_0{}^2 R_J^2 C_J^2}\right)}\right]^2}} \tag{3}$$

where, ω_0 is the cut off frequency of the circuit. At large reverse bias applied to a Schottky diode the junction resistance Rj →∞ and for large load resistance $R_s + R_L \approx R_L$. Applying these conditions in equation (3) we get

$$\omega_0 = \frac{1}{R_L C_T}, \text{ where } C_T = \frac{CjC}{Cj + C} \tag{4}$$

3. Results and Discussions

The circuit shown in Figure 1 was implemented on a breadboard in the laboratory. We use 1N5819, as the Schottky diode. The decoupling capacitor C = 0.01 μF, load resistance R = 10KΩ and input signal is a sine wave having peak to peak amplitude V_{in}= 1V (pp). The frequency of the input signal has been varied from 100 Hz to 1MHz and output response is taken for different applied reverse bias across the diode. The experimental set up is shown in Figure 2.

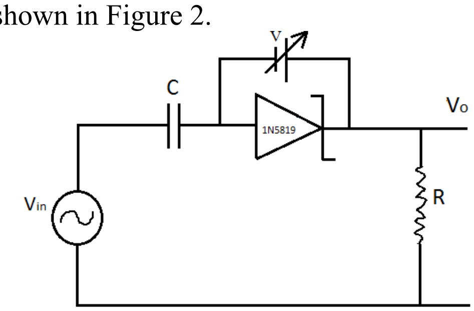

Figure 2: Circuit constructed on the bread-board

The gain of the circuit shown in figure 2 has been studied from the frequency range 100 kHz to 1 MHz for different applied reverse bias across the Schottky junction diode and for each bias voltage cut off frequency is evaluated. The junction capacitance of the diode can be calculated from the measured cut off frequency of the circuit for different applied bias and using equation (4). The capacitance voltage characteristic of the diode is shown in Figure 3.

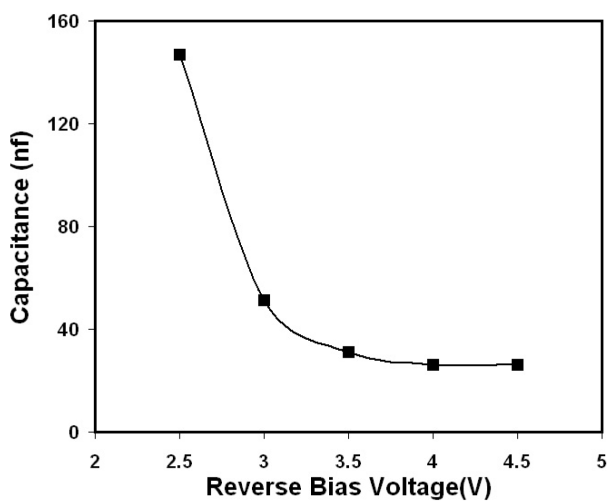

Figure 3: Capacitance vs. voltage plot

From Figure 3 it has been observed that the capacitance of the diode decreases with applied reverse voltage in non-linear manner almost consistent with the conventional C-V plot of a schottky junction diode. In Figure 4, $1/c^2$ vs. V has been plotted which shows an almost linear variation of $1/c^2$ with reverse applied voltage. In our calculation we have ignored the packing capacitance and packing inductance to simplify the measurement process.

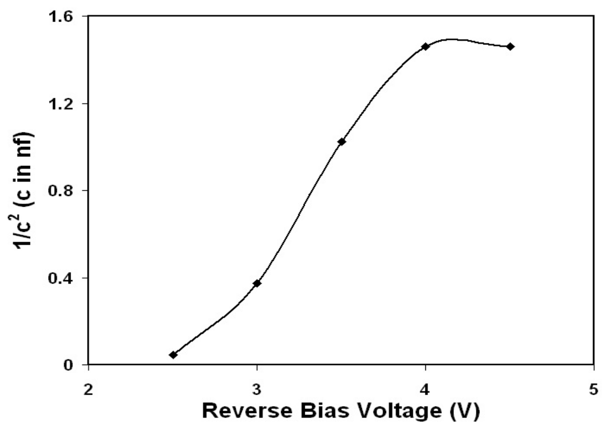

Figure 4: $1/C^2$ vs. V plot

4. Conclusion

In summary, a simple laboratory technique to determine the junction capacitance of a Schottky diode has been proposed in the low frequeccy range and this technique has been applied to determine junction capacitance of the diode for different bias conditions. In large frequency applied signals this method shows considerable limitations.

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